UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northeast Fisheries Science Center
166 Water Street
Woods Hole, MA 02543-1026

19 August 2011

2010 NORTHEAST MULTISPECIES FISHERY ELECTRONIC MONITORING PILOT STUDY

A multi-year Electronic Monitoring (EM) pilot study is underway in the Northeast (NE) multispecies fishery through a contract with Archipelago Marine Research Ltd (Archipelago). Electronic monitoring is the use of passive electronic systems (video cameras, automated computer systems, and sensors) to monitor vessel activity. NE multispecies sectors are required to monitor catch (landings and discards) to manage their allocations of fish. NOAA's National Marine Fisheries Service (NMFS) is evaluating EM as a possible way to reduce the costs of at-sea monitoring in the future. Before EM can be approved as a substitute for traditional at-sea monitoring, it must be proven to provide the types and quality of data that are needed to monitor catch accurately. Archipelago analyzed 2010 catch data and prepared a report of the results of the first year of this pilot project. This document is a summary of the agency's review of this report's findings.

2010 Study Results

1. Internal Peer Review

Archipelago's 2010 EM annual report was reviewed by NMFS staff. The objectives of the review were to evaluate the statistical and scientific approach, to identify areas for improved performance, and to analyze EM's potential for groundfish sector monitoring.

2. Results Summary

System Application

A more robust EM system is required to provide the high quality data needed for allocation accounting and sub-Annual Catch Limits (ACL) monitoring. Future research will be conducted to improve the accuracy and reliability of species identification, e.g., identifying species of flounders and hake. In general, given the practices, vessel configurations, and array of target species in the NE multispecies fishery, at this point EM is also not sufficiently effective at monitoring weights of discarded fish by species, a necessary component for monitoring sector Annual Catch Entitlement (ACE) utilization. System reliability improvements and catch handling modifications to improve the amount of quality data available will be considered to minimize lapses in monitoring, as 18% of trips had insufficient or poor quality data that was not useable for catch analysis in 2010.

This multi-year pilot project will continue to work to address these system deficiencies so that EM technology can be considered for use, in lieu of traditional at-sea monitors, in the NE multispecies fishery in the future.

Validation Data Sources

In the next stage of the pilot study, three additional data sources will be used in an effort to validate EM. Incorporating additional data sources into the analysis may identify the discrepancies between EM and observer data encountered this year and may clarify the effectiveness of the EM data. For the first year of the pilot study, NMFS provided four sources of data to be included in report analyses; observer/At-Sea Monitor (ASM), Vessel Trip Reports (VTR), dealer landings data, and Cooperative Research Study Fleet data. However, only observer/ASM data was used by Archipelago in the pilot study.

Data Gaps

Future research should investigate the causes of all data interruptions so that solutions may be found. Although the report states that "manually turning the EM systems off was the cause for all data gaps, incomplete data and data corruption in the project," this is not entirely correct. There were a number of interruptions (or incomplete data) in video and sensor data that did not last the entire trip, but occurred during some portion of catch sorting, net cleaning, and hauling activities. In order to determine the full utility of EM, occurrence and frequency of all data interruptions is required to provide an accurate assessment of equipment reliability.

EM Approval Process

Study results substantiate that additional work is required before the use of EM can be approved as an effective monitoring tool. The two predominant applications of EM technology include: catch estimation and validation of fisherman-reported data. Neither the quality nor quantity of EM data is adequate for meeting these monitoring requirements at this time. Given the issues identified under the first year of the pilot project, sector monitoring plans for fishing year (FY) 2012 will not be able to incorporate EM as a monitoring strategy. As discussed below, future research will attempt to address the issues so that approval of EM may be considered for use in future years.

Recommendations for Future Study

This first year of research focused on providing a foundation of data (detection, counting, and identification of catch) specific to the needs of the NE multispecies fishery. While data interpreted during 2010 have identified inadequacies (in regards to sector monitoring requirements) with the EM system, they also provide clear guidance for future project objectives and progression. Goals set forth for proceeding years include, but are not limited to:

a. Obtaining fish weight with a known accuracy and precision to estimate catch weight (length/weight regressions, weight estimation metrics, etc.); and
b. Developing methods to increase species identification of flounders and hake (i.e., catch handling, data collection strategies, etc.).

Information from the projects outlined above will help determine if EM is a suitable monitoring tool for sectors in the future and further define the role of EM in the NE multispecies fishery.

Contact for Technical Questions:

Amy Van Atten
Northeast Fisheries Science Center
Fisheries Sampling Branch
Branch Chief
(508) 495-2266
Amy.Van.Atten@noaa.gov

Contact for Approval Processes or Regulatory Questions:

Allison Murphy
Northeast Regional Office
Sustainable Fisheries Division
Sector Policy Analyst
(978) 281-9122
Allison.Murphy@noaa.gov

NEW ENGLAND ELECTRONIC MONITORING PROJECT 2010 ANNUAL REPORT

Contract EA133F-10-SE-0949

Prepared for:
U.S. Department of Commerce
National Oceanographic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, MA 02543

August, 2011

Prepared by:
Maria Jose Pria
Jason Bryan
Howard McElderry

Archipelago Marine Research Ltd.
525 Head St.
Victoria, British Columbia, Canada
V9A 5S1
www.archipelago.ca

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Pria, M.J., Bryan, J. and McElderry, H. 2011. New England Electronic Monitoring Project 2010 Annual Report. Unpublished report prepared for the Fisheries Sampling Branch by Archipelago Marine Research Ltd., Victoria, British Columbia, Canada. 69p.

The New England Fishery Management Council (NEFMC) has ruled that as of fishing year 2012, monitoring funding is to become an industry responsibility. The Fisheries Sampling Branch (FSB) of the Northeast Fisheries Science Center (NEFSC) of the National Oceanic and Atmospheric Administration (NOAA) is interested in determining the feasibility of using Electronic Monitoring (EM) technology to support the catch data requirements to manage the NE groundfish sector fleet. In April 2010, FSB contracted with Archipelago Marine Research Ltd. (Archipelago) on a multi-year project to test EM on a range of vessel layouts, fishing gears and geographic locations across New England that would enable an assessment of the feasibility of using this technology in sector based management. The overall objective of the project is to assess the applicability of EM technology to collect catch and effort data aboard Northeast vessels, with a particular emphasis on discarded catch, and evaluate the utility of EM technology in monitoring catch in the sector fisheries. Although data collection is ongoing, results as of December 31st, 2010 are summarized in this report.

In order to reach the overall project objective the following were identified through the initial project planning process as specific priorities for the first year:

1. Install equipment on up to 13 vessels while ensuring representation of all regions in New England, across multiple sectors and covering all gear types.
2. Conduct outreach meetings to interested fishermen, sector managers, members of the public and current project participants throughout the project.
3. Build local capacity to provide field services by selecting and training a local subcontractor.
4. Train FSB staff in EM data management, interpretation and quality assessment; familiarize them with wide range of information that can be interpreted from EM data; and introduce them to the operational components of an EM program.
5. Interpret a wide range of information from EM data including, but not limited to, determining fishing events and counting and identifying all kept and discarded catch to the lowest taxonomic level possible in order to gain an understanding of whether catch interpretation was possible with EM data and what factors may affect this interpretation.

To achieve effective project delivery in New England, the first phase of the project was focused on building local capacity for data collection, data interpretation and project coordination and identifying the factors that could affect EM sensor and video data collection and quality. For this reason, this phase of the project did not include an experimental design to collect EM interpreted data in weights for direct comparison to the current method for catch data collection by other data sources. The development of a comprehensive EM-based program weight estimation methodology will be included in a future phase of the project. Methodology development efforts will then be based on the data quality assessment results from the project first phase. Furthermore, stakeholder exposure to EM operations and data interpretation methodologies can aid in the establishment of standards on the acceptable variation that these data must meet.

EM systems, consisting of up to four closed circuit television cameras, a GPS receiver, a hydraulic pressure transducer, a winch rotation sensor, a system control box and a user interface were installed on ten vessels. These vessels were representative of the NE groundfish fishery with four vessels equipped with trawl gear, three vessels with gillnet gear, and three vessels with both gillnet and longline gear. Participants fished out of five ports from Point Judith, RI to Portland, ME. Nine vessels were members of five different sectors and one was part of the common pool. Captains were asked to keep the EM systems on for the entire duration of both groundfish and declared out of fishery (DOF) trips. Readings from the GPS, pressure and rotation sensors were used to detect fishing activity and create a complete characterization of fishing effort (trips and fishing events). A subset of EM video data from all groundfish trips was subsequently assessed to determine if the data were of high enough quality for catch monitoring and if not, which factors affected interpretation. A selection of groundfish trips deemed to be of high quality were further reviewed to count and identify all kept and discarded catch with emphasis on finfish and incidental takes of marine mammals, seabirds and turtles.

Nine of the ten vessels that had EM systems installed engaged in fishing during the eight-month project period summarized in this report for a total of 358 trips and 1,231 hauls of which groundfish fishing represented 204 trips and 745 hauls. Overall, EM system data collection while on the fishing grounds was 98% while 62% of the trips had the departure and return to port captured by EM sensor data. The cause for trip starts and ends not being captured and EM data gaps within trips for all 2010 data was EM systems being manually turned off. Although most of the data lost occurred during transit to and from the fishing grounds, comparison with observer data records showed that nine hauls occurred while the EM system was powered off on observed trips. It is not possible to know if hauls in non-observed trips occurred while the EM system was turned off.

Out of 204 groundfish trips monitored with EM, 73% were categorized as having high data quality, 9% had adequate data quality and 18% had poor data quality. Poor image quality, resulting from dirt, salt, or condensation blocking the view on the cameras, was the cause for 53% of the trips with poor data quality. Issues with camera views not capturing all of the catch handling were the second most common cause for poor data quality and resulted from irregular catch handling practices by crew and/or observers and usually involved catch either not being discarded in the close up camera view installed for that purpose or out of camera view all together. Incomplete and corrupt data were the third and fourth most common reasons for poor data quality and all instances were caused by manual EM system shutdowns by fishermen.

EM recorded a total of 25,504 pieces of groundfish species, 51% of them from trawl, 27% from longline and 22% from gillnet. Species composition varied with gear type in both EM and observer data. Longline trips had the simplest catch composition for groundfish species where seven groundfish species were recorded with Haddock and Atlantic Cod accounting for 99% of the groundfish catch by EM pieces and observer weight. Gillnet trips had ten groundfish species recorded but most of the groundfish catch was Pollock and Atlantic Cod which together represented 81% of EM pieces and 91% of observer weight. Trawl trips had all thirteen groundfish species recorded by EM and observer methods and catch of groundfish species was more evenly spread out across multiple species compared to longline and gillnet. Flounder species were almost exclusively recorded in trawl hauls with over 99% of total EM pieces and observer weight of flounder species corresponding to trawl hauls. Flounder species and White Hake did not show similar occurrence at the haul level between EM and observer methods while Atlantic Cod, Haddock Pollock, Redfish, nk, Ocean Pout and Wolffish showed similar occurrences in one or more gear types. Further work is needed to determine the minimum data quality requirements to identify all groundfish species. However this work must be based on detailed standards on acceptable differences between EM and observer data.

Secondary review showed a high replicability of EM piece counts with strong correlations (r^2>0.98) and a slope of 1.04 and 0.97 for trawl and gillnet respectively and piece differences of 5% and 2% for the two longline hauls. When filtered by disposition, correlations for kept and discarded catch for trawl and kept catch for gillnet remained strong (r^2>0.93) with slopes between 0.93 and 1.05. Comparisons of discarded catch for one gillnet and one longline trip showed over three times more discarded catch recorded by the second EM viewer due to inconsistent discarding practices between crew and observer, which in these hauls were not aligned to the requirements of EM data collection. Examination of the correlation between primary and secondary piece counts by species for Atlantic Cod, Haddock, Pollock, Redfish, nk and Ocean Pout reveal high replicability of catch identification in EM catch estimates for these species (r^2>0.92 and slopes between 0.87 and 1.2). Replicability was not observed for flounder catch at the species level but was high at the general flounder level (r^2=0.87 and slope of 0.87).

