A Preliminary Cost Comparison of At Sea Monitoring and Electronic Monitoring for a Hypothetical Groundfish Sector

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and Northeast Fisheries Science Center

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Executive Summary

The Greater Atlantic Regional Fisheries Office (GARFO) and the Northeast Fisheries Science Center (NEFSC), in collaboration with the Gulf of Maine Research Institute, Archipelago Marine Research, Ltd., Saltwater, Inc., and EcoTrust Canada, developed an assessment of the potential costs of an EM program for a hypothetical NE multispecies fishery sector, and compared it to the costs of the existing at-sea monitoring (ASM) program, which it could replace or augment. The objective of this comparison was to provide a better understanding for fishermen, the New England and Mid-Atlantic Fishery Management Councils, and NOAA Fisheries of the potential costs for an operational EM program, and how those costs would compare with an at-sea monitor or observer program for delivery of comparable and useful data. The Councils and sectors may wish to consider this information as they design EM applications in sector fisheries to achieve costs savings. It is necessary to balance a program design that is financially viable with a program design that ensures data quality and integrity

This cost assessment represents a starting point for developing future EM program designs, and some caveats to the assumptions contained in the paper must be noted. Costs of an actual program may be reduced from the costs associated with the EM program design represented in this document. Some areas where cost savings could be realized include the following program design changes.

- Start-up costs for the ASM Program already have been borne by NOAA Fisheries and can not be compared with those of future EM programs.

- Rather than requiring a technician to retrieve hard drives, video data could be submitted by mail.

- Specify assumed discard rates in lieu of additional video review in the instances where the primary EM validation fails.

- Design a random sampling program to select trips from which video would be reviewed.

- Limit documentation of all discards of all species including identifying and counting the fish, and measuring the length of the fish for the large mesh multispecies only. A sufficient level of review to determine that no unreported large mesh multispecies were discarded could further limit costs.

- Video data storage in the “cloud” could be authorized.

- Fixed costs per vessel would decrease as the number of participating vessels increased.

Table 7 (below) contained in this document compares the costs associated with Electronic Monitoring and at-sea monitoring for a hypothetical groundfish sector. Recall the caveats noted earlier when interpreting the results.

Table 7: Summary of Total Program Costs of Hypothetical Sector and Program Design

At-Sea Monitoring Annual Costs*	Sector Total	Per Vessel	Per Trip	Per Observed Trip
Seaday costs	$362,100	$18,105	$181	$1,006
NOAA Fisheries shore-side costs	$270,300	$13,515	$135	$751
Total At-Sea Monitoring costs	$632,400	$31,620	$316	$1,757

*Assumptions:

- 510 observer sea-days (18%)
- seaday cost = $710 per sea-day
- shore-side cost = $530 per sea-day

Electronic Monitoring Annual Costs	Per Sector	Per Vessel	Per Trip*
Sector costs	$1,012,372	$50,619	$506
NOAA Fisheries costs	$188,795	$9,440	$94
Total Electronic Monitoring costs	$1,201,167	$60,058	$601

*Note that electronic monitoring is required on all trips and therefore per trip and per observed trip costs are equal.

Electronic Monitoring Start-Up Costs*	Per Sector	Per Vessel
Sector costs	$1,191,508	$59,575
NOAA Fisheries costs	$558,000	$27,900
Total Electronic Monitoring start-up	$1,749,508	$87,475

*Note that Start-Up Costs for the ASM Program have already been borne by NOAA Fisheries and are not available for comparison.

1.0 Introduction

There is considerable interest in using electronic monitoring systems (EM) as an alternative to observers and at-sea monitors for the collection of data at sea and for other objectives, such as compliance monitoring for discards, in Northeast (NE) fisheries. A primary motivation for considering EM is the perception that EM is a more cost-effective monitoring option, particularly for fishermen, relative to other data collection tools. However, the true cost of an EM program relative to observers/at-sea monitors depends on the design and scale of the program and what objectives must be met. To date, early studies about potential EM programs for NE fisheries have not resulted in sufficient consensus about the design of potential programs to generate a cost estimate. Yet the costs of a potential EM program have continually been identified as a key piece of information needed by the fishing industry and the government to transition EM from pilot projects to fully operational programs (National Electronic Monitoring Workshop, 2014; Northeast Electronic Monitoring Workshop, 2014, New England EM Project Phase III, 2014, Pria et al 2014).

The Greater Atlantic Regional Fisheries Office (GARFO) and the Northeast Fisheries Science Center (NEFSC), in collaboration with the Gulf of Maine Research Institute, Archipelago Marine Research, Ltd., Saltwater, Inc., and EcoTrust Canada, developed an assessment of the potential costs of an EM program for two candidate NE fisheries. The objective of this analysis was to provide a better understanding for fishermen, the New England and Mid-Atlantic Fishery Management Councils, and the government of the potential costs for an operational EM program, and how those costs would compare with an at-sea monitor or observer program for delivery of comparable and useful data. The analysis focused on the NE multispecies (groundfish) sector fishery and the Atlantic herring and mackerel midwater trawl fisheries. This report (Part 1) summarizes the analysis for a hypothetical NE multispecies fishery sector. The Atlantic herring and mackerel midwater trawl fisheries will be addressed in a subsequent report, given the differing fishing operations and objectives.

1.1 How to Use This Report

This report discusses the estimated costs of an at-sea monitoring program for sectors, based on the NOAA Fisheries operated at-sea monitoring program, and a hypothetical EM program that could be used to meet the same objectives. The requirements of the hypothetical EM program were specified in fall 2014 so that the participating vendors could develop cost estimates (detailed requirements are described in the Appendix). In the time since the hypothetical program was outlined, NOAA Fisheries staff have continued to work with several sectors, the Gulf of Maine Research Institute, The Nature Conservancy, and EcoTrust Canada to develop an EM program for operational testing. The Executive Summary notes some different approaches that may be considered for an operational program, and how they might affect the cost estimates. There are several different combinations of design elements that would meet or exceed a sector's monitoring requirements. Determining the "right one" is the subject of continuing analysis and deliberation by NOAA Fisheries and the sectors. Rather than waiting to develop cost estimates until those questions are answered, this document estimates the costs of the hypothetical EM model as it was envisioned in the fall of 2014, and notes where different approaches could affect the cost estimates for the example program model.

Designing a monitoring program must weigh trade-offs between different design options, to find the configuration that best meets the program's objectives, produces acceptable information, at a reasonable expense. Conversations about goals and objectives, program design, and cost should be iterative throughout the development of a monitoring program, as the costs and benefits of different options are evaluated. We intend for this report to be a starting point for consideration of costs in the development of an electronic monitoring program for the NE multispecies fishery. The cost estimates published here are generated from broad assumptions and generalizations, averages, or otherwise aggregated data, and therefore should not be considered a precise cost figure. Rather, the estimates are intended to give the reader an idea of the potential scale of costs of the hypothetical program under consideration, to highlight the design elements that drive costs, and to illustrate the potential trade-offs associated with different options. We hope that this information will help clarify a direction for EM technology in sector monitoring programs. Although this report focuses on the NE multispecies fishery, many of the cost drivers and trade-offs discussed have broad applicability and are important considerations for other Northeast fisheries.

Prices and other business information that might affect the competitiveness of a business are confidential and protected under Federal law (Federal Acquisition Regulations, Competition in Contracting Act, Small Business Act). NOAA Fisheries cannot publish the actual prices paid for monitoring services. Therefore, cost estimates in this report are averaged over multiple service providers in order to protect the confidentiality of the information. We would like to stress that this is under the existing contract requirements and prices that the Government negotiated, and costs would likely change under other service agreements. These costs were averaged over multiple providers and estimated based on expenditure reports and invoices, and are not guaranteed to stay the same in future years. We believe that this information is the latest information that is available to provide a basis from which to explore and understand the costs and influencing factors. Future analyses will benefit from the collection of cost information in pilot EM projects around the U.S. that is currently underway.

Whether any of the cost estimates presented in this report are workable for the fleets discussed depends on the individual vessel's or sector's portfolio of catch and its profit margins. Estimating the profitability of fishing businesses is an analysis unto itself and is not part of this report. Instead, we provide these cost estimates as a tool for individual sectors and vessels to use in considering what monitoring options would work best for them. The cost estimates in this report may serve as a template for discussions between sectors, their members, and service providers.

2.0 Greater Atlantic Multispecies

The basic requirements for sector monitoring programs were implemented through Amendment 16 to the NE Multispecies Fishery Management Plan (FMP) (NEFMC, 2009a). Sectors are required to implement and fund a third-party monitoring program to ensure that their Annual

Catch Limit (ACL) is not exceeded. NOAA Fisheries has been funding at-sea monitoring to sectors to meet this requirement since 2010. Some sectors are interested in using EM as a potential cost effective alternative to at-sea monitors to meet monitoring requirements when these costs are borne by industry.

We can use information from the existing Federally-funded At-Sea Monitoring Program to estimate the potential costs of an industry funded At-Sea Monitoring program, which is likely to be very similar. A sector EM program would have to meet the same general requirements and objectives as a sector at-sea monitoring program (according to Amendment 16), but more specific standards or requirements are not yet available. Consequently, we made many assumptions about the design of a hypothetical sector EM program in order to generate cost estimates.

As noted above, NOAA Fisheries is currently working with a subset of vessels in several sectors which have been testing EM. The model currently under discussion assumes EM would be used to audit vessel logbook reports of discards. EM would be used to record video of each trip and a subsample of the trip's hauls would be reviewed to audit the vessel's logbook. This model is a variation of the successfully implemented EM program in the British Columbia groundfish fishery. A similar application in the NE multispecies fishery was tested in the New England EM project (Pria et al., 2014) and discussed in the draft New England Council EM Working Group report (Electronic Monitoring Working Group, 2014). The audit approach is a promising model for groundfish sectors, and for this analysis, because it could largely be implemented without changes to existing possession limits or other management measures. This greatly simplified the assumptions that needed to be made for the cost comparison. However, assumptions about the hypothetical EM design elements such as the level of video review necessary to perform an adequate audit were still necessary. Assumptions were conservative while remaining realistic, in order to provide useful information about potential costs. As a result, the costs for certain hypothetical program components may be at the upper end of the range for the model described. For example, we assumed that technicians would be deployed to retrieve hard drives instead of captains mailing the hard drives. The latter option is likely to be cheaper and has been implemented in the NOAA Fisheries Highly Migratory Species (HMS) program.

The level of video review is a major driver of EM program costs and the appropriate level of review depends on the objectives of the program. NOAA Fisheries is still working to determine the level of video review necessary to meet the objectives of sector monitoring. In absence of that determination, we had to make an assumption about how much video would be reviewed. The use of EM to validate logbooks and the use of human at-sea monitors to subsample fishing trips are two very different approaches to monitoring and vary in scope by the type of data and method by which that data is collected and therefore, are not easily compared. We assumed that 20 percent of hauls would be reviewed, with a 1 haul minimum from each trip to be relatively consistent with the approximate sampling rate of the at-sea monitoring program. This is greater than the 10 percent review rate used in British Columbia; however, upon applying the assumptions about sector effort, a 20-percent sample rate resulted in only one haul being reviewed from each trip (1 out of the average 3-5 hauls per trip). We discuss how these and other assumptions may have affected the cost estimates of different program components in the sections below. More detail about the monitoring program models and other assumptions used in the analysis is contained in the Appendix.

2.1 At-Sea Monitoring

Amendment 16 specified that sectors would have the responsibility to procure the services of and fund a third-party monitoring program to ensure sector catch allocations are not exceeded and to verify area fished, as well as catch and discards by species and gear type. Under the at-sea monitoring program, the sector would contract directly with a provider(s) to deploy at-sea monitors, who would submit data to NOAA Fisheries for evaluation to monitor sector allocations by stock area. The sector would bear all of the costs of the services associated with the deployment of at-sea monitors. NOAA Fisheries responsibilities under an industry-funded at-sea monitoring program would be those associated with administering and monitoring the performance of the sector's program and ensuring the quality of the data for management. Specific duties would include review and approval of sector monitoring plans; training and certification of individual at-sea monitors; debriefing of at-sea monitors; processing and quality assurance of at-sea monitor data; maintenance of the Pre-Trip Notification System (PTNS) to identify trips that must carry an at-sea monitor; and general oversight of the program. In the sections that follow we estimate the sector's and NOAA Fisheries costs for these duties. We differentiate the recurring operational costs of a program from the one-time or periodic investments to start or maintain the program, termed "annual" and "implementation" costs, respectively.

2.1.1 Industry At-Sea Monitoring Costs

Annual Costs

To generate estimates of a sector's ongoing operational costs, we used the estimated cost per sea day provided by the NEFSC for the federally-funded At-Sea Monitoring Program. The sea day cost of the At-Sea Monitoring Program has fluctuated over time as the amount of fishing effort, numbers of at-sea monitors, and terms of the program contracts have changed, in response to management needs. For this analysis, we used the actual At-Sea Monitoring Program expenditures from fiscal year 2014, averaged across multiple service providers under specified contract requirements. This was estimated at $710 per sea day for the sea day costs (which would be assumed by the sectors in an industry-funded program), and $530 per sea day for the shore-based infrastructure support (totaling $1,240) (Martins, pers. comm. 2015a). In order to expand this sea day estimate to an estimate of total annual costs for a single sector, we created a hypothetical groundfish sector with fictitious membership and activity that would drive total program costs. We used a hypothetical sector rather than a real sector's information to avoid misrepresenting this cost exercise as a precise estimate for any one sector. We assumed that the hypothetical sector had 20 active vessels in ports from Gloucester, MA to Saco, ME, fishing 2000 trips per year, based on averages of individual sector data contained in the Fishing Year 2014 Northeast Multispecies Sector Operations Plans and Contracts Environmental Assessment (NOAA Fisheries, 2014a). A detailed description of the hypothetical sector and program model is available in the Appendix.

We assumed that 18 percent of sector trips would be observed by at-sea monitors (the level of at-sea monitor coverage required in fishing year 2014 (NOAA Fisheries, 2014b)), which produced an estimated 510 observed sea days. The total annual cost for the hypothetical sector was estimated by multiplying the number of observed sea days for the sector (510 days) by the average cost per sea day ($710). This resulted in a total cost of $362,100 for one year of at-sea monitoring coverage for the sector. Divided among all 20 member vessels equally, the average annual cost per vessel is $18,105. Divided among observed trips, the average cost per observed trip is $1,006.[1] Divided among all of the sector's trips (observed and unobserved), the average cost per trip is $181 (Table 1).[2] The allocation of costs within a sector is a matter for the sector to determine but clearly can affect member costs substantially.

Table 1: Annual At-sea Monitoring Costs for Hypothetical Sector

	Estimated Cost
Per Observed Sea Day (at 100% coverage)	$710
Per Observed Trip (at 100% coverage)	$1,006
Divided over all Sector Trips (18% coverage)	$181
Divided amongst all Sector Vessels (yearly)	$18,105
Per Sector (yearly)	$362,100

In fiscal year 2014, approximately 57 percent ($710 of $1,240) of the at-sea monitoring cost was generated by the at-sea deployment component, and 43 percent of the at-sea monitoring cost is the land-based support (36% was training and data processing, and 7% was in physical infrastructure and travel for support staff) (Figure 1) (Martins, pers. comm. 2015a). Understandably, the at-sea deployment portion represents the greatest component of costs. Out of that $710 sea day cost, 79% of that is for the actual payment of the deployment at sea, 9.5% is the travel associated with the trip, 7% are the training costs (wages for training of the monitor), 2.5% is for meal reimbursements to the vessel (that would likely not exist in an industry-funded situation as it is the responsibility of the vessel to provide accommodations to the monitor), and 2% is for hourly wages for shore side activities such as waiting for vessel departures or extended debriefings by monitoring supervisors. The NOAA Fisheries At-Sea Monitoring Program has explored ways to reduce at-sea deployment costs, including pro-rating partial sea days (Martins, pers. comm., 2015b), simplified the data collection, streamlined electronic data collection, and establishing a pre-trip notification requirement to locate fishing effort. The college education requirement was eliminated for at-sea monitors by the Council through Amendment 16 in an effort to reduce the cost of at-sea monitors compared to observers. However, under the NOAA Fisheries At-Sea Monitoring Program, this measure has not produced an overall cost savings, because the conditions affecting wages are largely the same for at-sea monitors as for observers (e.g., work environment, job responsibilities), and has required additional costs in training and recruitment. In addition, pay is scaled to experience in order to attract and retain qualified and experienced monitors that collect quality data (Industry-funded Monitoring PDT/FMAT, 2014a).

[1] Assuming 360 observed trips.
[2] Assuming 2000 sector trips.

Observer attrition contributes to training and program management costs, so the longer an observer is retained; the more return the program is getting for the time and resources invested to recruit and train that observer. Reducing the amount of information collected by an at-sea monitor, to reduce the complexity of the work, has been suggested as a cost-saving measure. However, this does not so much affect sea day deployment costs as training costs, by reducing the amount of training that is required (Martins, pers. comm., 2015b). Operations and infrastructure support accounts for 20% of the At-Sea Monitoring Program costs currently (Figure 1). Training costs account for approximately 12 percent of the current At-Sea Monitoring Program costs, so reducing the amount of data collected by an at-sea monitor would not have a substantial impact on costs (Figure 1) and would affect the data quality levels and the data processing and debriefing time. And 11% of the costs are associated with data processing (Figure 1). The cost of At-Sea Monitors under an industry-funded model may change, but how much is difficult to precisely predict. The cost of data collection from a specific trip would vary depending on trip length. A longer trip, with more sea days, would have a higher per trip cost than a day-trip, but may reduce overall costs associated with the deployment planning and travel to the vessel (i.e. longer trips can have a better return for the cost in amount of sea days accomplished, lowering the rate per sea day).

Figure 1: Proportion of At-sea Monitoring Costs by Program Component, based on FY14 expenditures under current contract requirements, showing sea days, training, operations and infrastructure support, and data processing.

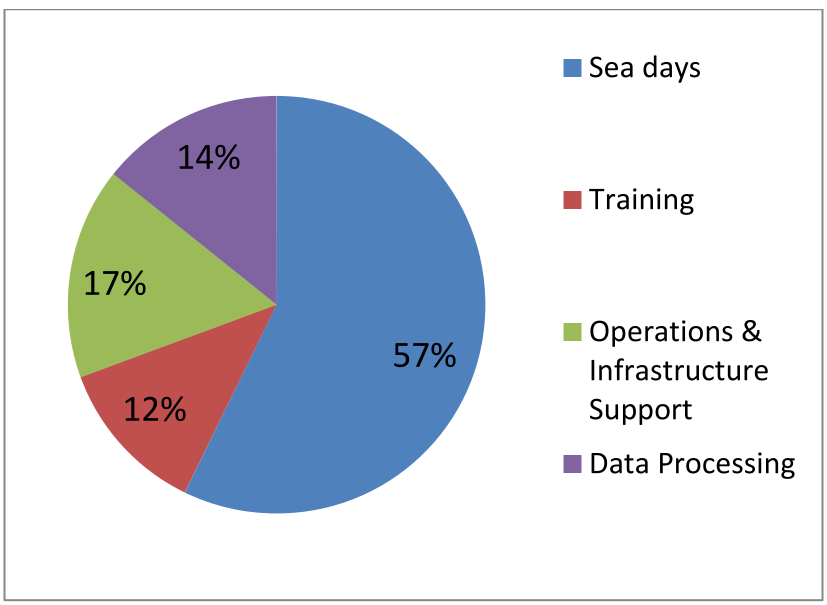


Table 1 shows average costs that would accrue to a vessel or for a trip in this hypothetical example. The exact travel costs of a particular trip would depend on where the vessel was leaving from and returning to and how good they were at relaying the logistics to the at-sea monitor, the cost of lodging (if required), mileage, and labor during travel. A trip leaving from or returning to a remote port would generate higher travel costs than a trip from a centralized port, depending on the at-sea monitor's point of origin, reliability of the departure planning, and advanced notification. Having a strategic number and distribution of at-sea monitors across ports can affect travel costs in this way. The travel costs presented here are based on the terms of the NOAA Fisheries At-Sea Monitoring Program contract, which reimburse travel costs for observers only when travel is 50 miles outside of their home port consistent with rules for Federal employees (Rossi, pers. comm., 2014b, and the contract requirements are posted online at: www.nefsc.noaa.gov/femad/fsb). When a vessel does not provide adequate notice of cancelling a trip that was selected for coverage, an at-sea monitor may be sent to the dock for deployment unnecessarily. Although no sea day deployments occur, costs associated with the observer's time at the dock and spent traveling are still incurred. Incidences of no call/no show trips, which impacted costs early in the program, have declined as the At-Sea Monitoring Program matured, but still can increase in efficiency by the continued cooperation of the industry. Depending on how these factors change when at-sea monitoring transitions to sector funding, travel costs could increase. Good communication between vessel operators and program coordinators could keep unnecessary travel costs down. This will likely be a greater challenge for smaller day-trip boats, which are more weather dependent.

As noted previously, the actual cost per vessel or per trip would also depend on how the sector chooses to recover monitoring costs from its member vessels. For example, in our hypothetical sector, if the vessel that carried the observer were charged for the observed trip, the average cost would be $1,006 per observed trip. In this model, vessels that receive more coverage will see higher monitoring costs than vessels with lower coverage. However, all vessels in the sector get to use in-season discard rates generated from the observed trips when they do not carry an at-sea monitor themselves. If the sector distributed monitoring costs equally among all its trips, such as a per-trip monitoring fee, regardless of whether or not the trip carried a monitor, the per trip cost drops to $181 per trip. Monitoring costs as a proportion of revenue may be higher in this scenario for vessels that typically take lower revenue trips. A per pound fee scaled to species value may be another way that a sector distributes monitoring costs throughout its membership, which would result in different per-vessel costs than those estimated here. Cost sharing arrangements could potentially vary by sector depending on member preferences.

Implementation Costs

Another important cost component of any monitoring program is the implementation costs, the one-time or periodic investment of equipment and infrastructure necessary to start and maintain the program. NOAA Fisheries, at-sea monitoring service providers, and the sectors have already developed and implemented much of the infrastructure for a sector monitoring program through implementation of the NOAA Fisheries At-Sea Monitoring Program. NOAA Fisheries already has established training and certification programs for service providers and at-sea monitors, as well as data processing and debriefing procedures for an at-sea monitoring program. NOAA Fisheries and service providers have staff and facilities to support these services in place. As a result, we anticipate that the program would largely remain unchanged when it transitions to industry funding and sectors would not be expected to have substantial additional start-up costs.

2.1.2 NOAA Fisheries Costs

In this section, we estimate NOAA Fisheries costs using the fiscal year 2014 costs of administering the At-Sea Monitoring Program for all sectors. Although the individual sector is the unit of importance to sectors, NOAA Fisheries administration costs are not so much influenced by the number of sectors as the number of service providers, monitors, vessels, and trips.