Comparisons with observer data show that EM reviewers were very successful at detecting incidental takes. Observer data included one incidental take record not detected by EM reviewers while EM reviewers detected two incidental takes not recorded by the observer. Identification of incidental takes was also good with nine of the thirteen items identified to species while the others were identified to the family level and one as an unidentified bird.

The first year of the project was successful at building local capacity and identifying key factors that negatively impacted EM data interpretation. Equipment was installed on ten vessels across five ports and in all three gear types, multiple outreach meetings were held to ensure that fishermen, sector managers, NOAA staff and council members were aware of the project, and local capacity to support the field requirements of the project was established through East West Technical Services (EWTS) a subcontractor and supported by FSB staff. FSB staff were additionally familiarized with EM technology and the operational aspects of an EM project including data management and interpretation.

The data quality assessment revealed three main issues that impacted the ability of reviewers to detect and identify catch. These were dirty cameras, incomplete or corrupt data, and conflicts between catch handling and camera views, all of which can be resolved with captain involvement. Of these, conflicts with camera views are the most complex but ongoing work in collaboration with captains to determine the best placement of cameras and feasible ways of streamlining catch processing (especially discarding) have shown promise in minimizing camera view issues. Participating captains have shown support for the project but need to become more aware of the importance of data quality from their vessel and how they can take concrete actions to improve it. Increasing accountability for keeping their system on, their cameras clean and agreeing to a catch handling protocols will minimize the three most common reasons for poor data quality. Issues impacting data collection that are related to captain behavior must be addressed through feedback and, in an operational program, through a mechanism of incentives and consequences. Moving forward on this project, the location of the EM system components, especially cameras, and catch handling protocols on each vessel will be documented using standardized templates or Vessel Monitoring Plans (VMPs).

There are three key considerations evident in regards to assessing the feasibility of implementing EM in the NE groundfish fishery. The first is the reliability of the EM equipment to capture data at-sea. Overall, the equipment performed well with technical problems resulting in minimal data loss. Manually turning the EM systems off was the cause for all data gaps, incomplete data and data corruption in the project. Equipment issues resulted in video data loss in two occasions affecting seven trips, both as the result of a camera not recording video. These system performance results are consistent with results from several other EM applications around the world (McElderry et al., 2010b; McElderry et al., 2010b; Dalskov et al., 2009).

The second consideration is cost. Without specific details on program design, it is very difficult to accurately estimate how much an EM program would cost in the NE groundfish fishery at this time. Costs associated to the fishery and the program operations can be properly estimated once the monitoring program is designed. Currently it is only possible to provide a rough order of magnitude estimate by creating a hypothetical vessel based on the internal and external factors observed in New England during the 2010 season. The rough cost based on 2010 data estimate for 100 monitored trips would be $505, $396, and $539 per trip for longline, gillnet and trawl boats respectively. These estimates are most likely high since they are based on the effort during this project and pilot projects typically are much less cost-effective than mature operational programs. Up to 85% of the costs of an EM based program can be the result of labor as a result of program design decisions on how often data needs to be retrieved and/or how much data needs to be reviewed and are therefore highly variable. Because data collection and interpretation in an EM based program are separate, large amounts of data can be collected relatively inexpensively and more or less data may be reviewed to meet program objectives and design.

The third consideration, and what remains to be developed to implement EM for catch monitoring in the NE groundfish fishery, is an acceptable method for estimating weight for all ACE managed groundfish catch by species. Currently in the NE groundfish fishery, observer and ASMs have established acceptable methodologies to estimate weights. EM technology reliably provides sensor and video data for a human reviewer to estimate catch from. What remains to be developed in order to implement an EM program for catch monitoring in the NE groundfish fishery is an acceptable method for estimating weight for discarded ACE catch by species that is parallel to the ASM methodology. Examples on how catch monitoring using EM can be achieved in a cost and logistically effective way can be found in other fisheries and include piece counting and applying an average weight, either per species or based on broad length categories. Based on t-tests results using 2010 retained EM piece counts and observer or NOAA survey average weights for four species, this methodology is worth further examination. Another method could involve using volumetric estimates of baskets sorted by species. Differences in overall catch volumes, catch composition, fishing methods and catch handling between gear types must be taken into account to arrive at gear specific catch monitoring methodologies. To determine the best way to collect catch data using EM it will be necessary to have a clear mandate as to the objective of an EM program in the NE groundfish fishery and the standards that need to be met by data from this program .

As considerable further work is needed in resolving this last consideration we recommend the following priorities for the next steps of the project:

1- Establish the objectives of an EM program in the NE groundfish fishery and data standards.

Discussions with NEFOP will be needed to define what the ultimate goal of using EM in the fishery is. There is a wide range of options spanning from full replacement of the current ASM program to the introduction of EM for specifically selected gears or sampling situations. An audit program could be applied in any of these options for cost savings. Given that the interpretation and nature of EM and ASM data are different it will be critical to document the standards, including acceptable error tolerances at the trip or haul level, that must be met by EM program data. These standards should be described in parallel to those in the current observer and ASM programs for clarity.

An EM working group with representation from all stakeholders would need to be established to generate guiding principles and standards for an EM based catch monitoring program and discuss potential program designs that would fit the requirements of both fishery management and industry. A clear mandate and governance structure around this group would also be needed.

2- Develop a methodology to use EM to provide estimates of catch weights for ACE species.

As sector management of the NE groundfish fishery requires accounting for total removals by weight for ACE species, a weight estimation methodology by species will need to be developed. Given that EM is a monitoring tool that lends itself well to counting pieces of fish, doing volumetric estimates of containers of known dimensions (such as checkers or baskets), and verifying activities or behaviors onboard, it should be feasible to develop a strong sampling program using these attributes. EM also allows for the collection of other types of information such as length estimates which could be investigated for length to weight conversions. Controlled experiments should be designed to determine weight estimation methodology and ensuring identification of catch by species. These experiments must be gear specific and include clear objectives and metrics to evaluate success. Experiment design plans are currently underway.

3- Define standard requirements for data quality in order to maximize data quality across all vessels and gear types.

Guidelines for determining EM data quality need to become better defined in order to maximize the usability of EM data. A clearer definition of minimum data quality requirements followed by existing feedback mechanisms between captains, field and data technicians is the first step to maximizing the proportion of high quality data collected. Adopting the use of VMPs will ensure this process is formalized and transparent to captains, EM field and data technicians, and project coordination staff.

1 INTRODUCTION

In May 2010 the National Marine Fisheries Service (NMFS) implemented Amendment 16 to the Northeast (NE) Multispecies Fishery Management Plan (FMP), which modified and expanded sector management in the NE Multispecies fishery (also referred to as the NE groundfish fishery). Under this management strategy, limited access NE multispecies permit holders may voluntarily join a sector on an annual basis. Each sector is allocated a Total Allowable Catch (TAC) for 16 stocks referred to as an Annual Catch Entitlement (ACE), based on the fishing history of its members. Sector managers must submit weekly reports to NMFS, which include the balance of ACE remaining, based on their members' landings and discards, as well as any compliance and/or enforcement concerns. Landings data are compiled by the sector managers from dealer reports or vessel trip report (VTR) if dealer reports are missing. For a trip that receives at-sea monitoring, sector managers use discard data collected from at-sea monitor (ASM) or Northeast Fishery Observer Program (NEFOP) observers. For trips that do not receive at-sea monitoring, sector managers apply either an initial discard rate to the trip based on the previous year's discard information or, once five trips are observed in the same stock area using the same gear types within a sector, an in-season rate based upon the observed trips within that sector.

Currently, at-sea monitoring for sector vessels in the NE groundfish fishery is accomplished either by NEFOP observers (8% coverage) or ASMs (30% coverage) (pre-season estimates). Data collection from NEFOP observers and ASMs differs in the scope of data collected. NEFOP observers collect a wider range of data than ASMs, including biological samples. Both, however, collect data to support sector management reporting requirements such as area fished and retained and discarded catch estimates by species. The New England Fishery Management Council has also ruled that as of fishing year 2012, monitoring funding is to become an industry responsibility. The Fisheries Sampling Branch (FSB) of the Northeast Fisheries Science Center (NEFSC) of the National Oceanic and Atmospheric Administration (NOAA) is interested in determining the feasibility of using Electronic Monitoring (EM) technology to support the catch data requirements to manage the NE groundfish sector fleet.

Over the past decade, Archipelago Marine Research Ltd. (Archipelago) has pioneered the development of EM technology and has carried out a number of pilot studies to test its efficacy in a variety of monitoring environments (McElderry, 2008). EM based monitoring programs have demonstrated to have advantages for aspects such as suitability across a broad range of vessels, creation of a permanent data record, cost and scalability (McElderry, 2008). Furthermore, these studies have shown that EM-based programs have a high level of industry engagement in self-reporting processes such as when using EM to audit fishing logbooks (Stanley et al., 2011).

The feasibility of an EM based program in the NE groundfish fishery is currently being assessed. Archipelago has completed pilot projects in Chatham, MA with longline and gillnet vessels to test the use of EM to monitor catch and effort by comparing EM data to observer data (McElderry et al., 2007 and McElderry et al., 2004). In these studies included comparisons of pieces counts by EM reviewers and observers. Staff reviewing EM data were able to reliably provide time and location information of fishing events as well as distinguish the predominant species in the fishery (including Atlantic Cod, Haddock and Pollock) and enumerate them. However results in identifying catch to species varied. Some catch were consistently identified to species if their identification features were readily captured by the EM video data as, for example, Atlantic Cod and Haddock. Catch items that required more subtle features to be captured or a close-up view of very specific features such as mouth features were not consistently identified to species, most notably some flatfish catch. These studies highlighted the need for improved alignment between catch handling and monitoring needs to improve species identification and interpretation of disposition, local infrastructure to support a program, and solidifying data models and structures that specify data collection needs and uses including a methodology for deriving weights from EM data if required.

In April 2010, FSB contracted with Archipelago on a multi-year project to test EM on a range of vessel layouts, fishing gears and geographic locations across New England that would enable an assessment of the feasibility of using this technology in sector based management. The overall objective of the project is to assess the applicability of EM technology to collect catch and effort data aboard Northeast vessels, with a particular emphasis on discarded catch, and evaluate the utility of EM technology in monitoring catch in the sector fisheries.

Although data collection is ongoing, results as of December 31st, 2010 are summarized in this report. All data collected as a result of this study were treated as confidential observer data under the Magnuson-Stevens Fishery Conservation and Management Act and are propriety to the government.

2 MATERIALS AND METHODS

2.1 PROJECT PLANNING AND PRIORITY SETTING

Planning for the EM project began in April 2010 with communication between FSB and Archipelago surrounding project timelines, vessel requirements, participant compensation criteria, project communications, and project methodology. As this is a multi-year project the different aspects of assessing the feasibility of using EM in the NE fishery could be phased in. Hence project planning concentrated on identifying the priorities for the first year of the project. FSB and Archipelago staff continued to have face-to-face meetings during Archipelago's outreach visits as well as regular conference calls to coordinate outreach activities, communicate on project status and ensure consistency around data interpretation between the two groups.

The design for this project was based on the findings of several other EM projects, in particular previous work that had been carried out on longline and gillnet groundfish vessels in NE (McElderry et al., 2007 and McElderry et al., 2004). This project looked at increasing the number of vessels involved, and variety of EM data collected.