NOAA Fisheries recently estimated its spending to support all NE monitoring programs in a presentation to the New England and Mid-Atlantic Councils (Gabriel, 2014). A more recent analysis has been done for fiscal year 2014 actual expenditures (Martins, pers. comm., 2015b). NOAA Fisheries spent an estimated $531,953 on training, $626,043 on data processing, and $719,548 on program management for the At-Sea Monitoring Program, for a total cost of $1,877,544 (Table 2). We divided this total cost by the number of at-sea monitor sea days accomplished (3,541 days) to get a per sea day administrative costs of $530 (Table 2) (Martins, pers. comm., 2015b). We estimated a per sea day cost to provide a comparison to the estimated per sea day cost of the sector operations in Table 1, but it is important to note that many of the costs to NOAA Fisheries are largely fixed and do not scale linearly with the number of sea days (Gabriel, 2014). For example, NOAA Fisheries must lease office space to house its staff and equipment. The size and cost of the space might differ between programs with 50 sea days versus 5000 sea days, but is not likely to change between 4,000 and 5,000 sea days. In this way, the facility cost might be fixed between 4,000 and 5,000 sea days, resulting in a higher cost per sea day at 4,000 sea days than at 5,000 sea days because the fixed cost is distributed over fewer days.

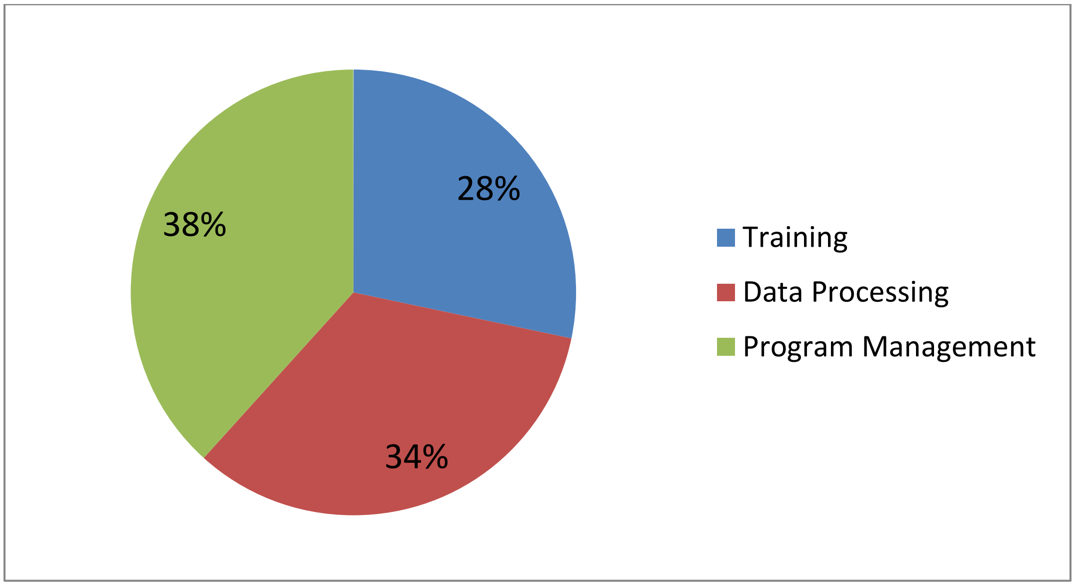
Table 2: Annual At-Sea Monitoring Costs for NOAA Fisheries

	Estimated Cost	
Program Component	**Total**	**Per Sea Day**
Training	$531,953	$150
Data Processing	$626,043	$177
Program Management	$719,548	$203
Total	$1,877,544	$530

Out of the shore-based costs for NOAA Fisheries, training made up 28% of the costs (Figure 2). Program management costs make up 38% of the shore-based costs and include labor, supplies, and facilities to provide sea-day schedule and deployment plans (vessel selection via PTNS), oversight and approval of service providers and monitors, liaising with service providers and sectors, and for the day-to-day operations of the program (Figure 2). Data processing makes up 34% of the shore-based cost and includes debriefing of at-sea monitors and quality checks of the data. NOAA Fisheries also has costs for archiving and securing observer data (i.e. Data Management Systems). Cost information for data management and analysis, as a general NEFSC support network, was not included in the estimates in Table 2. Data processing costs would not be expected to change substantially due to a transition to industry funded programs, because these costs are driven by the level of activity in the program rather than who pays.

As noted above the implementation costs are incurred over several years and would be minor. NOAA Fisheries does anticipate having one-time costs to re-program PTNS to accommodate sector contracts with specific service providers. A rough estimate of contract labor for this task would be $26,000 (Rossi, pers. comm., 2014a).

Figure 2: Proportion of the Shore-based At-Sea Monitoring Costs by Program Component, based on actual expenditures in FY14.



2.2 Electronic Monitoring

As noted at the beginning of Section 2, the basic requirements and objectives for a sector EM program would be the same as an at-sea monitoring program. Because an EM program has slightly different components than an at-sea monitoring program (e.g., an EM program includes duties for reviewing video and comparing EM data to the logbook, which do not exist in the at-sea monitoring model), we had to make assumptions about what responsibilities would lie with NOAA Fisheries and with the sector. In this comparison, the hypothetical sector is responsible for contracting with a third-party service provider, certified by NOAA Fisheries, to collect and submit the EM data to NOAA Fisheries. NOAA Fisheries would be responsible for developing performance criteria and monitoring the performance of the EM program. Based on our current understanding of cost responsibilities, we interpreted this to mean that the sector would contract with a service provider for equipment, data retrieval, and video review, while NOAA Fisheries would certify and audit the performance of the service providers. NOAA Fisheries does not currently have a training program for EM reviewers and technicians, but NOAA Fisheries would need some way to ensure that reviewers and technicians are appropriately trained. The service provider may be required to provide appropriate training on species identification and field/data services to technicians and EM reviewers, and the training program and individual technicians or reviewers may be required to be approved or tested by NOAA Fisheries. Or NOAA Fisheries may develop a specific training program for EM reviewers. NOAA Fisheries would also continue to operate the PTNS, which sector vessels would notify to determine if they will get a Northeast Fishery Observer Program (NEFOP) observer for Standardized Bycatch Reporting Methodology (SBRM) coverage. NOAA Fisheries may also conduct periodic audits of the service provider to ensure that EM data collection is being done accurately and consistently.

We assumed that EM would be used to audit reports of discards on vessel trip reports (VTRs) through review of video from subsets of individual fishing trips. A detailed description of the model and assumptions used is contained in the Appendix. Some key assumptions used included:

- Video would be recorded on all sector trips and 20 percent of hauls would be reviewed from each trip, with a 1-haul minimum, to determine the count and to estimate the weight of discards of all species.
- The service provider would be able to obtain VTR data for the audit without additional cost through the use of eVTR or other applications.
- The remaining video from the trip would be reviewed to check for discarding during transit. This includes the portion of hauls not reviewed (80%) as well as the time the vessel is in transit and not engaged in fishing activity.
- A technician would retrieve the hard drive from the vessel once a week.
- The service provider would review the video and associated data and submit a weekly report to NOAA Fisheries and the sector manager.

This model was applied to the same hypothetical sector used in the estimation of at-sea monitoring costs in Section 2.1. The description of the example program and hypothetical sector in the Appendix was supplied to three EM service providers, Archipelago Marine Research, Ltd., Saltwater, Inc., and EcoTrust Canada, to generate cost estimates of the hypothetical sector's costs. The individual cost estimates submitted by the providers were then averaged to get one cost estimate for each program component in order to protect the confidentiality of each service providers' price information. The service providers also provided a narrative analysis of factors and assumptions that drove the costs of the example program, as well as potential cost saving measures, which were incorporated into the discussion below. NOAA Fisheries estimated its own potential costs for administering the program in Section 2.2.2 to compliment the service providers' estimates of the sector's costs in Section 2.2.1.

2.2.1 Industry Costs

Annual Costs

The annual costs of the program can be binned in four categories: equipment, field services, data services, and program management. Equipment costs here refer to spare parts to replace broken or aging equipment and licenses for use of proprietary software. Costs for the EM system itself are discussed under Implementation Costs in the next section. Estimating annual equipment costs is difficult, because the rate of replacement or repair depends on several factors including how well the equipment is cared for; the conditions it is subjected to; and the service delivery model (Pria, pers. comm., 2014a). Two of the service providers estimated the annual cost of spare parts based on an assumption about failure rates, while the third estimated it as a percentage of the initial system package cost amortized over the contract term. This resulted in very different equipment cost estimates, which were averaged to get the estimate presented in Table 3.

Field services include labor and other costs associated with repairs, technical support, and retrieving hard drives from the vessels. Data services costs are the costs associated with review and analysis of the video, reporting to the sector and NOAA Fisheries, and archiving of the data. Program management encompasses the day-to-day costs to the service provider of running the example EM program. The average estimate of the total annual cost for the example EM program using the hypothetical sector was $1,012,372 (Table 3). Dividing the total annual cost equally among the 20 member vessels resulted in a total annual cost per vessel of $50,619. The estimated average cost per sea day is $357[3] and the estimated average cost per trip is $506[4] (Table 3).

Table 3: Annual Electronic Monitoring Costs for Hypothetical Sector

	Estimated Cost			
Program Component	**Per Sector**	**Per Vessel**	**Per Sea Day**	**Per Trip**
Equipment	$26,063	$1,303	$9	$13
Field Services	$139,909	$6,995	$49	$70
Data Services	$656,526	$32,826	$232	$328
Program Management	$189,874	$9,494	$67	$95
Total	$1,012,372	$50,619	$357	$506

The majority of ongoing costs are generated by data services (65 percent) followed by program management (19 percent) and field services (14 percent), as can be seen from Figure 3. The factors driving field services costs are simpler, so we discuss them first. For this analysis, we assumed that a technician would be deployed weekly to retrieve the hard drive from each vessel in order to provide an estimate of what this option would cost. The fact that a technician must be deployed weekly to meet each vessel generates labor and travel costs, which make up the field services costs. Other options for data transmission that could reduce costs are to allow the vessel operator to switch out the hard drive weekly and mail them to the provider, or to change the frequency of retrievals. Increased latency of the audit may be a feasible option for reducing field services costs in later years, when reporting quality improves. If logbook discard estimates become of sufficient quality, drastic revisions to the discard estimates would not be expected from the audit (EcoTrust Canada, 2014). Allowing the vessel operator to deliver the hard drives themselves could be a substantial cost savings and a feasible alternative if appropriate incentives and measures are in place to ensure the security and integrity of the data. In this case, the cost to the vessel or sector would be for securing and shipping the hard drives, rather than for visits by a technician.

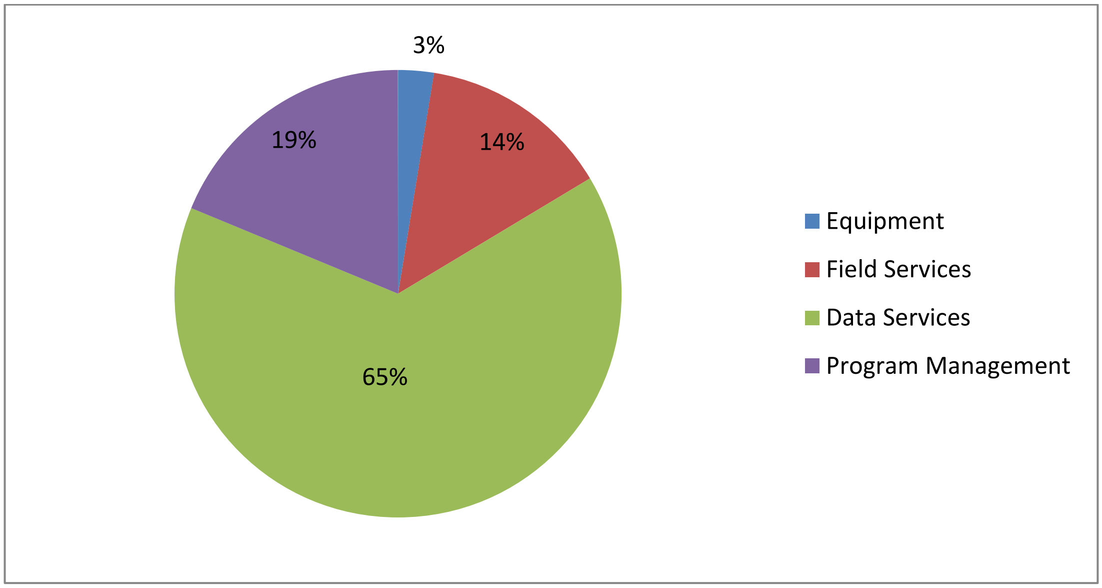
Data security measures to render the data tamper evident or tamper proof have their own costs. End-to-end encryption is an effective way to ensure that data cannot be easily manipulated, but is more costly than other technological options. The EM service providers indicated that digital signatures are currently used in Canadian fisheries monitored with EM and are an effective method to render the EM data tamper evident (Van Oyen, pers. comm., 2014; Pria, pers. comm. 2014). The data can be digitally signed by the EM control box, allowing the service provider to detect if the trip data were changed during transit. Once digitally signed, any change to the underlying data would invalidate the signature. While not physically preventing tampering, digital signatures may be sufficient to dissuade tampering if combined with appropriate penalties or other incentives. As open source algorithms are available, digital signatures may be a cost effective way to ensure the integrity of EM data in transit (Van Oyen, pers. comm., 2015).

[3] Assuming 2,834 observed sea days.
[4] Assuming 2000 observed trips.

Field services costs are also driven by repair and technical support needs. The type and frequency of visits depends on several factors, including how well the equipment is maintained by the vessel operator; whether the vessel operator is allowed or able to make simple fixes on his/her own; whether the service is covered under warranty; and the complexity of the service issue. Data retrieval technicians may be trained to handle service issues to reduce the need for dedicated service visits. However, training data retrieval technicians to handle complex issues that occur rarely may not be worth the cost in time and resources. The appropriate service model will depend on the needs of the sector and the distribution of its fleet. Different options and their trade-offs were discussed in greater detail in the New England EM Project Phase III report (Pria et al., 2014). For this cost analysis, the service providers assumed that many minor technical issues with the system could be addressed on the weekly visits to retrieve the hard drive, so estimated costs of exclusive equipment/technical support visits are low. If vessel operators are submitting the hard drives directly, more equipment/technical support visits may be necessary, although the total number of visits to the vessel would be less than would be expected under a model where technicians retrieved the hard drives. If it is necessary for the hard drive to be retrieved by a technician to ensure data integrity, coordinated or centralized visits may help reduce costs (e.g., service multiple vessels on a single visit).

Program management costs are the most difficult to estimate, because they vary by the scale and complexity of the program; the level of cooperation from participants; the service delivery model desired by the sector and the government; and the amount of efficiency in the program. For example, a sector may have its own resources like a sector manager or other staff that it would prefer conduct outreach and training for vessel captains and crew. A different sector may wish its service provider to do frequent outreach with individual vessels or the sector manager. For this analysis, some of the service providers developed itemized estimates of program management costs, while others estimated program costs as a fixed percentage of direct costs. This resulted in a wide range of cost estimates, which were incorporated into the average cost in Table 3. In general, the service providers would expect there to be higher total program management costs for a large or complex program with many, or uncooperative, vessels. However, per vessel program management costs would decline with more vessels in a program due to the ability to achieve economies of scale. Whether there is one or more service providers in the fishery would also affect program management costs; multiple providers may limit each provider’s ability to achieve economies of scale. Some changes to other program components to reduce costs could also reduce costs for program management by simplifying or reducing the scale of the program. For example, training for technicians is included in program management costs. If vessel operators were allowed to submit their own hard drives for analysis, fewer technicians would be employed, reducing training and logistical costs. Lower levels of video review would similarly reduce program management costs, by reducing labor and training costs (Pria, 2014), though the consequences to the data quality requirements would have to be made clear.

Figure 3: Proportion of Annual Sector Electronic Monitoring Costs by Program Component



Data services costs are the most significant component of total annual costs given that the processing and review of EM data is the backbone of the EM program. To better understand the program elements driving data services costs, we broke down data services costs into finer detail in Figure 4. In our example EM program, data analysis includes three types of video review:

1) The primary video review is conducted on video recorded during catch processing. The objective of this review is to document all discards of all species, including identifying and counting species, and measuring the length of each discarded fish in order to calculate a weight to compare to the logbook. In our example model, the primary review is done on 20 percent of hauls to audit the logbook (or 1 haul per trip).
2) The secondary video review is the review of the remainder of the catch processing from the trip, which only takes place when the VTR discard estimates fall outside of the acceptable margin of error during the audit. In this way, secondary review costs are greatly driven by the accuracy of the captain's estimates and how the performance standard is defined. If the captain and crew are not careful about estimating discard weights or if the standard for the audit is very high, more of the video will have to be reviewed, increasing the secondary review costs. In the British Columbia EM program, the secondary review costs are paid by the vessels reviewed as an incentive for more accurate reporting (Stanley, 2008). To account for the variability in reporting quality, we assumed that 5 percent of trips annually would trigger secondary review.
3) The discard compliance review is a review of the remaining video of the trip to ensure that no fish are discarded during steaming between hauls or on the return to port. The objective of this review is to ensure that discards recorded during the review of audited hauls are accurate. This review can be done at high speed resulting

in a much shorter review time relative to the amount of video reviewed, when compared to the primary video review.

The primary video review, secondary video review, and discard compliance review account for 40 percent ($262,610), 8 percent ($52,522), and 33 percent ($216,654), respectively, of data services costs for the hypothetical sector. Although the discard compliance review can be done quicker than the primary review, the large amount of video reviewed (nearly the entire trip) results in a high review cost. Given that the objective of this review is to counter an incentive to discard outside of the window of time when the higher resolution cameras are recording catch processing, the service providers suggested that reviewing a random selection of segments, rather than the entire trip, or certain trips selected at random or based on a risk scale, may be sufficient (Saltwater, 2014; Pria, 2014). It is difficult to know how much video review would be necessary to encourage compliance or to detect non-compliance, but this may be a worthwhile option to explore to reduce review costs. The simple fact that the camera is recording all the time and there is the possibility that any segment of video could be reviewed may encourage compliance with catch handling requirements.

The primary video review costs are similarly driven by the amount of video reviewed. We used an assumption that 20 percent of hauls from each trip, rounded up to the next whole haul, would be selected for audit. Because of the low number of hauls per trip, this resulted in only one haul being reviewed from each trip, which is the minimum necessary to be able to audit each trip (i.e., 1 haul out of the average 3-5 hauls per trip). However, because each trip is audited, the large number of trips fished by the sector (2,000 trips) drives up the total primary review costs. This large number of trips may not be entirely realistic for a single sector, so actual review costs to a sector may be lower. However, as the same number of trips was applied to both the at-sea monitoring and EM models, the estimates are still relevant for comparison. It should be noted that the review ratios used in the report were taken from pilot projects and may not entirely reflect the rates that might be feasible in a mature program. Some of the service providers believed that slightly faster review rates would be possible, with experienced reviewers, which would reduce costs slightly. On the other hand, the primary review ratios used from the New England EM Project were based on quantification of only allocated groundfish species. If the objective of the primary review were to quantify discards of all species in order to validate the logbook, the review may take longer resulting in higher costs.

There may be other options for subsampling methods that could reduce program costs while still providing sufficient confidence in catch estimates. The EM service providers suggested several alternative approaches that may be worth exploring for the groundfish fishery:

- Lower levels of review may be appropriate in scenarios where the audit is simply to "spot-check" vessel reports. Depending on the objectives of the program, it may be that the "radar trap effect" can provide sufficient incentive for accurate self-reporting at low levels of audit.[5] Determining what level of review would create this effect and catch the

[5] Having the camera recording on all trips encourages accurate reporting of all fishing events on logbooks, because any trip could be randomly selected for review. This has been called the "radar trap effect" of EM and is credited with the improved accuracy and accountability of reported catches in the British Columbia EM program (Stanley, 2008).

majority of misreporting events is difficult (Saltwater, 2014; Pria, 2014; EcoTrust Canada, 2014).

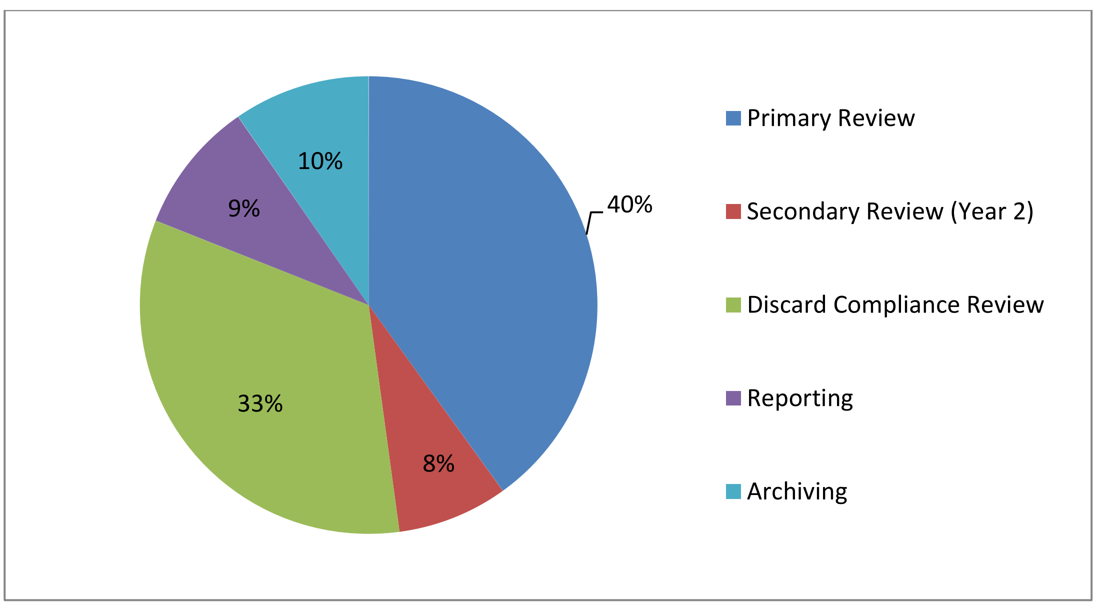
- Define fleet or vessel-specific sampling levels – video is recorded and retrieved for each trip to maintain incentives for accurate reporting, but only a subsample of trips from the fleet or vessel are randomly selected for review according to the "coverage" level determined to provide sufficient confidence in that fleet or vessel's logbooks (Saltwater, 2014).
- Software solutions – software programs that could automate or expedite review to reduce review time, labor, and costs (Saltwater, 2014). There are a few ongoing efforts to develop software applications that can automate portions or the entirety of the video review to substantially reduce the human labor and costs involved in data analysis. These efforts are described in more detail in Section 3.3.

Other options were discussed in Pria et al. 2014, such as sampling hauls for review on a weekly, bi-weekly, or monthly basis rather than a trip basis. Different methods may be considered for different phases of a program, such as early in a program where there is a learning curve for vessels versus later in a program when reporting has improved (New England EM Project Phase III, 2014). However, it is necessary to assure that information is sufficient to monitor in-season sector catch against Annual Catch Entitlement (ACE) allocations.

Trip and vessel level costs for video review may differ by gear type, due to differences in the length of trips as well as the time to review video. Review of catch handling on otter trawl trips generally takes longer than other gear types because the greater volume of catch on a single haul lengthens catch sorting and review time.