All three major gear types used in the NE groundfish fishery; longline, gillnet and trawl; were to be included in the project. Experience using EM data to assess catch on longline and gillnet vessels was the most extensive and it previously included working in the New England area. Also, methodologies for assessing catch were well documented for other fisheries around the world (McElderry, 2008) and could be used as reference points for methods used in this project. Experience around using EM to do full catch accounting in trawl vessels was more limited. The introduction of trawl vessels required additional efforts to determine how EM data needed to be collected and what kinds of catch handling protocols were needed.

Another important aspect of vessel selection was related to geographic distribution of participants and vessel configuration (size, deck layout, etc.). Representation from all regions in New England at an early stage on the project was identified as a priority. Outreach efforts were focused on ensuring that within the first year of the project vessel participation spanned from Rhode Island to Maine. Supporting an EM program that would span a wide geographic area required building local capacity in order to ensure that data could be retrieved and systems maintained as needed. Local capacity to manage and interpret data was also seen as a priority and required selecting and hiring a local subcontractor. Furthermore, it was identified that an objective of the project was to familiarize FSB staff with the different operational aspects involved in an EM-based project. Due to three different groups (Archipelago, FSB and a subcontractor) being involved in project operations, a strong emphasis in defining roles and responsibilities, documenting procedures and work flow tracking was necessary to ensure the operational success of the project.

To achieve effective project delivery in New England, the first phase of the project was focused on building local capacity for data collection, data interpretation and project coordination and identifying the factors that could affect EM sensor and video data collection and quality. For this reason, this phase of the project did not include an experimental design to collect EM interpreted data in weights for direct comparison to the current method for catch data collection by observer, dealer, and VTR records. The development of a comprehensive EM-based program weight estimation methodology will be included in a future phase of the project. Methodology development efforts will then be based on the data quality assessment results from the project first phase. Furthermore, stakeholder exposure to EM operations and data interpretation methodologies can aid in the establishment of standards on the acceptable variation that these data must meet.

The following were identified as specific priorities for the first year of the project:

1. Install equipment on up to 13 vessels fishing in the NE groundfish fishery while ensuring representation of all regions in New England, across multiple sectors and covering all gear types.
2. Conduct outreach meetings to interested fishermen, sector managers, members of the public and current project participants throughout the project.
3. Begin building local capacity to provide field services by selecting and training a local subcontractor.
4. Train FSB staff in EM data management, interpretation and quality assessment; familiarize them with wide range of information that can be interpreted from EM data; and introduce them to the operational components of an EM program.
5. Interpret a wide range of information from EM data including, but not limited to, determining fishing events and counting and identifying all kept and discarded catch to the lowest taxonomic level possible in order to gain an understanding of whether catch interpretation was possible with EM data and what factors may affect this interpretation.

2.2 EM SYSTEMS ON FISHING VESSELS

EM System Specifications

Each vessel was provided with a standard EM system consisting of a control box, a user interface (monitor and keyboard), a suite of sensors including GPS, hydraulic pressure transducer and/or a drum rotation sensor and up to four waterproof armored dome closed circuit television (CCTV) cameras (Figure 1). Detailed information about the EM system is provided in Appendix I.

EM System Software and Data Capture Specifications

All control boxes were loaded with Archipelago's control box software, which was designed to boot up immediately when powered on, or automatically after power interruption. The software recorded sensor data, controlled video recording according to programmed specifications, and provided continuous feedback to the captain on system operations through a user interface. Sensor data was comprised of: date, time (local time in seconds), location (degrees ± 0.0001), vessel speed (knots ± 0.1), hydraulic pressure (psi as an integer), rotation sensor readings (counts as an integer), and a variety of EM system performance data.

EM sensor data were recorded continuously while the EM system was powered, which was intended to be for the entire duration of the fishing trip (i.e. from the time the vessel leaves port to engage in fishing to the vessel's return to port). Sensor data were recorded every 10 seconds with a data storage requirement of roughly 0.5 MB per day.

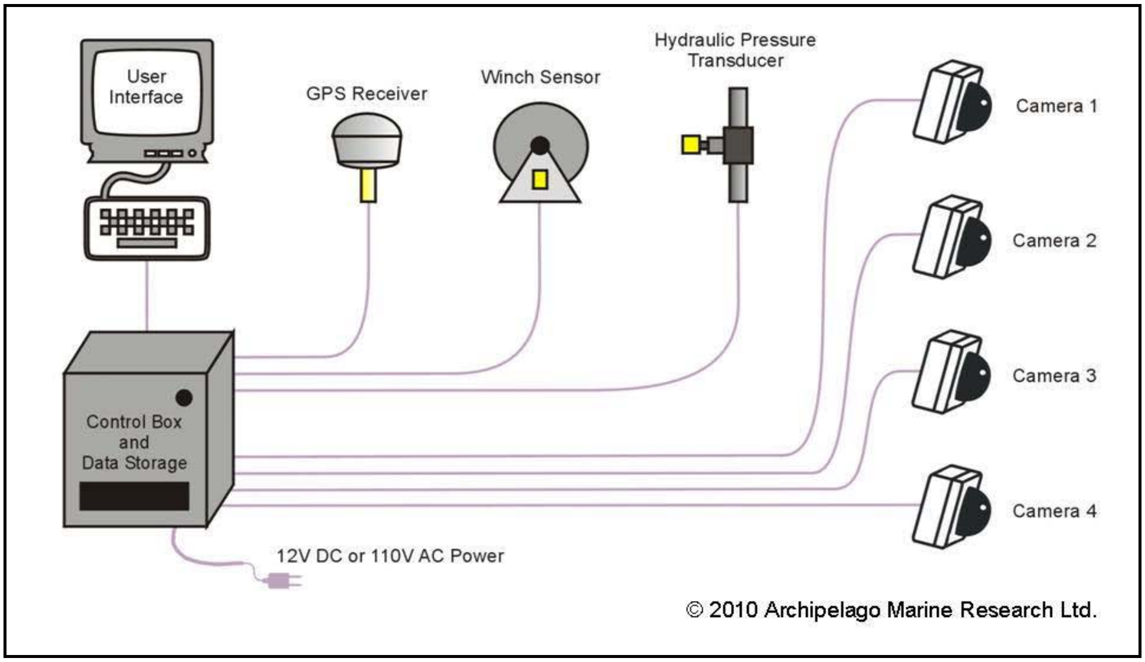

Figure 1. Schematic diagram of the electronic monitoring system, which can record video data from up to four cameras per vessel.

Video recording was triggered differently depending on the gear type used to ensure that all catch handling activity was captured in video. For trawl vessels, video recording started once the vessel was outside of a predefined rectangular area around their home port (referred to as a port box) and the winch rotated or hydraulic pressure exceeded a threshold level, set by the technician according to each vessel's hydraulic system, and video recording ended when the vessel re-entered the port box. Port boxes were used to limit the amount of video collected in the immediate area around the vessel's home port where fishing would not take place. Furthermore, this method for triggering video recording ensured that all catch processing activity was captured on the video data.

For vessels with gillnet or longline gear, video recording started when the drum rotated (if a drum rotation sensor was installed) or when hydraulic pressure exceeded a threshold level, set by the technician according to each vessel's hydraulic system, and video recording ended a predetermined amount of time after no sensor activity was detected, which varied by vessel from 10 to 50 minutes depending on how long it usually took to process all catch after hauling. The predetermined amount of time after sensor activity ended was determined based on experience from previous EM studies around the world, information from the captain about catch processing times, and reviewer feedback in cases when video recording did not capture all catch processing.

All video included text overlay with vessel name, date, time, and position. Each EM system was capable of receiving video inputs from up to four CCTV cameras at selectable frame rates (i.e. images per second). Frame rates are set balancing viewing detail required versus storage requirements versus overall system capacity. A typical frame rate per camera of 5 frames per second (fps) is used to provide adequate viewing quality for close up views used in catch detection and identification while deck overview cameras may be configured at lower rates. The data storage requirement was 60–100 MB per camera per hour, equating to a system capacity of roughly 42 days of continuous recording when using four cameras and a 500 GB hard drive.

Field Operations

The 2010 field component began in May 2010 and continued through the end of December 2010, when data collection for the 2011 calendar year commenced. Field operations consisted of provision of regular service to participating vessels including installing equipment, performing data retrievals and delivery of EM data to FSB staff as well as hardware inspections and maintenance and troubleshooting of each system, both routinely and as required.

FSB staff were responsible for selecting appropriate participants for the project, carrying out a pre-install vessel visit, explaining the project goals before EM equipment was installed, and getting data release forms signed by participants. Archipelago staff then communicated with the vessel owners directly to schedule the EM system installation, services and removals. FSB staff carried out service events during the first five months of the data collection period until a subcontractor was selected and hired. East West Technical Services Ltd. (EWTS) staff were brought into the project in September 2010 to lead all EM equipment field work in a subcontractor role. FSB continued to participate in equipment installations, data retrievals, and equipment service events throughout the duration of the project.

Archipelago technicians lead the equipment install effort and carried out training of the local technicians on the hardware and software. FSB and EWTS staff assisted during installs where they received basic training on EM system operation and set-up. Training involved an introduction to the EM system and its components, introduction to component placement on a vessel, introduction to camera placements and adjustments, software configuration, data retrievals, and basic troubleshooting.

Ten vessels participated in the project during 2010, referred to by the letters A to J in order to protect their privacy. These were representative of those operating in the NE groundfish fishery with four vessels equipped with trawl gear, three vessels with gillnet gear, and three vessels with both gillnet and longline gear. Participants fished out of five ports from Point Judith, RI to Portland, ME. Nine vessels were members of five different sectors and one was part of the common pool (Table 1).

Table 1. Summary of participating vessels during 2010 per sector and per home port.

Gear Type	Sector	Port	Vessel Size (feet)
Trawl	NEFS V	Point Judith	55
	NEFS V	Point Judith	72
	NEFS V	Point Judith	63
	NEFS X	Scituate	55
Gillnet	Sustainable Harvest	Gloucester	44
	NEFS III	Gloucester	31
	Common Pool	Portland	44
Gillnet/Longline	NEFS III	Gloucester	35
	GB Cod Fixed Gear	Chatham	42
	GB Cod Fixed Gear	Chatham	42

EM equipment installs occurred during three periods: three vessels were installed in April, four in July, and three in October. Installations began with program staff and the vessel's captain discussing EM system component placement, wire routing, fishing operations, and the vessel's power supply.

The EM system's GPS receiver was mounted to existing structures above the cabin away from other electronics and provided independent information on vessel position, speed, heading, and time. The hydraulic pressure transducer was installed on the supply side of the hydraulic system powering the fishing gear and indicated when hydraulic equipment (winches, pumps, lifts, etc.) was operating. Winch sensors were installed on the hauler for gillnet gear or one of the winches for trawl gear. Winch sensors were not installed for longline gear because no suitable location was available. Cameras were mounted in locations that provided unobstructed views of catch according to the description of catch handling by the captain during the initial interview (Figure 2). The cameras were mounted either on existing or on temporary fabricated structures according to deck layout, available structures and the intended view of the camera. Three or four CCTV cameras were mounted on each vessel depending on how many different locations on deck needed to be captured by video and whether an overview or close-up views were required. These criteria in turn depended on gear and vessel specific catch handling practices and deck layouts.

Figure 2. EM cameras on a gillnet vessel (highlighted by red circles). Note the camera on a swing arm over the starboard rail. Photograph used with captain permission.

The EM control box, monitor, and keyboard were mounted in a secure dry area in the vessel cabin. Sensor cables were run through bulkheads where hydraulic and electrical lines were already in place and out of the way from standard operation of the vessels. Power to the EM system was supplied as 120V AC from the vessel's inverter or as 12V DC from the vessel's batteries. Upon completion of the installation, the EM system was powered up and sensors and cameras were tested to ensure functionality and the vessel hydraulics were run, if the captain was available, to test the pressure threshold. The captain was given an overview of the EM user interface and basic EM functionality including how to run a function test. A function test was a feature of the EM system that prompted the captain, or an EM technician, through a series of steps that highlighted the data being collected from each of the EM system components and required an answer on whether each component was performing correctly. A record that a function test was run as well as the results from it was stored in the EM data for later review by a field or data technician. The captains were asked to monitor the status of the EM system on each fishing trip and to contact Archipelago if any concerns or issues arose.