Data services costs may also include any data entry that would be needed to enable data analysis. In our model, we assumed that an open source electronic logbook application would be used to transmit VTR data to the service provider and NOAA Fisheries at no additional cost.

Figure 4: Composition of Annual Sector Electronic Monitoring Data Services Costs



The remainder of data services costs is generated by reporting and archiving costs. Reporting costs are relatively small compared to the data analysis costs, only 9 percent, and consists of mainly labor associated with generating regular reports for NOAA Fisheries, the sector manager, and vessel operators, as well as uploading of any data to NOAA Fisheries for audit. The frequency or complexity of reports will drive reporting costs.

Archiving costs account for 10 percent of data services costs, or $65,653 annually. Archiving costs are driven by the amount of data and the length of time it needs to be stored, security requirements, and whether the data needs to be accessed regularly or simply archived. Individual file sizes are driven by the amount of video, resolution, frame rate, type of codec[6] used, and even the amount of light and movement in the video (Pria, pers. comm., 2014). The following specifications are determined by the objectives of the program in several ways:

- The objective of the program and how it relates to the layout of the vessel will determine the number of cameras. If sorting is taking place in multiple locations on the vessel, more cameras will be needed. More cameras increases archive requirements.
- The speed at which activities of interest are occurring on the vessel will determine the frame rate of the video (fps). Slow activities such as identifying large objects in a pile of fish being sorted, requires more frames per second. The higher the frame rate, the more likely it is that the camera will capture detailed information. Higher frame rate results in increased demands on storage.
- The amount of detail needed will determine the camera frame size (i.e., image resolution). Identifying fish to species requires higher resolution than verifying when fishing gear is deployed. Higher resolution results in larger video files and requires additional storage requirements.
- The objective of the program will determine when video is being recorded. If objectives can be narrowly defined, video recording could be targeted to certain periods during the trip to avoid large data volumes (Pria, 2014).

Rough estimates of average file sizes per camera from the EM service providers ranged from 0.6 GB/hr at 5 fps to 2.1 GB/hr at 15 fps with resolutions 1280 x 800. Based on these file sizes, a rough estimate of potential data volumes are 168 TB per year for the 20-vessel sector (Pria, 2014). The capacity to collect more information will grow over time as technology improves, creating a temptation to collect and retain as much data as possible. As data storage technology improves, storage costs will decline but the service providers cautioned that storing all EM data would not be practical (Pria, pers. comm., 2014).

For this analysis, we asked service providers to assume that all video imagery, sensor data, etc., needs to be stored for five years after the trip (the statute of limitations under the Magnuson-Stevens Act), as a worst-case scenario. Data storage options include cloud storage, centralized storage on servers, or simply storing the video on the original hard drive. The appropriate option will depend on the future record-keeping and security requirements specified for EM data. The service providers indicated that cloud storage would be the most cost effective option.

[6] A codec is a device or program that compresses data to enable faster transmission (PCmag.com).

Companies like Amazon have low rates for simple storage ($0.01/GB/month[7]) and take care of all maintenance and data backups. This could be a viable option if the data simply needs to be stored, but additional fees are typically charged for access to the data (Pria, 2014). Centralized storage on servers requires facilities and staff to house and maintain them, increasing costs for the service provider, but may be appropriate if regular access to the data is needed. Storing the data on individual hard drives would require purchasing many hard drives as well as storage space to house them. In addition, hard drives can degrade over time, threatening the integrity of the data (Rossi, pers. comm., 2014a). The service providers believed that the individual hard drive storage option would be a worst-case cost scenario. The service providers each assumed a different type of storage would be used, resulting in a wide range of storage cost estimates that made up the average presented here.

Somewhat related to, but separate from, the archiving and reporting costs are the costs of transmitting the raw video and sensor data to NOAA Fisheries for audit of the service providers. A single trip can produce large file sizes that may take up to 1-2 days to upload using a standard internet connection (Van Oyen, pers. comm. 2014). This would be an additional cost to take into consideration in future discussions about program design. For this analysis, the service providers assumed that existing bandwidth would be sufficient.

Implementation Costs

In addition to the ongoing operational costs of an EM program, there are one-time or periodic investments to implement and maintain the program. We asked the EM service providers to characterize these start-up costs, where possible, to illustrate the investment that would be necessary to implement an operational EM program for a sector. We binned implementation costs into the same four broad categories, equipment, field services, data services, and program management, although they represent different activities here than under the discussion of annual costs. The equipment costs of implementation include the cameras, associated sensors, integrated GPS, control box, and hard drives. In this analysis, we asked the service providers to assume that the equipment would be purchased, but leasing equipment is another option. Depending on the circumstances, one or the other option may make more economic sense for the vessel or sector). The average estimated costs of purchasing the equipment was $8,904 per vessel (Table 4), representing 15 percent of implementation costs. In addition to these costs of the system itself, some vessels may require modifications at additional cost to accommodate the EM system. These costs vary greatly by vessel and so were not estimated by the service providers. However, the Northeast Fishery Observer Program noted the types of modifications that were necessary to outfit vessels for the New England EM Project: shielding of electrical cables to prevent interference with the vessel's Vessel Monitoring System (VMS); additional deck lighting; installing conveyors; the addition of discard chutes; dedicated or upgraded power supply; reconfiguring antennas; and installing mounts for cameras.

Field services costs of implementation include the labor and travel associated with the installation of equipment. The average estimated field services costs were $2,391 per vessel. As with data retrieval services, the exact installation costs would depend on where the vessel was located relative to the technician's base of operations and the complexity of the installation. For example, a complex installation may require a technician to stay overnight in order to conduct

[7] https://aws.amazon.com/archive

repeated tests or troubleshoot problems. An installation would also typically include follow-up visits to tweak equipment settings following the first few fishing trips. The service providers used the distribution of the vessels across ports in the example provided to estimate the travel costs of servicing these vessels.

The data services costs of implementation consist of the costs of additional data review due to the learning curve for vessel captains in recording discards. It can take time for captains and crew to estimate discards with sufficient accuracy to pass the audit, perhaps even two to three years after the start of the program (Pria et al., 2014). During this time, the secondary video review may be triggered for nearly every trip, greatly increasing the data services costs for the first year. To simulate the effect of this learning curve on data review costs, we asked the service providers to estimate the review costs separately for three phases of the program, assuming that no trips pass the audit in the first 6 months, 50 percent pass it during 7-12 months, and 95 percent pass it after 12 months. The latter phase was included in the annual data services costs in Table 3. The costs of the first and second phases were summed to get the data services implementation costs, estimated at $853,681 total for the hypothetical sector (Table 4). This is a substantial investment for a sector. As was discussed in the previous section, several other options may exist for sampling video for review, which could also be used to reduce these implementation costs in the first few years of the program. Archipelago also suggested other options, such as reviewing a random sample of video and extrapolating the results to the rest of the fleet, as is done with the at-sea monitoring data, or to set less strenuous standards for the audit in the first year (Pria, 2014). This would allow vessels time to work on their discard estimation, without incurring high costs for review. A less strenuous audit standard does allow for a potential trade-off in the quality or credibility of the data.

The estimated cost to the vessel for the additional review is $42,684, when divided equally among all 20 vessels (Table 4). Assuming that the individual vessel would be charged for any secondary review of its own trips, as in the British Columbia program, the actual cost to each vessel would depend on the quality of that vessel's reporting. If a vessel captain and crew are able to pick up the discard handling and estimation methods quickly, they could reduce their secondary review costs earlier in the program than a vessel that took much longer to meet the performance standards. The actual cost to the sector will depend on how its individual vessels perform, how well the crew works with the system, and the functionality of the catch handling procedures

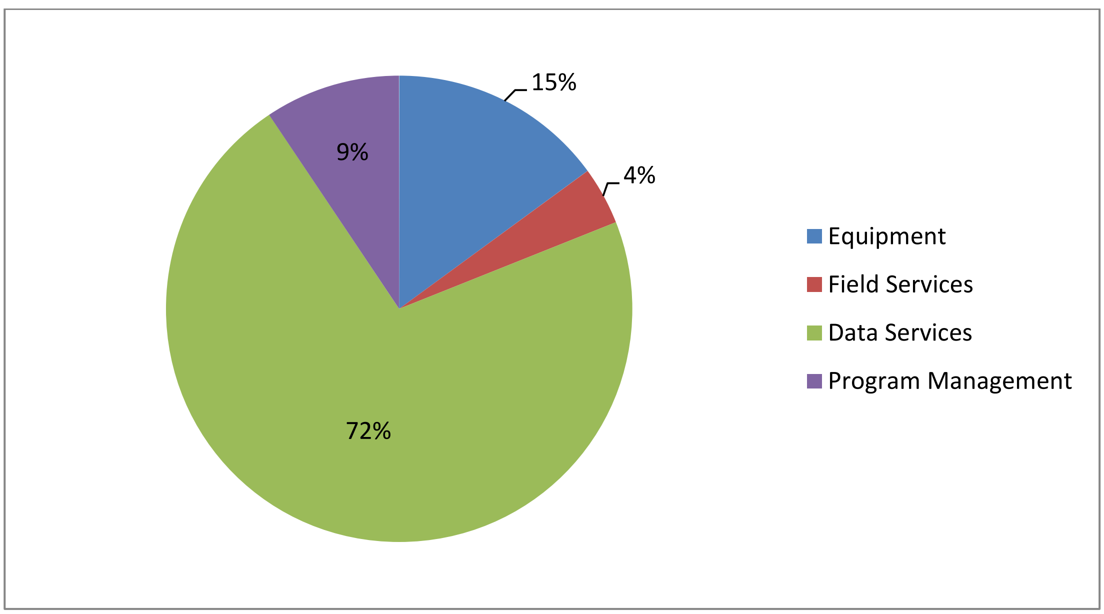
Table 4: Electronic Monitoring Implementation Costs for Hypothetical Sector

	Estimated Cost	
Program Component	**Per Sector**	**Per Vessel**
Equipment	$178,079	$8,904
Field Services	$47,829	$2,391
Data Services	$853,681	$42,684
Program Management	$111,919	$5,596
Total	$1,191,508	$59,575

Program management during the implementation phase includes the one-time labor and equipment associated with setting up the program (9 percent; Figure 5). As with annual program management costs, the costs of the implementation phase depends on the program scale, level of cooperation from participants, and service delivery model. Some service providers itemized estimated program management costs and others used a fixed percentage of direct costs, resulting in a wide range of estimates that were incorporated into the average. As with ongoing costs, a large or complex program with many vessels or vessels requiring a lot of attention would be expected to have higher program management costs. Some aspects of program management during the implementation phase are relatively fixed and do not scale directly with the number of vessels in the program. This results in a high per vessel cost when looking at a small group of 20 vessels. Adding more vessels or sectors to the program would spread the fixed costs over more vessels resulting in a lower cost per vessel and sector (Pria, 2014).

The total estimated one-time investment of all these components was $1,191,508 for the sector, or $59,575 per vessel if divided equally (Table 4). These costs are presented as total one-time costs, but could be considered as amortized costs over a contract period. If considered over a five-year contract, for example, the average annual cost to the sector for implementation would be $238,302 or $11,915 per vessel though sectors re-form annually. These estimates of implementation costs are substantial, but are not presented for comparison to the at-sea monitoring program for which much of the infrastructure has already been established. These estimates are simply provided to paint a full picture of the funding that may be needed to get an operational EM program started for a sector.

Figure 5: Proportion of Sector Implementation Costs by Program Component



2.2.2 NOAA Fisheries Costs

Annual Costs

In this section, we estimate NOAA Fisheries costs for administering the example EM program based on the roles and responsibilities described at the beginning of Section 2.2. Many of the costs to NOAA Fisheries for administering the example EM program would be driven by the scale of the program and the level of participation, although these costs do not necessarily increase linearly with the amount of sea days. Thus, we present a range of potential NOAA Fisheries costs from overseeing an EM program for a single hypothetical sector (20 vessels) to a program for the entire active groundfish fleet (400 vessels). We based NOAA Fisheries costs for the EM program on costs the Northeast Fishery Observer Program incurred for administering programs with similar roles and responsibilities and from the New England EM Project. These are rough estimates of NOAA Fisheries potential costs and, unlike the at-sea monitoring program costs presented in Section 2.1, may not reflect efficiencies or economies of scale that are possible in a mature program. NOAA Fisheries would also have other incremental costs for enforcement and use of the data for management, which were not estimated here in order to be consistent with the estimates of the at-sea monitoring program.

The estimated annual cost to NOAA Fisheries from the EM program would be $188,795, for the hypothetical sector, and $929,405-$1,171,905, for the fleet-wide program (Table 5). NOAA Fisheries training costs were estimated to be $25,000 for a 20 vessel program to $187,500-$250,000 for a fleet-wide program (Table 5). Training costs include labor and costs of licenses for any proprietary EM review software. The number of annual trainings that would need to be held and, hence, the number of trainers, would depend on the number of EM reviewers employed by the service providers, which would depend on the number and activity levels of vessels using EM in the fishery. Note that these costs do not increase linearly. Although the number of participants increases by a factor of 20 when scaling up from 20 vessels to a fleet-wide program, the training costs increase by a factor of 8. This type of relationship makes it difficult to estimate costs at a unit that is easily multiplied (e.g., sea day cost).

NOAA Fisheries may also have some costs for reviewing and approving, or inspecting, Vessel Monitoring Plans (VMPs) and equipment on the vessel. Annual labor and travel associated with this activity is expected to cost between $31,000 for 20 vessels and $232,500-$310,000 for 400 vessels (Table 5). NOAA Fisheries costs for auditing the service provider's review of logbooks were estimated to be $46,795 for 20 vessels and $432,405-$525,905 for 400 vessels (Table 5), assuming NOAA Fisheries audits 5 percent of trips. These costs include staff time and licenses for proprietary EM review software. Use of open source software would negate the cost of software licenses in this category. Program management cost is labor for a program manager, which is necessary to administer the new program irrespective of the number of vessels. Not included in these cost estimates is the cost of storing any EM data submitted by the service providers or sectors. NOAA Fisheries data storage costs would be driven by record-keeping and security requirements for EM data, which NOAA Fisheries is still working to determine. Alternately, NOAA Fisheries may be able to get remote access to EM data and video stored by the provider, and reduce or eliminate its data storage costs (Van Oyen, pers. comm., 2014).

Table 5: Annual Electronic Monitoring Costs for NOAA Fisheries

	Estimated Cost	
Program Component	**20 vessels**	**400 vessels**
EM Reviewer Training	$25,000	$187,500 - $250,000
VMP Approval, Inspections	$31,000	$232,500 - $310,000
EM Review Audit	$46,795	$423,405 - $525,905
Program Management	$86,000	$86,000
Total	$188,795	$929,405 - $1,171,905

Implementation Costs

NOAA Fisheries would also have implementation costs associated with setting up and maintaining the example program. These items would include equipment; training for NOAA Fisheries staff; development and modification of databases to accommodate EM data; analysis to support the integration of EM data into management; and initial approval of VMPs. Analysis costs include additional auditing of the provider in the first year to establish a baseline performance standard for the service providers.[8] These costs are largely one-time investments that may be repeated periodically, but generally not annually. Some of these costs increase with the number of vessels in the program, such as training. More trips taken means more trips selected for audit (e.g., 5 percent of 1000 trips is greater than 5 percent of 100 trips), and more staff to review these trips. However, modifications to existing and development of new databases to accommodate the use of EM data for management must be completed regardless of the number of vessels. This makes some investments appear expensive when divided among a small number of vessels, but more reasonable when divided among a fleet. On the other hand, these same investments may be approached with more than one fishery in mind, such that the investment does not have to be repeated when another fishery implements EM. For example, EM data and databases may be standardized to accommodate multiple fisheries.

NOAA Fisheries hypothetical implementation costs would be $558,000 for 20 vessels, and $1,422,500-$1,755,000 for 400 vessels (Table 6). These cost estimates are presented not for comparison with the At-Sea Monitoring Program, which has already been implemented, but simply to illustrate what investments may be necessary to get from Point A (status quo) to Point B (a fully operational EM program).

[8] We assumed that NOAA Fisheries would review 10-15 percent of trips during the first year, and 5 percent each year after, as a general estimate.

Table 6: Electronic Monitoring Implementation Costs for NOAA Fisheries

	Estimated Cost	
Program Component	**20 vessels**	**400 vessels**
Equipment	$5,000	$37,500 - $50,000
Training	$2,000	$15,000 - $20,000
Database Development	$260,000	$260,000
VMP Development and Approval	$62,000	$465,000 - $620,000
Analysis	$229,000	$645,000 - $805,000
Total	$558,000	$1,422,500 - $1,755,000

3.0 Other Considerations

In addition to the costs, drivers, and program elements discussed in the previous sections, there may be other cost considerations that need to be taken into account for different program designs. For example, in a full or maximized retention scenario, dockside and portside sampling programs could be used to supplement EM. These programs have additional costs and cost drivers that need to be considered by the industry and managers in the design process. Portside sampling is being considered as an option for the Atlantic herring and mackerel midwater trawl fishery and will be discussed in more detail in Part II of this report. Full or maximized retention protocols also raise issues of what to do with the unmarketable fish that would be landed but could not be sold and any costs associated with handling these fish. The Gulf of Maine Research Institute (GMRI) explored these topics and their potential costs, as well as technological advancements that may reduce costs for EM programs in the future. Its findings are summarized in the sections that follow.

3.1 Unmarketable Fish

An additional consideration for a full or maximized retention program is what to do with the previously discarded fish that would now be landed, but perhaps not sold. These unmarketable fish impact costs at various points in the product chain, from the fishermen who land the fish to the dealers or processors who may be collecting and storing the discards and to the plants that may utilize the unmarketable fish. To better understand the potential impacts of unmarketable fish in a full or maximized retention EM program in Northeast fisheries, GMRI interviewed representatives from 12 dealers and processors[9] across the region, several fishermen, and fishery managers from other regions and countries that have implemented a discard ban.

[9] To protect the anonymity of the responses, the specific names of the dealers and processors are not included in this report.

Northeast Fisheries

Dealers classified unmarketable fish under the current management system into several categories, including:

- *Not fit for human consumption* due to low quality or inappropriate handling;
- *Lack of market* due to low demand, sporadic availability and/or low volumes;
- *Consumer unfamiliarity* with preparation of smaller fish of allocated species, such as haddock, whiting and scup;
- *Undesirable* parts of a fish after processing, such as the head, rack, and tail.

These unmarketable fish are handled in different ways:

- *Disposal* - by fishermen or dealer. In some cases, the dealer may dispose of the fish as a courtesy or, in other cases, for a fee.
- *Block frozen market* – lesser quality product gets filleted, deboned, and processed for frozen fish products and/or chowder.
- *Bait* – monkfish heads, skate racks and herring, mackerel, redfish and whiting when there is not a good market for them.
- *Fish meal market* – high volumes of fish, e.g., herring, may be used in fish meal products.
- *Food banks* – food fit for human consumption that is unable to be sold may be donated.[10]
- *Fertilizer* – fertilizer plants will accept certain species as long as they have been properly handled. Some species, like dogfish and crabs, are not accepted for fertilizer.
- *Pet food* – pet food facilities predominantly utilize groundfish but will accept a wide variety of species with the exception of ammoniated species, such as dogfish, shark and skates.

Dealers stated that handling unmarketable fish increases work and, therefore, costs for their operations. Some of the additional labor costs include offloading, record keeping (at 15 minutes per offload), sorting of fish (e.g., removing foreign matter and ammoniated fish), and clean up. Dealers also incur opportunity costs from use of cold storage space for unmarketable fish instead of more valuable species. A truck may deliver the fish to another facility, such as a fertilizer plant. An example of potential transport costs was $1,300-$1,800 for a round-trip from Gloucester, MA to Portland, ME. If unmarketable fish is not fit to be used under any of the options above, it must be taken to a landfill at a cost of $150 per metric ton, according to one dealer's estimate. Although, another dealer noted that some landfills will not accept the fish if it is badly decomposing. In addition, some states are considering limits on commercial food waste disposal in landfills, which could impact dealers' and vessels' ability to dispose of unmarketable catch. The State of Massachusetts recently implemented a limit of one ton per week, which applies to commercial food waste from fish dealers and processors (EEA, 2015). It was not clear from the interviews whether the dealers would absorb any of these costs or pass them on to the fisherman in some way. Dealers noted that, given all these costs, the volume of the fish and the price per pound of the fish are deciding factors in the feasibility of utilizing unmarketable fish. Fishermen interviewed noted the additional costs of dealer/auction fees and [groundfish] sector fees that must be weighed against the value of the unmarketable fish.

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[10] NOAA Fisheries explored utilization by food banks during the New England EM Project and found that, due to food handling requirements, food bank donations may be a more viable option for dealers than fishermen directly.

Some dealers expressed the importance of having a plan and ensuring that the estimated volumes of unmarketable catch have somewhere to go before the retention system is implemented. New markets may be developed, but only if high volumes are consistently available. Although dealers can find markets for non-food quality and lower value fish, it may be difficult to address the volumes of catch landed at the beginning of the program when participation may be low. The New England EM Project found that two day boats participating in a test maximized retention program had unmarketable catch of 13-111 lbs. (gillnet) and 200-1031 lbs. (bottom otter trawl) per trip over 5 and 3 trips, respectively[11]. In this project, the unmarketable catch was consumed by the captains and crew, used as bait or fertilizer, disposed of in the garbage, or taken back out to sea (Pria et al., 2014). Most dealers and fishermen interviewed felt that selectivity and the volume of unmarketable fish would not change, with the exception of dogfish, which could increase if a viable market were found.

Other concerns raised included: Safety due to the requirement to land increased volumes of fish, especially for smaller vessels; sanitary and quality issues with storing poor quality fish onboard and in the dealer facility; and the opportunity costs of sorting, icing, and storing less valuable fish onboard. Some dealers worried that fishermen may not be able to adapt their vessels or operations to deal with these issues in the current groundfish fishery climate. Dealers and fishermen also raised ecological or moral concerns about full retention – some felt that all dead fish should be landed, with exceptions made for flea-bitten or seal depredated fish or large volumes of fish, while others thought that discards are an important food source for organisms at sea, or, if alive, would contribute to the fishery in future years. Some gear types may be more suitable for full retention than other gear types that have high post-release survival rates. Some thought that fishermen may appreciate the exact discard weights they could get from a dealer weigh out as opposed to observer estimates. There was general consensus from the dealers that the market could gradually handle this unmarketable catch over time. They believe that fertilizer and pet food industries are well situated to handle the increase in product and the infrastructure and trucking routes are currently in place to adapt to these changes.

National and International Fisheries

There are various examples, both nationally and internationally, where discard bans are in place or full retention is used in conjunction with EM. Below are some examples, describing the fleet in which the retention rules/discard ban is implemented, the use of unmarketable fish and lessons learned from the implementation process overall that may provide insight on the feasibility of its application in New England.

The Central Gulf of Alaska rockfish fishery does not utilize EM but does require the retention of all species allocated to the cooperatives with the exception of halibut Prohibited Species Catch (PSC) which must be discarded at sea.[12] The volume of unmarketable catch in this fishery did not present a problem because there are few discards. The balancing of objectives when selecting species for maximized retention was an important lesson-learned that allowed for the reduction of discards without increasing unmarketable fish. Full retention of all species would

[11] These volumes represent possible unmarketable catch volumes from day trips. Higher volumes may be expected from multi-day trips.