On-site EM technicians visited each participating vessel roughly once a month for a total of 33 scheduled service events (also referred to as data retrieval events) as of December 2010. During these scheduled events program staff exchanged the hard drive containing EM data for an empty one, monitored EM system performance, and addressed equipment or data quality issues as needed, including providing feedback to the captain regarding data quality. In addition to regularly scheduled service events, non-scheduled visits were carried out whenever an EM technician required follow up after a data retrieval, or a potential problem was reported by a captain or detected during data quality assessment for a total of 13 non-scheduled service events during 2010. One system was removed due to the captain selling the vessel.

2.3 EM DATA QUALITY ASSESSMENT, INTERPRETATION AND ANALYSIS METHODS

Data interpretation began in July 2010, after data had been retrieved from the three vessels that had EM systems installed in April. After retrieval, EM data were taken to the FSB office where sensor data was posted to a secure FTP site and a copy of the video data was placed onto USB hard drives for shipment to Archipelago. Archipelago staff was responsible for the overall coordination of data management, assigned specific datasets to be interpreted by FSB or Archipelago staff, and ensured feedback on EM system performance was delivered to field technicians. Archipelago and FSB staff collaborated to pass on feedback to captains and FSB dealt with feedback related to observer/ASMs behavior.

EM data assessment and interpretation were carried out using two proprietary software packages developed by Archipelago for EM data review and interpretation. EM Interpret 1.1 (EMI) provided access to sensor data in the form of timeline graphs and geographic representation of the vessel cruise track as well as simultaneous playback of video from all cameras. EMI was used to examine EM data completeness and quality and create records for time and location of trips and fishing events. Video Analyzer provided synchronized playback of all camera images and a data entry form for recording catch observations in a sequential manner. Video Analyzer was used to review catch processing video in detail and record catch information and other events. Both EMI and Video Analyzer outputted EM interpreted data as xml files that were then imported into relational databases for analysis. EM sensor, video and interpreted data were tracked, managed, and analyzed using a combination of an intranet, MS Excel spreadsheets, MS Access databases and file naming and organization. FSB staff was trained by Archipelago in July 2010 to operate EMI and Video Analyzer as well as on data management and interpretation protocols. Validation rules to prevent missing or incorrect entries were in place throughout the EM data interpretation steps including ensuring that all data pertinent to the start and end time and location of fishing events was entered or that each catch record had a valid utilization code assigned to it.

Data Quality Assessments and Interpretation Prioritization

Protocols were in place to ensure that all EM data collected was assessed for completeness (Figure 3) (i.e. whether the EM system was powered on during the entire duration of each trip), whether EM sensors functioned as expected, and whether video data was triggered appropriately. All trips identified in the EM data were interpreted to determine time and location of fishing activities. FSB provided information on which EM trips were groundfish trips in accordance with NMFS protocols. Groundfish trips underwent EM video data quality assessment which included examining factors such as whether EM video data was available for the entire time catch was being processed, whether catch was handled in camera view, and whether image quality was adequate for identifying catch. Program staff completed a checklist to categorize data quality (Appendix II). EM data quality categories were defined as follows:

- Category A. Data was of high quality; overall sensor and video data from all catch handling was clear and complete; retained and released catch could be detected and identified.

- Category B. Data was of medium or low quality; overall data from catch handling was complete and reasonably clear; retained and released catch could be detected and identified but with difficulties.

- Category C. Data was poor; data from when catch was handled may have been incomplete and/or catch may not have been detected or identified from the video or hauls could not be determined.

- DOF. Trip was declared “out of fishery", or not a groundfish trip, by VMS or IVR systems and hence quality was not further assessed.

High-quality observed groundfish trips were reviewed for catch interpretation while only some high-quality non-observed trips were reviewed for catch interpretation. With a few exceptions, non-groundfish trips were not reviewed for catch interpretation as the catch composition and catch handling in these trips was significantly different than for groundfish trips and fell outside of the scope of this report. In some cases, data quality issues were detected once catch interpretation was underway, resulting in changes to the trip’s data quality category.

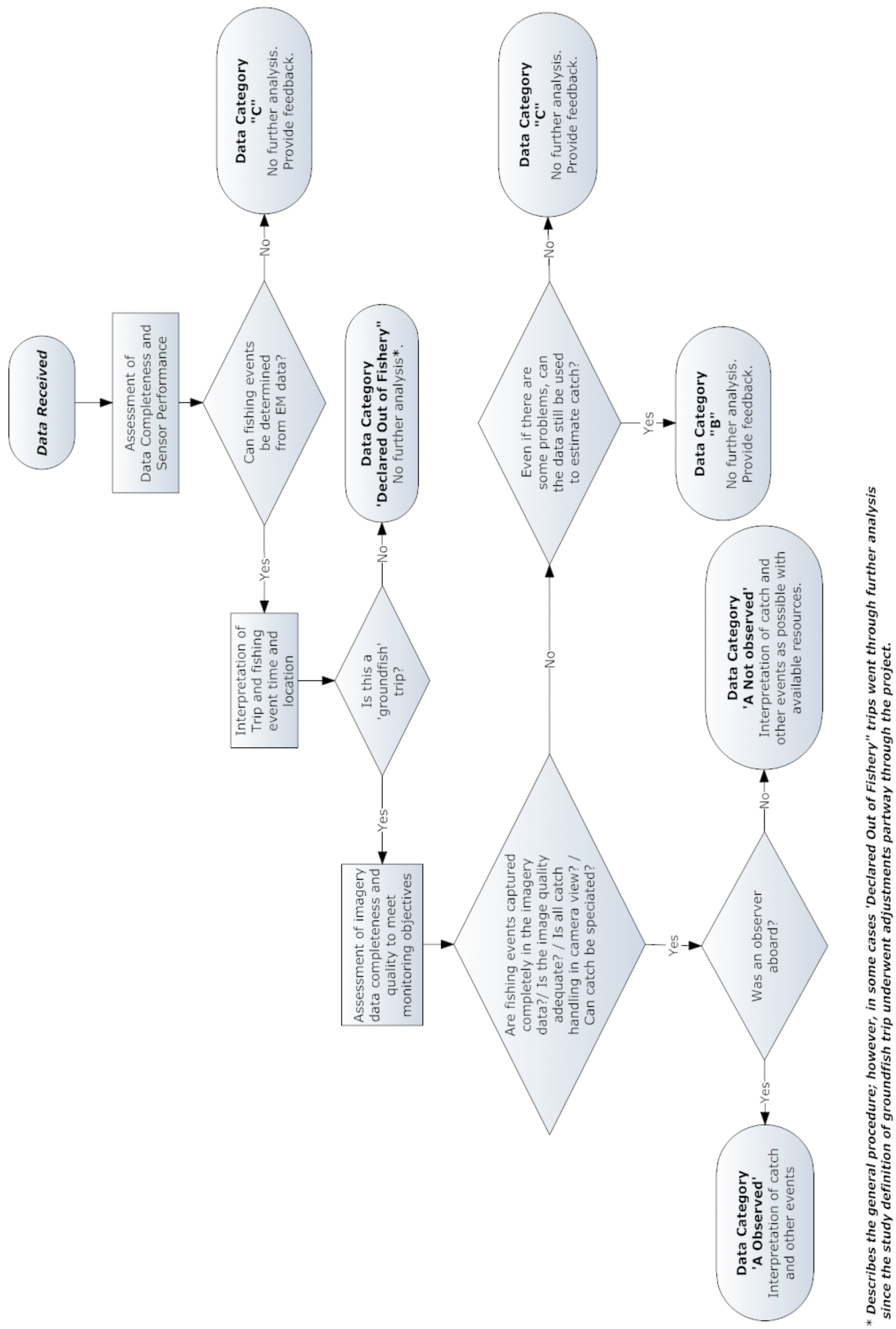

Figure 3. Conceptual model of EM data quality assessment and interpretation protocol.

Fishing Activity Interpretation

EMI facilitated interpretation of fishing activity as illustrated in Figure 4 and Figure 5. Vessel speed, hydraulic pressure, winch rotations and cruise track shape often correlate uniquely with various activities such as transit, setting, hauling, and towing for trawl gear.

For longline and gillnet, hauling was associated with high hydraulic pressure, low drum rotations and a slow speed. Setting activity was associated with a constant speed, that varied by vessel from three to seven knots, and geographic proximity to a haul; no other sensors were active since the hauler and drum were not used during setting. Gillnet and longline sets were determined from sensor data whenever they occurred within the same dataset (i.e. hard drive) and their sensor signature was easy to read, otherwise only hauls were determined. Longline and gillnet sets and hauls were defined as extending from the first high flyer to the last high flyer.

Trawl net setting was associated with high speed, while gear hauling was associated with low speed and both setting and hauling had high hydraulic pressure and winch rotations. Trawl tows were defined as extending from the time the gear was in the water and towing speed was reached to the time that the gear began to be hauled back to the vessel. Trawl tows and their associated catch processing events are collectively referred to as hauls in this report.

Gillnet and longline haul start times and trawl towing end times from sensor data interpretation provided an initial reference for accessing image data for catch interpretation.

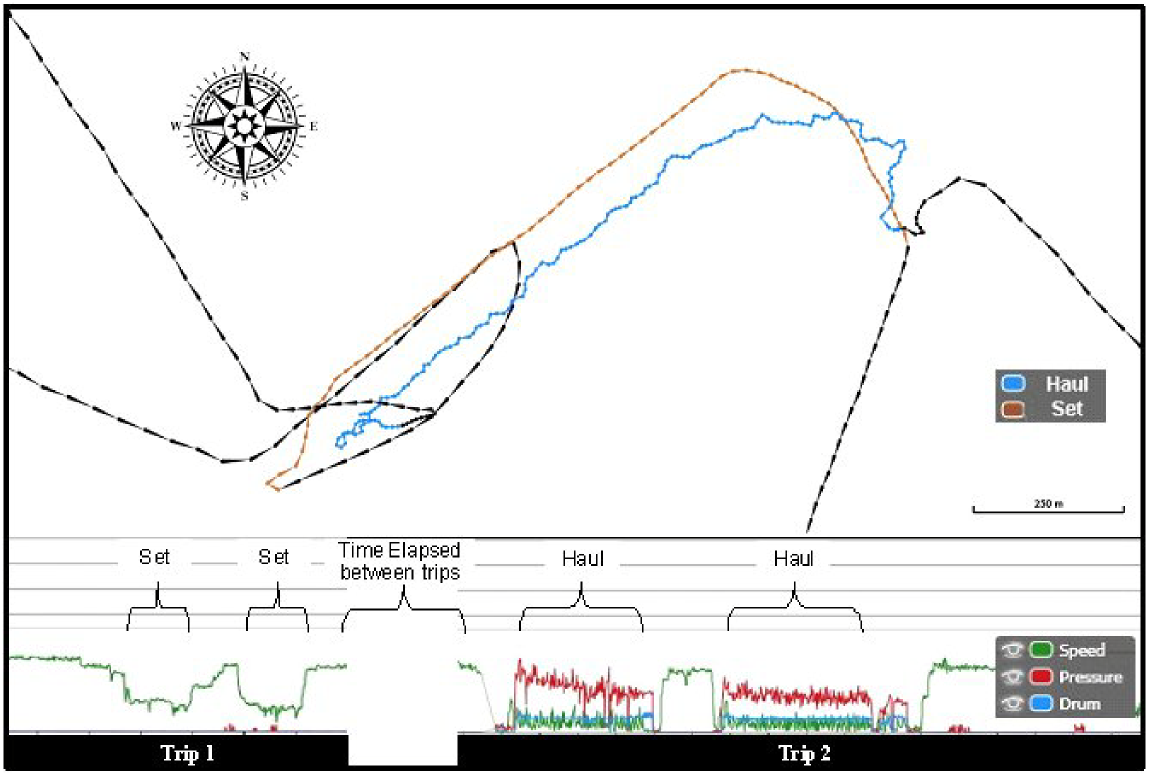

Figure 4. Example of gillnet sensor data from one of the project vessels for a trip, also representative of longline. The time series graph (lower) shows vessel speed, hydraulic pressure and winch rotations for two different trips. In longline and gillnet vessels gear was set on one trip and hauled the following trip. The spatial plot (upper) shows the vessel's cruise track for a single set and haul.

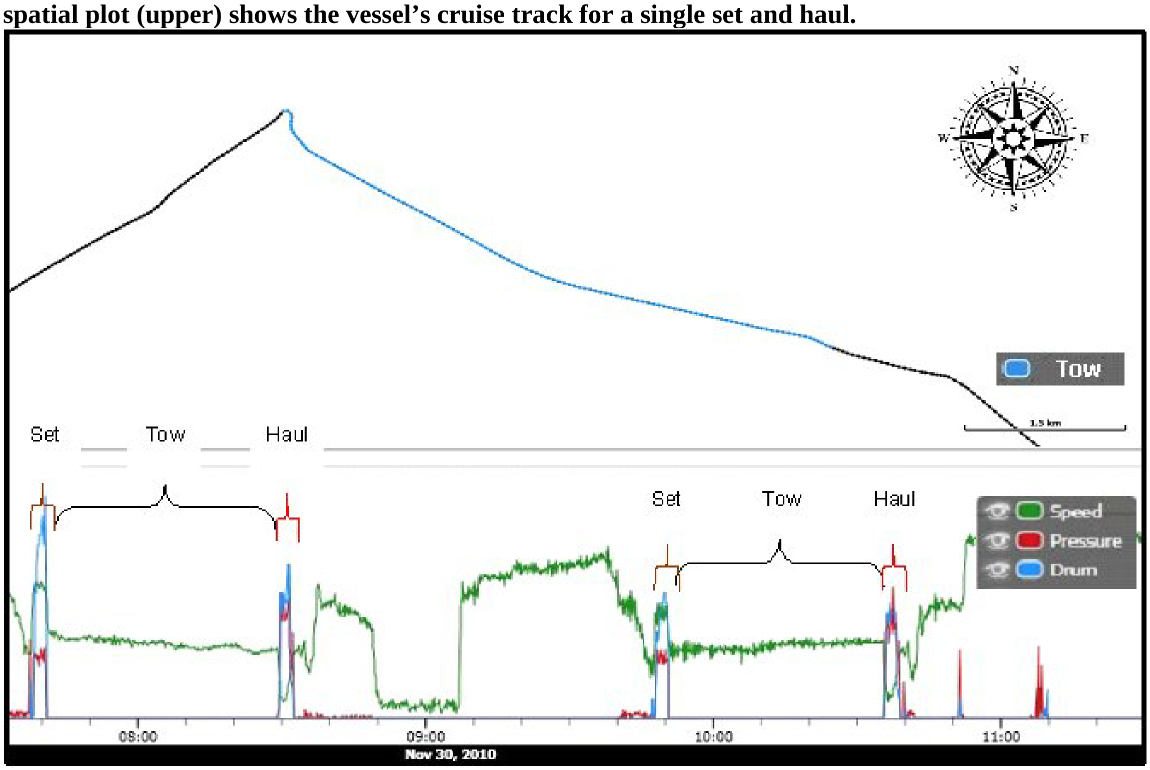

Figure 5. Example of trawl sensor data from one of the project vessels. The time series graph (lower) show vessel speed, hydraulic pressure and winch rotations. The spatial plot (upper) shows a single tow in blue.

Catch Interpretation

Archipelago and FSB staff estimated catch by a census method in which each catch item was identified to the lowest taxonomical grouping possible and recorded in a serial manner into the software along with disposition (kept or discarded). The only exception to the EM piece count methodology involved accounting for retained skates in targeted skate groundfish trips by 'barrel' instead of by individual pieces. This method was introduced in January 2011 as a way to reduce reviewing times after it was observed that vessels use standard-sized barrels. Data were recorded as one-quarter, half, three-quarter and full small or large barrels. Catch interpretation using the barrel counting method did not allow identification at the species level for skates due to some of the skate species not having readily visible features in the EM video data in the wide angle camera views used for counting barrels in this project. A general skate species code (skate, nk) was used.

Catch was not assumed to be discarded based on species, regulations or condition and only catch items seen to be discarded were entered as such. All other catch observed was recorded as kept.

Catch was assessed on a haul by haul basis with the exception of ten trawl hauls in which catch from one haul had not been completely processed before catch from the subsequent haul was emptied on deck (deckloading) and so catch for these hauls was assessed together. When these catch data were compared to observer data, the observer data from both hauls was aggregated.

Reviewers counted pieces and classified all fish as kept or discarded. American lobster was the only non-finfish catch that was consistently piece counted although other invertebrates, seaweed and debris were also recorded. Species identification materials and methods used were based on those used by observers and ASMs, although identification had to be concentrated on features visible on the camera. If this level of identification was not possible identification was done at the next higher species group level. Captains and observers were not instructed to handle catch differently to aid in catch identification by EM data reviewers.

A list of common and scientific names of the groundfish species reported is provided in Appendix III. These species include all ACE managed and prohibited species (although Redfish, nk is a species group, it is referred to as a species in this report given that species in this group are not differentiated in the current monitoring program). The groundfish species reported also include two general species groups containing groundfish and non-groundfish species ('all flounder' and 'all hake'). 'All flounder' contains all flounder catch identified at the species level as well as catch identified as unknown flounder (flounder, nk). All hake contains all hake catch identified at the species level as well as catch that could only be identified as either red or white hake (red/white hake mix) or unknown hake (hake, nk).

Other Event Interpretation

The following events and associated data were also documented as part of EM data interpretation:

- Date/time, location and animal condition (dead, alive, entangled, hooked, etc.) of incidental takes of mammals, birds or turtles during fishing events,
- Reviewing video for trawl net cleaning events to determine if any incidental takes took place (data interpretation introduced in January 2011 after as requested by FSB to ensure all possible instances where incidental takes could occur were monitored by EM).
- Date/time, location, and description of gear issues observed during hauls (e.g. gear damaged or broken, large tangle on a groundline or gillnet, etc.),
- Time and location of US Coast Guard boardings during catch processing; and
- Time, location, and general behavior of protected species sightings (i.e. marine mammal, bird or turtle seen in the video but not caught in gear).

Secondary Viewing

A selection of hauls were reviewed independently by a second data technician and the results were compared with the data from the original review. Archipelago used a stratified sampling by vessel and gear type to choose 48 hauls for secondary review. Original piece counts and species identifications used in this report are referred to as “EM interpreted data” or “primary” and data resulting from secondary data technician review is referred to as “secondary”.

Data Comparisons

Catch data for groundfish species and species groups were compared between EM interpreted data and observer data at the haul level. In order to ensure the comparisons were correct, it was important to appropriately match the two data sets. FSB aligned EM and observer data using trip start and end dates and provided associated observer trip IDs for each observed EM trip record. Records of EM and observer hauls were then matched by haul start and end times and dates and verified manually.

Observer data for the participating vessels were delivered to Archipelago by FSB once EM data had been interpreted. Archipelago staff imported all of these data into MS Access databases and used them to compare EM interpreted data. Any hauls for which only a portion of the haul was interpreted before data quality issues were noticed were removed. Only catch interpretations from hauls that were aligned between the data sources were used in catch comparisons. Unobserved hauls and limited hauls (those where the observer only recorded limited data) were not used in catch comparisons. However, the observer incidental take records for limited hauls were included.

Participating vessels in this project were subject to standard NEFOP vessel selection, coverage levels, and data collection protocols as non-participant vessels in the NE groundfish fishery. All observer data used in comparison underwent FSB’s audit and testing procedures.

2.4 OUTREACH

FSB and Archipelago recognized that industry involvement was a key component to the design and implementation of the project. To ensure involvement Archipelago and FSB collaborated to organize two participant meetings and a series of outreach meetings for industry. FSB organized two outreach meetings with NOAA staff to which Archipelago staff were invited to present.

Participant meetings were held in Plymouth, MA in July 2010 and in Brewster, MA in November 2010. The meetings allowed Archipelago, FSB, project participants, and other interested parties to review the project objectives, roles and responsibilities and compensation principles for vessels participating. Meetings created an opportunity for all groups to give and receive project updates and engage in discussions to improve the project.

Outreach meetings with industry were held in Marshfield, MA in April 2010 as well as Gloucester, MA, Brunswick, ME and Narragansett, RI in October 2010. These meetings provided interested fishermen and sector managers with basic information on EM technology and the pilot project. Outreach meetings with NOAA staff were held at the North East Regional Office and the FSB office in November 2010 and presentations included an overview of EM technology, examples of applications of EM in operational projects elsewhere, and an update on the pilot project. A demonstration booth was set up during the November 2010 New England Fisheries Management Council in Brewster, MA to demonstrate the EM technology and answer questions about EM and the pilot project.

2.5 PARTICIPANT RESPONSIBILITIES AND COMPENSATION

To maximize EM data collection and ensure that each vessel participating in the program was providing valuable insight towards the project objective, all project participants were required to:

- Keep the EM system powered for the entire fishing trip.
- Monitor the EM system performance via the monitor provided and complete a function test of the system prior to fishing activity on each fishing trip.
- Call program staff within 24 hours of detecting a system problem.
- Provide prompt and efficient vessel access to program staff to service EM equipment.
- Work with program staff to develop onboard catch handling methods suitable for program.
- Complete a vessel questionnaire after system has been removed from vessel.

Volunteer participants received $25 for any portion of a fishing day with an EM system aboard. A 30% monetary bonus in addition to the daily compensation rate was awarded if participants meet the participant requirements listed above. Participants were encouraged to participate in project meetings and received $250 and mileage expenses for meeting attendance.

3 RESULTS

3.1 EM TRIALS ON FISHING VESSELS

EM System deployments and data captured

A total of 3,530 hours of EM sensor data were collected from 358 trips and included a total of 1,231 hauls (Table 2). Individual vessels contributed between 151 and 800 hours of EM data and between 3 and 85 trips excluding Vessel J, which did not fish in 2010 after the EM system was installed. This variability was mainly due to differences in activity levels by vessel and partly due to some vessels carrying an EM system for a longer period of time (e.g. Vessel F and Vessel G were installed in the fall). During the project, only 42% of trawl trips were groundfish trips, with 99% of trips for Vessel G being non-groundfish trips. In contrast, 98% of longline and gillnet trips monitored were groundfish trips.

Table 2. Inventory of EM data collected as of December 31st 2010 per vessel. Data collection within trip was calculated as the percentage of EM sensor data available while a vessel was at-sea on a fishing trip but did not include missed data at the beginning or end of trip if the start or end was not captured.