[12] Three EM projects were piloted, and concluded that EM was more expensive than onboard observers (Bonney and McGauley, 2007; Haist, 2008; McElderry et al., 2008; Bonney et. al, 2009; Mamigo Inc, 2010).

not have been practicable, due to the low value of some species and the desire to discourage targeting of other species (Bonnie, J., personal communication, 2014). In the Alaskan pollock fishery, some fishermen and processors established a non-profit organization to distribute high volumes of retained PSC to food banks. SeaShare is permitted by NOAA Fisheries and gets donations of goods and services from fishermen, processors, community organizations, private donors, and food bank networks to obtain bycaught fish and then process, store, and ship it to food banks in Alaska and across the United States.[13]

Most of the vessels participating in the Pacific midwater trawl fishery (e.g., hake) in Canada utilize EM systems, and are required to retain all catch, (aside from “prohibited species”) which is seen as a necessary requirement to have confidence in catch information. Salmon is an example of a “prohibited species” that fishermen are not permitted to retain and must discard at sea and document the catch in their logbook. The EM data is then subject to an audit review by an independent third party after the fishing trip is complete, which is used to verify the accuracy of the fishing logbook. In addition, all landings are subject to 100% dockside validation of catch by species and by weight (Davis, N., personal communication, 2014). The opportunity costs of keeping these unmarketable catch in the hold, along with the disposal of these fish, is solely the responsibility of the harvester. Unmarketable fish are put to the same uses as in New England, although research is also ongoing into the feasibility of its use in aquaculture feed.

The European Union (EU) is utilizing a phased approach to minimize and eventually eliminate discards. In Scotland, a discard ban for cod in the North Sea is currently in place for a part of the fleet, with EM systems installed on about 25 groundfish vessels operating in a mixed demersal fishery. This will be expanded to the pelagic mackerel and herring fleet in 2015, followed by the full demersal fleet in 2016, with a discard ban on all allocated species for each of the respective fleets. A blanket discard ban for all species for which there are specified quotas is scheduled for 2019. There has been little formal discussion around the use of unmarketable catch as of yet, but the EU has set aside money to fund the development of fish meal processing plants and storage facilities. The need to develop new markets for underutilized species has been identified as an area in need of further effort (Needle, pers. comm., 2014).

In New Zealand, all catch of IFQ species must be retained and debited from quotas including damaged and unmarketable fish, with the exception of undersized fish of 11 species that have minimum size limits. Unmarketable or damaged fish primarily end up as aquaculture feed or fishmeal, though some end up as fertilizer or in landfills. Dealers pay fishermen for unmarketable catch on a sliding scale, but sometimes the price paid does not cover the cost of quota. Unmarketable catch of bycatch species that are not under IFQ management are generally not brought ashore, but must be reported on catch reports as discarded.[14] Currently, some inshore fisheries have approximately 65 percent industry-funded observer coverage focused on protected species interactions and catch verification. The governments is testing an EM program in the inshore fleet for catch verification, and have previously tested EM systems to monitor protected species interactions (Geytenbeek, pers. comm., 2014).

[13] http://www.kplu.org/post/bainbridge-island-nonprofit-brings-seafood-alaska-food-banks-across-country; https://www.seashare.org/about.

[14] There is also a provision in the New Zealand Fisheries Act that certain species are to be returned to the sea if they are likely to survive. This applies to a mix of finfish and shellfish.

3.2 Emerging Technologies

As EM continues to gain traction, technological advances are emerging that could streamline video review and analysis, data storage, and data transmission in the future, reducing costs as technologies become practical and available. One such example is the work being done by the NOAA Fisheries West Coast Region in Computational Vision-based Monitoring (CVM). CVM attempts to fine tune where a camera is focused on a scene and to use information in that region of the image to aid in data analysis. For example, the entire deck of a fishing vessel could be within the camera's view, but a "bounding box" can be drawn around only the net reel, such that the camera is triggered to record by the net reel as opposed to other movement on the deck. This system can allow for a more precise method of capturing both catch and discard activity while reducing the overall amount of video. Further applications of CVM include automated species identification and length/weight calculation, which, if successful, would automate and greatly streamline video review time. The NOAA Fisheries West Coast Region tested a CVM system to monitor and analyze a 2-hour offload of a groundfish trip. A high speed internet connect was set up at the dock to relay images from the conveyor to the Regional Office for analysis within 15-20 minutes. Being in its infancy, this prototype system is expensive – running $20,000 or more for the system and $600/month for the high-speed internet connection. However, with time and improvements in technology, project managers believe this could become a highly efficient and cost effective method for transmission and analysis (Brady, C., pers. comm., 2014).

Sea State, Inc., is testing a similar system at sea in the Pacific whiting fishery with funding from the National Fish and Wildlife Foundation. This project uses algorithms to flag activity on the video that indicates discards are likely to occur. Because discarding can occur any time during the trip from the first haul to the time the vessel reaches the dock, EM program designs often include extensive review of video throughout the trip in order to identify discard events for closer inspection. This led to high review costs in the example EM program discussed in previous sections. Sea State is developing software-based approaches that can identify segments of video for closer review and thereby greatly reduce manual video review effort (Sea State, 2013). In a fishery with compliance as the primary objective of review, the software was able to reduce video review time to less than 25 percent of real time. Sea State has also been testing the necessary resolution for the software to work successfully, and found that the software was able to identify the same motion events at lower resolution as at high resolution. Higher resolutions (1280 x 1024) are available and may still be necessary for EM programs with catch accounting objectives. Sea State has also successfully paired the computer vision algorithms with graphics processing unit-based (GPU) parallel processing technology, such as Nvidia CUDA, to achieve a threefold improvement in processing time (Torgerson, pers. comm., 2014).

OLRAC SPS is working to address the problem of large file sizes by using frequent image captures (a picture every 2 seconds) in lieu of video . While a system like this will not capture every detail, it allows for much smaller file sizes – total size can be as much as 25 percent of a comparable video trip – and higher resolution images, which can aid in species identification. Corroborated by vessel logbook data, frequent images may be sufficient for data collection for some programs, depending on the goals and objectives. OLRAC also offers an automated data processing system called "eEye," which is currently being used in Spanish fisheries for compliance monitoring (Barkai, 2014).

In addition to new technologies like OLRAC's system, other systems that exist in similar spheres may become adaptable to an EM solution. An example of which is the field tested "Observer XT12" system developed by Noldus. While not currently deployed in any sort of fisheries management, the program is designed to use video data to provide automated and comprehensive analysis of environmental/wildlife data, and could be useful in emerging EM technology, especially to reduce the analysis workload (Noldus, 2014).

4.0 Summary

NOAA Fisheries and the sectors would have to make substantial financial investments to implement an EM program for the groundfish fishery (Table 7). Because much of the infrastructure for an at-sea monitoring program is already in place, substantial investments are not expected for NOAA Fisheries and the sectors when the At-Sea Monitoring Program transitions to industry funding (Table 7). This may not be a fair comparison, but it is important to take the implementation costs of an EM program into account for planning purposes. As discussed in Section 2.1.2, NOAA Fisheries costs for administering the At-Sea Monitoring Program are derived from the number of service providers, monitors, vessels, and trips. Costs incurred are representative of these elements and are associated with the entire fleet. However, to provide a more direct comparison of at-sea monitoring and electronic monitoring costs under the hypothetical model presented, we calculated a per sector cost for the NOAA Fisheries at-sea monitoring administrative costs. To do so, we identified the per sea day administrative cost of $530 and factored it with the estimated number of sea days of the hypothetical sector of 510. The resulting factor of $270,300 was then distributed among each vessel, total trips, and total observed trips. As discussed in Section 2.2.1, it may be possible to reduce some EM implementation costs for the sector. The largest component of sector implementation costs was for additional data analysis services during the first year as a result of the learning curve for captains in meeting the performance standards for the audit. It is hard to say what the actual failure rates will be, but as current VTR discard reporting is poor it is likely that there will be some additional review and higher review costs in the first year or two of the program. We discussed some ideas to reduce these costs, including having an easier performance standard or different sampling rate for the first year, while vessels adjust to estimating their discards. Educating captains and providing feedback on VTR data quality after trips could reduce the time it takes for captains to meet the performance standard and improve pass rates more quickly (Pria et al., 2014). This may require a substantial time investment from the captains and the service provider, but could be worth it in terms of reduced review costs. Additionally, including industry in the development of catch handling protocols would help ensure methods are realistic in an operational setting. This would have to address the requirement to monitor sector ACE, however.

Ongoing operational costs are greater for the example EM model than for the At-Sea Monitoring Program for the hypothetical sector (Table 7). This is greatly dependent on the design of the EM program that we used in fall 2014. Our discussions with the service providers revealed specific areas of a future EM program design that may be worth considering to reduce costs.

- Field services represented a substantial cost (14 percent of annual program costs) in part due to the reliance on technicians to retrieve the hard drives. It may be worth considering whether captains could submit their own hard drives to reduce costs, in light of data security measures that service providers can offer. If technicians must be used, increased reporting latency could be considered to reduce the cost of this service, although this could lead to management uncertainty if accounting for bycatch. VTR discard reporting is currently very unreliable, but as the program matures and reporting improves less frequent audits could be considered to reduce costs for good performers without impacting the reliability of discard estimates.
- Data analysis was responsible for the greatest portion of program costs (65 percent of annual program costs), because of the large amount of video reviewed. Lower levels of discard compliance review would substantially reduce data services costs by reducing the amount of video reviewed. Primary video review costs are the largest component of data services costs. As our model reviewed the minimum number of hauls necessary to audit each trip (1 haul per trip), lower levels of review may not be possible with this approach. However, the service providers suggested other sampling models, which could be considered to reduce costs while still providing the necessary quality assurance. The sector system's emphasis on co-management and sector accountability may allow for consideration of more individualized performance standards for sectors or vessels. Reducing the frequency of hard drive retrievals would also reduce data services costs and reporting costs.
- Archive costs can be substantial, depending on the amount of data and the length of time it needs to be stored. NOAA Fisheries is still working to determine the record-keeping requirements for EM data, so it is difficult to say what this will cost. The service providers recommended identifying and retaining only the essential information, and not storing this data longer than necessary.

Reducing these costs would also reduce corresponding program management costs and may bring the example EM program costs more in line with the At-Sea Monitoring Program costs as estimated. Either way, costs are just one factor that must be considered in discussions about program design.

For NOAA Fisheries, operational costs appear to be cheaper for the example EM program than an At-Sea-Monitoring Program at the fleet level. However, this assumes that the programs are mutually exclusive. Some sectors want to be able to choose at-sea monitoring or EM at the sector or vessel level. Operating both options may limit efficiencies and cost savings that would otherwise be possible in a single model scenario.

Table 7: Summary of Total Program Costs of Hypothetical Sector and Program Design

At-Sea Monitoring Annual Costs*	Sector Total	Per Vessel	Per Trip	Per Observed Trip
Seaday costs	$362,100	$18,105	$181	$1,006
NOAA Fisheries shore-side costs	$270,300	$13,515	$135	$751
Total At-Sea Monitoring costs	$632,400	$31,620	$316	$1,757

*Assumptions:

- 510 observer sea-days (18%)
- seaday cost = $710 per sea-day
- shore-side cost = $530 per sea-day

Electronic Monitoring Annual Costs	Per Sector	Per Vessel	Per Trip*
Sector costs	$1,012,372	$50,619	$506
NOAA Fisheries costs	$188,795	$9,440	$94
Total Electronic Monitoring costs	$1,201,167	$60,058	$601

*Note that electronic monitoring is required on all trips and therefore per trip and per observed trip costs are equal.