Vessel	Gear	Data Collected (Hours)	Trips	Hauls Captured	Groundfish Trips	Groundfish Hauls	Trips with Start and End Captured	Data Collection within Trip
A	Trawl	415	47	119	24	60	100.0%	99.9%
B	Trawl	800	75	300	1	3	82.7%	100.0%
C	Trawl	674	85	224	44	132	95.3%	99.6%
D	Trawl	446	55	181	41	140	16.4%	98.4%
E	Gillnet	185	3	31	3	31	100.0%	100.0%
F	Gillnet	335	5	43	5	43	60.0%	99.8%
G	Gillnet	151	24	37	22	37	54.2%	99.8%
H	Gillnet/Longline	314	57	252	57	252	1.8%	89.5%
I	Gillnet/Longline	210	7	45	7	45	42.9%	94.0%
J	Gillnet/Longline	0	0	0	0	0	N/A	N/A
Totals		**3,530**	**358**	**1,232**	**204**	**743**	**62.0%**	**98.3%**

EM data collection success per vessel was measured using two different calculations. The first was whether the EM system was powered on during the vessel's departure from port (trip start) and return from port (trip end). The second was the amount of time within a trip when the EM system was powered on and recording EM data. EM data gaps may occur within a trip if a captain manually turns off the EM control box or if there is a severe software or hardware problem that prevents the EM control box from being operational during a trip. During an EM data gap there is no EM sensor data (GPS and sensors) recorded and hence video recording cannot be triggered.

During the project period, EM data collection success within trips was very high with 98% data capture across all vessels and individual vessels ranging between 100% and 90% and six vessels having more than 99% data completeness (Table 2). Complete EM data collection from vessel departure from port to return varied substantially by vessel from 100% of the trips for Vessel A and Vessel E to only 2% of trips for Vessel H. Overall 62% of all trips had both start and end captured by sensor data. The cause for trip starts and ends not being captured and EM data gaps within trips for all 2010 data was EM systems being manually turned off. EM data gaps for Vessel I were justified while issues with its VMS were being dealt with as described below.

A total of 32 individual equipment issues were identified and addressed by program staff (Table 3). Eighty-four percent of these issues resulted in no impact to the data collected. Issues resulting in video data loss during fishing occurred twice, both due to camera connections failing and no video data being collected from such cameras. This issue affected one groundfish trip, which fell into data quality B as a result of the data loss, and six non-groundfish trips. Two other issues with cameras did not result in video data loss.

Equipment configuration and camera views accounted for almost half of the equipment issues. Even after initial consultation with the captain on catch handling practices onboard the vessel, camera views and catch handling by observers and crew members had to be adjusted. On eight occasions camera views were substantially modified to improve catch interpretation. In five of these occasions, data previously collected was of high or adequate quality while in three occasions, on different vessels each time, data previously collected were not conducive to catch interpretation with EM. On one occasion, poor data quality was due to dirty cameras causing the image quality to be deemed unusable and the other two occasions were due to poor alignment between the camera placements and the catch handling activities on deck. Sensors were the third most common equipment issue. These occurred on six vessels and affected drum rotation and hydraulic pressure readings on 9% and 32% of all trips captured in the project respectively. However, EM sensor data allowed interpretation of all fishing activity without problems and did not affect EM video data during fishing activity; although it increased EM video data collection outside of fishing activity in some gillnet trips.

Problems with the control boxes were encountered in four occasions, none of them negatively impacting data collection. In two occasions, control boxes were removed and replaced with spare ones to further investigate the problems. GPS antennas did not require any troubleshooting.

On three occasions, and on three different vessels, circumstances not related to the performance of EM equipment resulted in issues that were addressed by field technicians. In one instance a captain reported a problem powering the system on as the result of overloading the inverter to which the EM system was powered. This was due to the inverter lacking the capacity to supply power to both the EM system and additional computing equipment. In another occasion a participating vessel was accidentally hit by another vessel while docked resulting in damage to the vessel including to EM camera mounts that had to be re-installed. A third issue was caused by the VMS unit on Vessel I not functioning properly. At one point it was believed that the EM system satellite antenna or GPS could have been creating interference but the issue was eventually diagnosed as a problem with the VMS antenna and not the EM system. However, it was deemed appropriate for the captain to only turn the EM system on during hauling until problems with the VMS were resolved.

Table 3. Equipment issues identified. No impact refers to data quality not being impacted by the issue troubleshot, data loss refers to part of either the sensor of video data not being collected due to the issue, and data unusable refers to data quality issues being identified in EM sensor or video data due to the problem.

Troubleshooting Category	No Data Impact	Data Loss	Data Unusable	Total Troubleshooting Occurrences
Equipment set up/ configuration	9	0	0	**9**
Camera views	5	0	3	**8**
Sensor issue	7	0	0	**7**
Camera issue	2	2	0	**4**
Control box issue	4	0	0	**4**
GPS issue	0	0	0	**0**
Total occurrences by impact	**27**	**2**	**3**	**32**

Out of 204 groundfish trips monitored with EM, 73% were categorized as having high data quality, or Category A, (Table 4). An additional 9% of the trips had adequate data quality, or Category B. Trips with poor data quality, Category C, represented 18%. Five vessels had more than 85% of their trips data quality classified as A and every vessel except Vessel E produced more Category A trips than B and C together. Vessel E only had Category C trips.

Table 4. Data quality categories for groundfish trips monitored with EM per vessel.

Vessel	Category A Trips	Category B Trips	Category C Trips	Groundfish Trips
A	19	2	3	24
B	1	0	0	1
C	27	9	8	44
D	37	1	3	41
E	0	0	3	3
F	5	0	0	5
G	20	0	2	22
H	34	6	17	57
I	6	1	0	7
Totals	**149**	**19**	**36**	**204**

A summary of the data quality issues that resulted in trips being assessed under Category C is shown in Table 5. Poor image quality resulting from dirt, salt, or condensation blocking the view on the cameras was the cause for 53% of the trips under Category C with 13 out of 19 affected trips coming from a single dataset for one vessel. Image quality examples are provided in Figure 6. Issues with camera views not capturing all of the catch handling were the second most common cause for poor data quality. These camera view issues resulted from catch handling by crew and/or observers not being aligned with EM objectives and usually involved catch not being discarded in the close up view set up for that purpose or out of camera view all together.

Out of 36 trips under Category C, five trips had poor data quality due to the EM system being manually turned on once a haul was underway (resulting partial capture of the haul). Four trips had un-repairable corrupt EM video data during catch processing and was caused by the EM systems being manually powered down soon after hauling or entering their port box when video was still being recorded. Only corrupt EM video data that was not possible to repair is reported here as repaired video data resulted in no impact to the trip data quality rating.

Table 5. Number of trips and vessels affected by data quality issues resulting in data quality Category C (i.e. unusable data).

Causes for poor data quality (Category C)	Trips Affected	Vessels affected
Image Quality	19	2
Camera View	8	3
Hauls partially captured	5	3
Corrupt EM video data	4	2
Totals	**36**	**6**

Figure 6. Example video from two different cameras to illustrate the different image quality assessments. From top to bottom: high, medium, low and unusable. Image quality was determined as an average of all cameras throughout an entire haul based on the use of each camera view to meet video review objectives. Images used with captain permission.

Data Source Alignment

Fishing activity alignment for fishing activity records between EM and observer data were possible for 100 trips and 330 hauls. Alignment with observer data for these trips revealed that there were four unobserved hauls as well as seventeen hauls that had not been captured by EM due to data gaps caused by the EM system being manually powered down by the captains.

Of the 330 observed hauls aligned 227 were reviewed. Out of these a total of 223 comparisons were possible due to four deckloading events. The remainder 103 observed but not viewed hauls were from DOF, Category B, or Category C trips.

3.2 EM CATCH DATA

Groundfish Species Catch Data

Catch interpretations using EM video data were completed for a total of 400 hauls corresponding to 113 trips from eight of the nine vessels that collected data during 2010. All of the hauls for Vessel E had data quality problems related to camera views and hence no hauls for this vessel had catch interpreted. A table listing all the catch recorded by EM by gear type can be found in Appendix IV.

Of the 223 haul comparisons with observer data, EM recorded a total of 25,504 pieces of groundfish species, 51% of them from trawl, 27% from longline and 22% from gillnet. Hake and flounder catch were in general not identified to species by EM reviewers but were instead identified at the species group level. Flounder catch were recorded as unidentified flounder for 62.5% of all flounder records. Similarly, catch was rarely identified as White Hake and 45% of hake catch was recorded as unidentified hake and an additional 2% as unidentified red/white hake. For this reason flounder and hake catch were compared both at the species level and at the species group level.

Tables 6 to 8 show groundfish catch composition by gear type according to EM and observer methods as well as comparisons in groundfish catch occurrence by haul between the two methods. In order to compare occurrence of species and species groups between EM catch records and observer records, these tables show two results. The first occurrence result is the number of hauls with matching occurrence for each species or species group as well as the number of hauls in which the species was recorded by EM only or observer only (shown under 'occurrence comparison by haul'). The second occurrence result is the proportion of EM pieces or observer weight within the occurrence match hauls (shown under 'catch percentage within matches'). Occasionally there were comparisons that produced non matching hauls but included minimal catch in either pieces or pounds. In those cases, the matching comparisons were still considered to be significant based on the percentage of catch contained in them.

Species composition varied with gear type in both EM and observer data. Longline trips had the simplest catch composition for groundfish species (Table 6). EM identified six groundfish species and observers identified five; the difference being two pieces of Pollock recorded in the EM data on one haul. Haddock and Atlantic Cod occurred in all of the hauls by both methods and together accounted for 99% of the groundfish catch. Winter Flounder, one of only two groundfish flounder species recorded, had a higher occurrence in observer than in EM records. At the flounder species group level, however, occurrence is higher in EM than in observer records. Occurrence for Ocean Pout was inconsistent between the two methods.

Table 6. Groundfish species occurrence and catch estimates recorded by Observer and EM for longline gear. Species occurrence per haul was compared from each method and the percent of catch within occurrence match is provided. Hauls compared totalled 29.

Species Name	Occurrence Comparison by Haul			Catch Percentage Within Matches		EM Pieces	Observer Weight
	Match	*EM Only*	*Observer Only*	*EM Pieces*	*Observer Weight*		
Atlantic Cod *	29	0	0	100%	100%	1,407	7,143
Haddock *	29	0	0	100%	100%	5,388	15,688
Pollock *	0	1	0	0%	N/A	2	0
Winter Flounder *	2	2	9	50%	4%	6	140
Yellowtail Flounder *	1	2	0	33%	100%	3	2
Ocean Pout **	9	7	5	58%	70%	43	72
All flounder ***	12	6	0	74%	100%	38	147
All hake ***	0	0	2	n/a	0%	0	15

* ACE Managed ** Prohibited species *** Species group

Gillnet trips had a more varied groundfish species composition than longline trips. EM and observer records for gillnet hauls included a total of ten groundfish species although observer records did not include any Yellowtail Flounder (two pieces in EM catch) and EM records did not include American Plaice Flounder (eleven pounds in observer catch). Groundfish catch was dominated by two species, Pollock and Atlantic Cod, which together represented 81% of EM pieces and 91% of observer weight (Table 7). Atlantic Cod, Haddock, Pollock and Redfish, nk, the four most abundant groundfish species in gillnet trips, had similar occurrences between EM and observer records.

White Hake was the third most abundant groundfish species in gillnet trips according to observer weight estimates (5% of the total groundfish species weight). Occurrence match for this species was poor with nine out of 28 hauls matching occurrence between EM and observer records and only 24% of observer weight within matched hauls. Much higher agreement in occurrence was obtained at the ‘all hake’ species group level (26 out of 34 hauls match and 97% and 98% of EM pieces and observer weight within occurrence match hauls respectively). Winter Flounder was the most abundant flounder species had poor occurrence matching (33% of observer weight within five match occurrence hauls out of 17). Three other flounder species had very little catch recorded by either method (11 pounds or less for observer recorded weight and two or less pieces in EM records). Agreement in occurrence at the flounder species group level was high with 26 out of 34 occurrences haul match and 90% to 98% EM pieces and observer weight respectively within match occurrence hauls. Observer recorded Atlantic Wolfish in one haul (nine pounds) not recorded by EM.

Table 7. Groundfish species occurrence and catch estimates recorded by Observer and EM for gillnet gear. Species occurrence per haul was compared from each method and the percent of catch within occurrence match is provided. Hauls compared totalled 48.

Species Name	Occurrence Comparison by Haul			Catch Percentage Within Matches		EM Pieces	Observer Weight
	Match	*EM Only*	*Observer Only*	*EM Pieces*	*Observer Weight*		
Atlantic Cod *	39	1	1	99%	100%	870	7,057
Haddock *	15	1	9	99%	91%	167	796
Pollock *	34	0	2	100%	100%	3,768	29,706
Redfish, nk *	19	1	2	80%	99%	863	557
White Hake *	9	1	18	98%	24%	50	2,111
American Plaice Flounder *	0	0	6	N/A	0%	0	11
Winter Flounder *	5	0	12	100%	33%	12	148
Witch Flounder *	1	0	2	100%	33%	1	5
Yellowtail Flounder *	0	2	0	0%	N/A	2	0
Atlantic Wolffish **	1	0	1	100%	53%	1	19
All flounder ***	26	6	2	90%	98%	142	277
All hake ***	26	4	4	97%	98%	310	2,316

* ACE Managed ** Prohibited species *** Species group

Catch composition had the highest species diversity in trawl trips were all thirteen groundfish species were recorded by EM and observer methods (Table 8). Compared across all three gear types, flounder species were almost exclusively recorded in trawl hauls with over 99% of total EM pieces and observer weight of flounder species corresponding to trawl hauls. Unlike longline and gillnet, where two species dominated over 80% of the groundfish catch estimates, groundfish catch on trawl trips was more evenly spread out across multiple species in both data collection methods. The most abundant groundfish species by EM pieces and observer weight were Yellowtail Flounder and Atlantic Cod, which together represented 58% of EM pieces and 63% of observer weight.

Occurrence for Atlantic Cod, Haddock, Redfish, nk, Ocean Pout and Atlantic Wolffish was similar between the two methods. Overall, flounders occurred in all 146 hauls by observer (for a total of 34,204 pounds) and in 145 hauls by EM (for a total of 29,995 pieces) resulting in virtually identical occurrences. The difference in occurrence consisted of one haul in which the observer recorded one pound of flounder and EM did not record any. However, all groundfish flounder species differed in occurrence between the two methods. American Plaice Flounder, Winter Flounder and Yellowtail Flounder had higher occurrence in observer than EM records (over 50% observer only haul occurrence and observer weight within occurrence match hauls between 51% and 77%). Witch Flounder had higher occurrence in EM than observer records (occurrence match hauls less than EM only hauls and EM pieces within occurrence match hauls 44%). Occurrence for Atlantic Halibut was inconsistent between the two methods with three hauls being recorded by EM only and four hauls by observer only.

Table 8. Groundfish species occurrence and catch estimates recorded by Observer and EM for trawl gear. Species occurrence per haul was compared from each method and the percent of catch within occurrence match is provided. Hauls compared totalled 146.

Species Name	Occurrence Comparison by Haul			Catch Percentage Within Matches		EM Pieces	Observer Weight
	Match	*EM Only*	*Observer Only*	*EM Pieces*	*Observer Weight*		
Atlantic Cod *	35	9	3	98%	100%	3,085	17,419
Haddock *	8	1	2	88%	91%	34	183
Pollock *	6	5	1	65%	96%	26	167
Redfish, nk *	3	4	0	99%	100%	796	139
White Hake *	0	1	10	0%	0%	1	31
American Plaice Flounder *	5	10	19	7%	61%	76	1,091
Winter Flounder *	46	9	67	94%	51%	1,413	6,644
Witch Flounder *	9	20	0	44%	100%	519	760
Yellowtail Flounder *	25	5	19	100%	77%	4,426	7,940
Atlantic Halibut **	6	4	3	50%	68%	12	63
Atlantic Wolffish **	5	0	0	100%	100%	6	99
Ocean Pout **	7	1	2	98%	99%	62	138
Sand Dab Flounder**	47	15	61	85%	59%	2,465	5,366
All flounder ***	145	0	1	100%	100%	29,995	34,204
All hake ***	61	14	31	85%	72%	3,129	1,738

* ACE Managed ** Prohibited species *** Species group

Two tailed paired t-tests were run on four different groundfish species with the intent of providing a preliminary exploration of whether the use of mean weights could be a viable methodology for estimating total weights (kept or discarded) by species using EM pieces. Two different average weights were applied to EM retained pieces for Atlantic Cod, Haddock, Pollock, and Redfish nk. The first was the median of the average weights for all statistical areas by species for kept catch from historical observer data. The median was chosen due to small sample sizes for each species in the historical observer data provided. The second was the mean of the average weights by species for legal length catch from NOAA survey data.

Average weight used to estimate EM weight had an effect on t-test results for some species. Using average weights from NOAA survey data, statistically significant similarities were shown for trawl caught Haddock and highly significant similarities were shown for longline and trawl caught Atlantic Cod and longline and gillnet caught Haddock. Using average weights from historical observer data, statistically significant similarities were shown for gillnet caught Redfish, nk and highly significant similarities were shown for longline and trawl caught Atlantic Cod and longline caught Haddock. Although statistically significant similarities were not shown for gillnet caught Atlantic Cod or for gillnet and trawl caught Pollock, evidence of statistical significance for the bulk of the species tested indicates that this method could be feasible in the NE groundfish fishery.

Table 9. Two-tail paired t-test results between two different weight estimates calculated by multiplying EM pieces by an average weight per piece. Average weight per piece for test 1 (Avg 1) was taken from historical observer data. Average weight per piece for test 2 (Avg 2) was taken from NOAA survey data.

Species/ Gear Type	Observer Weight		Avg 1	Estimated EM weight 1		Paired T-test 1		Avg 2	Estimated EM weight 2		Paired T-test 2	
	Mean	*SD*		*Mean*	*SD*	*DF*	*P-Value*		*Mean*	*SD*	*DF*	*P-Value*
Atlantic Cod												
LL	232.6	112.1	7.96	354.1	157.5	28	0.000**	7.1	315.8	140.5	28	0.000**
G	151.6	162	7.96	154.6	138.1	39	0.803	7.1	137.9	123.2	39	0.269
T	404.3	596.4	7.96	515.3	698.4	40	0.001**	7.1	459.6	622.9	40	0.044**
Haddock												
LL	524.2	286	4.48	791.4	415.7	29	0.000**	3.3	583.0	306.2	29	0.005**
G	30.2	27.1	4.48	27.2	34.6	24	0.476	3.3	20.1	25.5	24	0.005**
T	16.5	18.5	4.48	13.0	12.7	10	0.321	3.3	9.6	9.4	10	0.090*
Pollock												
G	830.6	1218.1	8.58	879.6	1177.9	34	0.368	7.7	789.4	1057.1	34	0.476
T	16.5	20.7	8.58	20.6	15.2	9	0.368	7.7	18.5	13.7	9	0.658
Redfish, nk												
G	24.2	1218.1	1.35	49.4	1177.9	21	0.050*	0.9	32.9	52.0	21	0.252

* Significant at α= 0.5 ** Significant at α= 0.01
Gear type: LL= longline; G= gillnet; T= trawl

Secondary Viewing

A total of 48 hauls (two longline hauls, 24 gillnet hauls, and 22 trawl hauls) across 17 trips were selected for a secondary review of video to test the precision of EM piece count estimates. Eight vessels were represented in this sample as no catch interpretations were available from Vessel E. Secondary reviews involved Archipelago and FSB staff for 21 comparisons and two Archipelago staff for 27 comparisons. No comparisons were made with data interpreted by two FSB data technicians.

Examination of the correlation between primary and secondary total groundfish species catch per haul data reveals excellent replicability of catch detection in EM catch estimates. Total groundfish species catch per haul data matched very closely between primary and secondary data for both trawl and gillnet hauls with r squared values of 0.98 and a slope of 1.04 and 0.97 for trawl and longline respectively (Figure 7). When filtered by disposition, trawl data comparisons per haul remained very close with r squared values of 0.93 and 0.98 and slopes of 0.93 and 1.05 for kept and discarded catch respectively. Retained groundfish species totals per haul for gillnet data had a correlation >0.99 and a slope of 0.94. Comparisons of discarded data for gillnet had a slope of 3.5 and an r^2 of 0.82 due to ten hauls from a single trip in which primary and secondary review data contained similar numbers of hake pieces but the secondary reviewer recorded over three times more hake discards than the primary reviewer. Similarly, the primary and secondary review of longline data recorded Atlantic Cod total pieces within one piece but discarded catch differed by seven pieces. Although both reviewers recorded the catch when it was brought onboard, only the second reviewer was aware of the catch being discarded. This was likely the result of inconsistent discarding practices between crew and observer, where crew discarded catch in one location and often piece by piece and the observer discarded catch at a different location and often en masse from a basket.

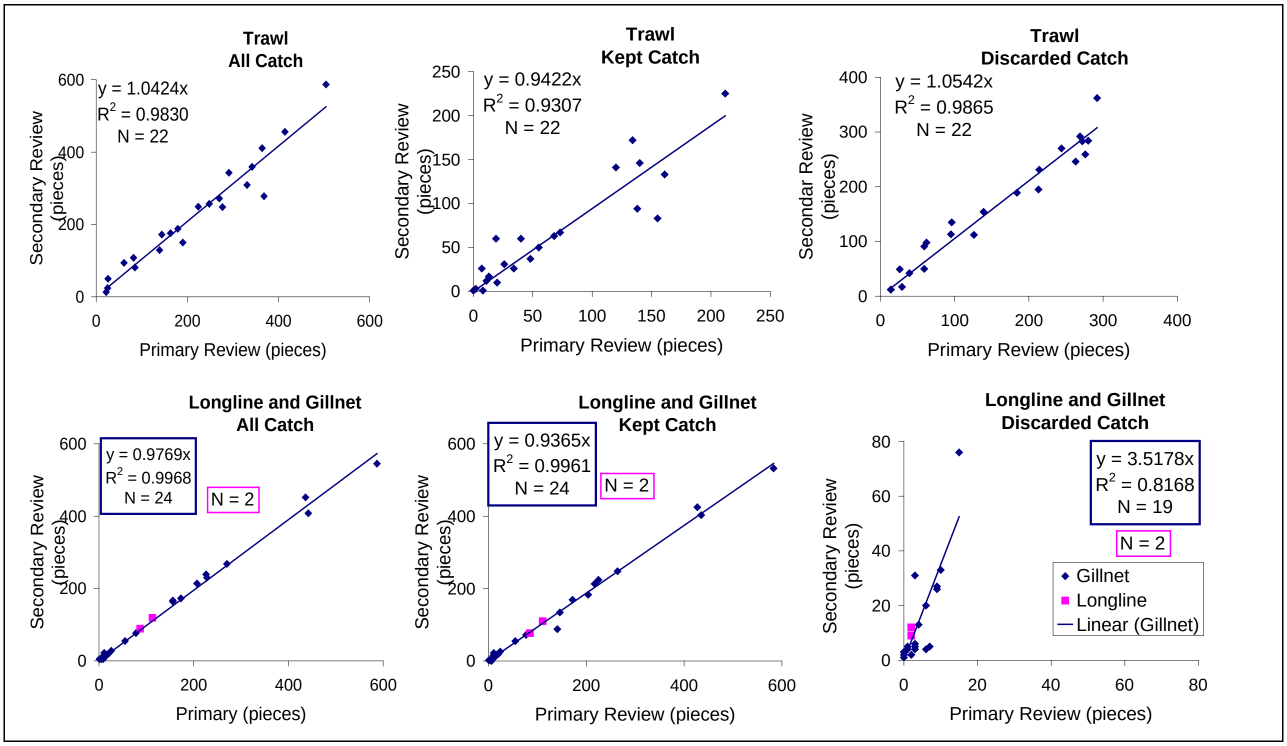

Figure 7. Scatter plots of total groundfish species catch counts of primary vs. secondary review data for trawl, gillnet and longline hauls. Best fit linear data for gillnet is shown inside blue boxes while longline sample size is shown inside pink boxes.