Electronic Monitoring Start-Up Costs*	Per Sector	Per Vessel
Sector costs	$1,191,508	$59,575
NOAA Fisheries costs	$558,000	$27,900
Total Electronic Monitoring start-up	$1,749,508	$87,475

The costs presented in this report must be evaluated in the context of the At-Sea Monitoring Program's objectives, and needs for data quality, data timeliness, operational feasibility, and a number of other factors. The sectors, the Council, and NOAA Fisheries must weigh the trade-offs between these factors, as well as each sector's individual needs, to determine which model is the better option for each sector. We hope that the information presented in this report will be useful to the sectors, the Council, and NOAA Fisheries, and allow costs to begin to be part of the ongoing conversation to develop an effective and feasible EM alternative for sectors.

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6.0 Appendix

This section describes the hypothetical models used in the analysis, including the assumptions that were made about program design and context for the purpose of the analysis. This section does not necessarily reflect a detailed proposed model for each fishery, but rather makes only those assumptions that are necessary to calculate cost estimates. Assumptions were made based upon the goals and objectives or other regulatory requirements described in previous management actions and the regulations, as well as examples from programs with similar objectives in other regions.

The sector monitoring program framework and requirements were implemented through Amendment 16 to the NE Multispecies FMP. Amendment 16 specified that sectors would have an independent, third-party monitoring program to ensure sector allocations are not exceeded and to verify area fished, as well as catch and discards by species and gear type. Sectors may use EM systems to meet their monitoring requirements, if approved by NOAA Fisheries. The model described by Amendment 16 was for the sector to have the responsibility to implement and fund the program, as approved by NOAA Fisheries through its operations plan. In this model, the sector would contract directly with providers for services, maintain a database of reports, monitor sector quota usage, and submit the data to NOAA Fisheries for evaluation of whether it exceeded its allocations. Amendment 16 included standards and performance requirements for monitoring providers and individual at-sea monitors (NEFMC, 2009).

At-Sea Monitoring Program (ASM)

NOAA Fisheries has been contracting with providers to provide at-sea monitoring coverage to sectors to fulfill their at-sea monitoring requirements since 2010. When the burden to satisfy this requirement transitions to industry, some services that NOAA Fisheries has contracted for and some components of the design may not change. However, under the government contract model, NOAA Fisheries may contract with a company to fulfill inherent government functions, which sectors would not be expected to do when they take on the responsibility to run their own at-sea monitoring programs. As described in Amendment 16, it is expected that the sector would be responsible for developing an ASM program with a certified provider and contracting with the provider to provide the at-sea monitoring services. NOAA Fisheries would have the responsibility to review the provider's application and the sector's program proposal, certify the provider, and train and certify at-sea monitors. The coverage level would be specified on an annual basis by NOAA Fisheries to meet the 30 percent coefficient of variance (CV) performance standard for each stock on sector trips, as is done currently. NOAA Fisheries would also continue to operate the PTNS, which sector vessels would call-in to before each trip to determine if they will get selected for a NEFOP observer, at-sea monitor, or waiver.

At-sea monitors would follow the same or similar data collection protocol as under the current ASM program to verify area fished, catch, and discards by species, by gear type. Data collected by at-sea monitors would be submitted directly to NOAA Fisheries for processing and storage. NOAA Fisheries would continue to be responsible for quality checking observer data, and would de-brief at-sea monitors as needed. NOAA Fisheries would continue to calculate sector-specific discard rates and provide them to sector managers on a daily basis.

Fishing activity, port distribution, and trip type, among other things, can all be drivers for monitoring costs. In order to calculate a cost estimate, we used an hypothetical sector with fabricated membership and fishing activity. Table 8 below summarizes the assumptions made about the hypothetical sector for the cost analysis.

Electronic Monitoring Program

Similar to the sector At-Sea Monitoring Program, it is assumed that the sector would be responsible for developing an EM program and contracting with a certified provider to provide the electronic monitoring services. NOAA Fisheries would have the responsibility to review the provider's application and the sector's program proposal, and certify the provider. NOAA Fisheries does not currently have a training program for EM reviewers and technicians, but NOAA Fisheries would need some way to ensure that reviewers and technicians are appropriately trained. The service provider may be required to provide appropriate training to technicians and EM reviewers on species identification and field and data services, and the training program and individual technicians or reviewers may be required to be audited or tested by NOAA Fisheries. NOAA Fisheries may also review VMPs and inspect equipment installations. NOAA Fisheries would also continue to operate the PTNS, which sector vessels would call-in to before each trip to determine if they will get a NEFOP observer.

If used in place of an at-sea monitoring program, the sector EM program would have to meet the same purpose as the sector At-Sea Monitoring Program, to verify area fished, catch, and discards by species, by gear type. It was assumed that the audit approach would be used, because this model could be implemented within existing regulations. In this example, EM is used to verify the piece counts or weights of discarded species reported by the vessel operator in a logbook. In general, the EM system set-up on board the vessel consists of a configuration of digital cameras that provide 1) a wide-angle view of the deck to monitor for discards outside the control point; 2) a view of catch being brought on board; and 3) a view of discards at the control point. Hydraulic or motion sensors are used to trigger the video recording when fishing gear is engaged and to monitor the presence/absence of fishing activity. A GPS records the location of fishing events. This set-up and catch handling requirements would be documented in a vessel's individualized Vessel Monitoring Plan, which would be maintained onboard the vessel as an aid to crew, technicians, and enforcement personnel.

This example assumes that status quo possession limits remain the same. Allocated ACE stocks of legal size are retained, non-groundfish species are retained under trip limits or discarded, sub-legal sized fish are discarded. Sorting and discarding occurs in camera view only and discards are done at the control point. The vessel operator records the location, gear type, piece counts and weights of all discards for each haul in a logbook for comparison with the video. It is assumed that the vessels would use an electronic VTR application that would allow the service provider to obtain the VTR data in a timely fashion for comparison with the video at no additional cost.[15] On a weekly basis, an EM technician would meet the vessel at the dock to

[15] Haul level reporting allows a single haul to be selected for the audit comparison, rather than an entire trip. Currently, VTRs are required to be submitted at the sub-trip level (each time stat area or gear is changed), and the current paper forms do not support piece count reporting nor reporting at the haul level. Some eVTR software allows haul-level reporting although they may not currently have a field for piece counts. Use of eVTR would allow for more timely validation, whereas paper logs would either have to be entered by the provider or sector at additional cost, or the provider would have to wait for the paper logs to be entered by NOAA Fisheries. Use of

retrieve the hard drive, replace it with a clean hard drive, and configure the system for the next trip. It was assumed that hard drives would be retrieved weekly. Some sort of trip-start and trip-end hails would be needed to coordinate these services and it is assumed that the current trip-start and trip-end hail system would suffice. Additional appointments with a technician between trips may be needed to maintain or repair the system. The provider must be available 24/7, with a telephone system monitored at a minimum of four times daily.

The hypothetical EM system would be on and recording 100 percent of sector trips. Cameras would be triggered by hydraulic or motion sensors to record haul-back and catch sorting. One camera with a wide-angle view of the deck would remain on for the duration of the trip to ensure sorted catch is not later discarded. It is assumed that 20 percent of hauls, rounded to the next whole haul, and a minimum of 1 haul from each trip, would be reviewed. Reviewers would determine piece counts and weights of discarded fish (taking a length and converting to weight using a length-weight key), area, and gear type and compare these to the vessel logbook at the haul-level.[16] If the comparison falls within some acceptable range of error, the trip passes and the VTR-reported discards are used for catch accounting. If the estimate does not meet the standard, then the entire trip is reviewed and compared. If the trip still does not meet the standard in the secondary review, the vessel reported discards would be corrected using the video and an amended VTR is submitted to NOAA Fisheries for catch accounting. Some report would have to be submitted by the provider to NOAA Fisheries weekly to notify NOAA Fisheries which trips passed/did not pass review. This process would be expected to be completed within three weeks after the trip lands. The provider would also provide feedback in some sort of report to the technician or vessel operator after each reviewed trip to adjust equipment or catch handling practices. Under the program model implemented by Amendment 16, it is assumed that a sector would contract with a third-party provider for the field and data services described above. In addition, it would be necessary for the provider to maintain a secure archive and database of raw video and sensor data, and logbook data for comparison and for later auditing. It was assumed that the video and associated data would be archived for a minimum five years after a fishing trip, consistent with the statute of limitations for fisheries violations under the Magnuson-Stevens Act. The provider may also be required to archive selected trips indefinitely, if requested by NOAA Fisheries. Once data is archived, hard drives may be scrubbed and returned to the field.

NOAA Fisheries would have the responsibility to ensure data quality and compliance with approved sector monitoring proposals. Therefore, it is assumed that NOAA Fisheries would periodically audit the EM provider's trip reviews. This may involve submission of video and other EM data from selected trips to NOAA Fisheries for review and comparison with VTRs.

Fishing activity, port distribution, and gear type, among other things, can all be cost drivers for an EM program. In order to calculate a cost estimate, we used an hypothetical sector with fictitious membership and fishing activity. Table 8 below contains the assumptions made about the hypothetical sector for the cost analysis.

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eVTR is currently not mandatory, but for the purpose of this analysis it is assumed that eVTR would be used. The purchase of eVTR software or modifications to eVTR software or paper logs was not addressed in this analysis and may be an additional cost to the cost estimates developed in this report.

[16] See Pria et al., 2014 for a detailed description of the weight estimation method.

Table 8: Key Assumptions about the Hypothetical Sector

Characteristic		Assumption
Number of active vessels	Total	20
	Otter trawl	8
	Gillnet	10
	Longline	2
Distribution of vessels by port		
	Gloucester, MA	5
	Portsmouth, NH	5
	Portland, ME	6
	Port Clyde, ME	2
	Boothbay Harbor, ME	1
	Saco, ME	1
Number and duration of trips[a]		2,000
	Otter trawl	860 trips/2.5 days/2150 sea days
	Gillnet	1,040 trips/0.6 days/624 sea days
	Longline	100 trips/0.6 days/60 sea days
Number and frequency of trips by season		
	Spring	400/Weekly
	Summer	680/Daily
	Fall	500/Daily
	Winter	420/Infrequent
Number and duration of fishing events (haul back) per trip[a]		
	Otter trawl	5/1.56hr
	Gillnet	3/1.06hr
	Longline	4/0.7
Review ratio (review time/imagery duration) per fishing event for reviewing catch handling[b]		
	Otter trawl	1.78
	Gillnet	1.5
	Longline	1.0
Review ratio (review time/imagery duration) per trip for reviewing discard compliance[c]		
	Otter trawl	0.05
	Gillnet	0.05
	Longline	0.05
% of fishing events audited per trip		20% rounded to next whole haul
% trips that pass review – first 6mos		0% pass
% trips that pass review – 6-12mos		50% pass
% trips that pass review – after 12mos		95% pass
Frequency of video retrieval		Weekly
Mean time for video retrieval[d]		0.87 hr
Frequency of reporting		Validation and reporting complete 3 weeks

	after end of fishing trip

[a] Duration of trips and number and duration of fishing events are based on average calculated from observer data for sector trips May, 2010 – September, 2014.
[b] Review ratios for catch handling for gillnet and otter trawl were based on ratios observed during New England EM Project (Pria et la., 2014). Longline review ratios were not available and so were estimated based on experience.
[c] Review ratios for discard compliance were estimated based on experience of the service providers and results from the Pacific whiting EM project for similar review objectives (McElderry et. al., 2014).
[d] Time for video retrieval taken from New England EM Project (Pria et al., 2014).