Linear regressions between primary and secondary piece counts by species for Atlantic Cod, Haddock, Pollock, Redfish and Ocean Pout reveal excellent replicability of catch identification in EM catch estimates for these species (Figure 8). Correlation values between primary and secondary piece counts are strong for all of these species (r^2>0.92) and slopes close to 1.0 (all between 0.87 and 1.2). Replicability was not observed for flounder catch at the species level. For example, piece counts from primary and secondary review for sand dab and summer flounder both had low correlation (r^2<0.33) and slopes between 0.56 and 0.73. However, when all flounder catch was aggregated (catch recorded at the species level and flounder, nk level), piece count replicability between primary and secondary reviewers is very high (r^2=0.87 and slope of 0.87) revealing the consistent detection of flounder from EM video data between reviewers. The outlier haul in the comparison of all flounder resulted from the primary reviewer identifying discarded catch that the secondary reviewer did not, likely due to inconsistent discarding behavior and observer sampling.

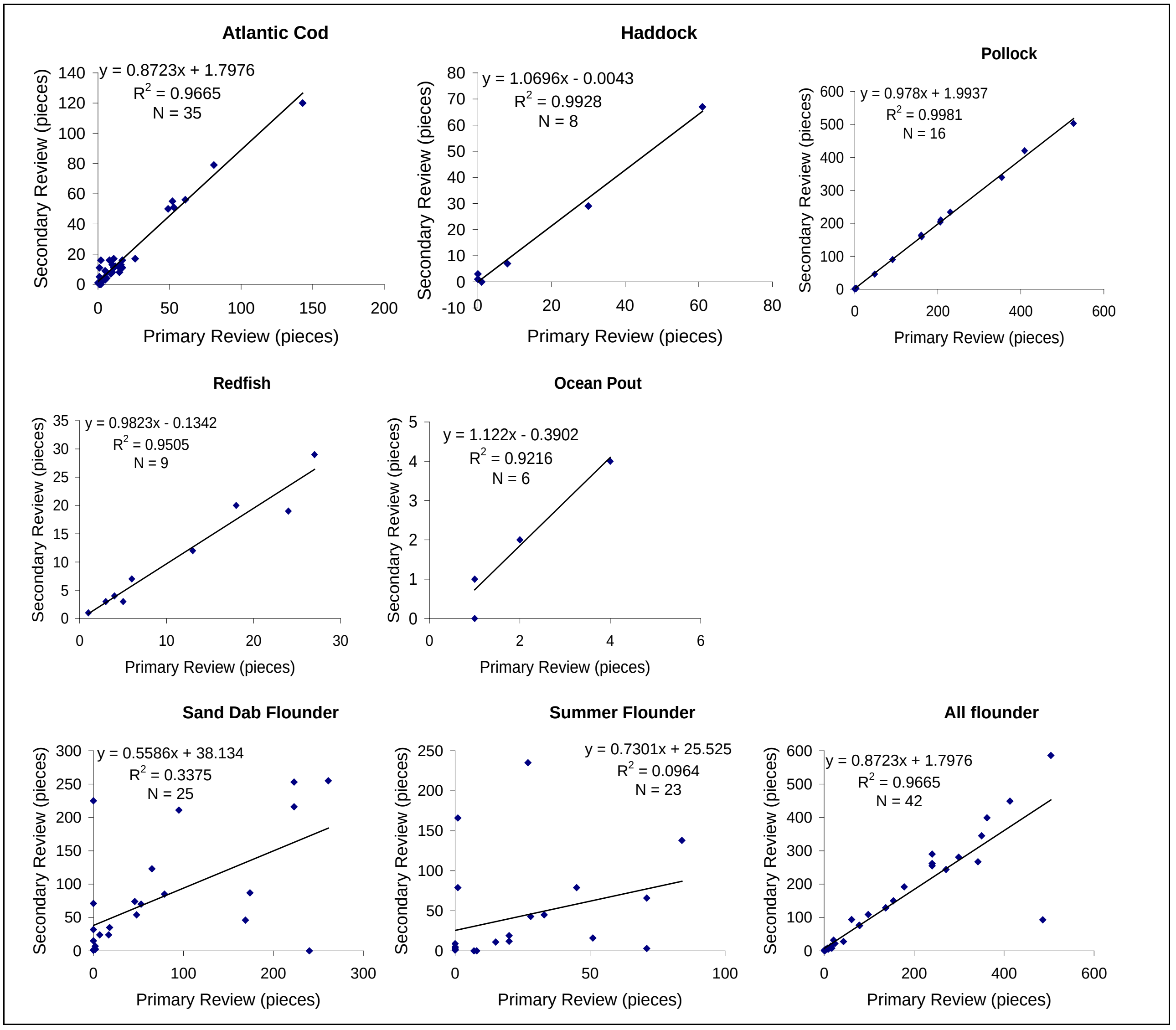

Figure 8. Scatter plots and linear regression of primary vs. secondary total pieces counts for Atlantic Cod, Haddock, Pollock, Redfish, nk, Ocean Pout, Sand Dab Flounder, Summer Flounder, and all flounder.

Incidental Takes

A total of 13 incidental takes were detected during catch interpretation using EM video data in ten distinct gillnet hauls across eight separate trips (Table 10). Reviewers were able to identify three species of marine mammals (gray seal, harbor porpoise and harbor seal) and one species of seabird (greater shearwater) and used general Codes (seal, nk and bird, nk) when identification to species was not possible from the EM video data.

Eight incidental take records were matched at the species level between EM catch interpreted data and observer data. In one occasion EM data reviewers identified an incidental take at a broader taxonomic level than observer (bird, nk vs. greater shearwater). There were a shearwater, nk and a bird, nk incidental takes indentified via EM video data that were not recorded in observer data. A greater shearwater was recorded by observer but was not recorded in the EM incidental take data. Two additional incidental takes of marine mammals were recorded in the EM incidental take data from non-observed trips.

Marine mammals, due to their large size, were readably seen in EM video data. In contrast, seabirds were smaller and the ability to detect them was similar to that of the majority of finfish catch. Possible explanations for the EM reviewer not detecting one of the incidental takes recorded by the observer include the catch item being tangled and undistinguishable from the net and decomposition of the carcass (animal condition). Factors that could have impacted the identification to species of seabirds caught on gillnet gear from EM video data are similar to those for other catch items: difficulties in locating features used in identification especially if the catch item has started to decompose, catch handling practices and low image quality due to accumulation of excess saltwater or fish slime.

Based on available footage the two items recorded in the EM incidental catch data and not in the observer data could have been missed by the observer when the item was quickly discarded after being untangled on the sorting table or at the hauling station. Camera placement on gillnet vessels includes a hauler view, which provides a camera view of all catch items as they exit the water. This is an advantage compared to observers who's location is often restricted to the most opportune place for sampling (often toward the stern or off to the side behind crew members).

Table 10. Incidental takes of seabirds and marine mammals recorded by EM.

Alignment Level	Identified through EM video data	Number of Records	Alternative Identification by Observer
Species Level			
	Gray Seal	1	
	Harbor Porpoise	1	
	Greater shearwater	6	
Record Level			
	Bird, nk	1	Greater shearwater
EM Only			
	Shearwater, nk	1	
	Bird, nk	1	
Observer Only			
	Not recorded	1	Greater shearwater
Not observed trip			
	Harbor Seal	1	
	Seal, nk	1	

4 DISCUSSION

4.1 FIRST YEAR PRIORITIES

Priority 1. Install equipment on up to 13 vessels fishing in the NE groundfish fishery while ensuring representation of all regions in New England, across multiple sectors and covering all gear types.

Installation of equipment in a representative portion of the fishery was successful. EM systems were deployed on ten vessels across five ports and all three gear types in the NE groundfish fleet. Nine of these vessels collected EM data for an overall total of 3,530 hours or the equivalent of about 380 days of fishing, 358 fishing trips and 1,231 hauls. Out of these, 204 were groundfish trips for a total of 739 groundfish hauls.

Priority 2. Conduct outreach meetings to interested fishermen, sector managers, members of the public and current project participants throughout the project.

This priority was successfully met through meetings and demonstrations to ensure that fishermen, sector managers, NOAA staff and council members were aware of the project.

Priority 3. Begin building local capacity to provide field services by selecting and training a local subcontractor.

This project successfully established local infrastructure to support equipment servicing. Significant effort was put into training local technicians on basic EM equipment functionality and progressively to a more advanced level to enable them to install equipment and do intermediate troubleshooting in EM systems. Documentation of each vessel's service events has allowed Archipelago to maintain oversight of field operations while local technicians have become more familiar with running EM field operations. Archipelago staff continue to provide support as necessary. FSB staff has remained actively involved in equipment servicing activities and working with local technicians. Local technicians have now carried out EM installs and they continue to take a larger role in the coordination of field efforts; scheduling data retrievals directly with captains and looking after the EM equipment inventory on-site.

System troubleshooting is a standard part of running any EM program and since all technology can fail the EM system was designed to be robust and minimize impacts to data collection when problems arise. The two most common troubleshooting issues were related to equipment configuration and camera placements. These issues were expected as have been the main issues in several other pilot programs (McElderry et al., 2010a; McElderry et al., 2010b; McElderry et al., 2007). Timely reporting of issues from captains and quick responses from field staff to repair them also contributed to minimizing data collection impacts. For example, although sensors had to be examined during services in seven occasions their performance never deteriorated to the point where the problem caused a negative impact on the data.

Priority 4. Train FSB staff in EM data management, interpretation and quality assessment; familiarize them with wide range of information that can be interpreted from EM data; and introduce them to the operational components of an EM program.

FSB staff were involved in the planning and operations of all aspects of the project, in particular around data interpretation as this responsibility was shared between Archipelago and FSB staff. This aspect of the project was very important because it enabled FSB staff to gain first hand experience on the strengths and weaknesses of interpreting EM data.

Priority 5. Interpret a wide range of information from EM data including, but not limited to, determining fishing events and counting and identifying all kept and discarded catch in order to gain an understanding of whether catch interpretation was possible with EM data and what factors may affect this interpretation.

The 204 groundfish trips monitored with EM systems were assessed for overall data quality and the results are satisfactory with 73% of the data falling within Category A, 9% into Category B and 18% into Category C. The data quality assessment revealed Category C trips had three main issues that impacted the ability of the data to meet monitoring objectives: dirty cameras (53% of issues), camera views (22%), and incomplete or corrupt data (25%). All of these issues can be solved with captain involvement if they are motivated to ensure high quality data is collected. Feedback to captains has already been geared toward ensuring that they are aware of the issues affecting data quality on their vessels and encouraging them to minimize these problems. Also, in December 2010 FSB issued observer and ASM sampling instructions specific for EM vessels aimed at ensuring that all catch was handled and discarded in a manner suitable for EM catch assessment.

Dirty cameras and incomplete data have relatively simple solutions such as cleaning the cameras periodically and keeping the EM system on for the entire fishing trip. Resolving camera view issues can be more complex as they interface camera placements and catch handling on deck. This project involved both crew and observers handling catch. There were physical limitations to where cameras could be placed and practical considerations to changing catch handling on deck. Modification of camera placements was always considered first as a more practical solution but crew and observer catch handling changes were a key aspect in data quality in all cases since the main issues identified were related to discarded catch. Although some vessels may have had a location where most of the discarding took place, some catch was discarded in different locations on any given haul, mostly out of habit or convenience but 'control points' (i.e. locations where catch consistently is in camera view when discarded) are necessary to ensure accurate and efficient review of EM video. Because every vessel deck layout is different, the location of EM system components, especially cameras, and control points on the vessel will be documented using standardized templates or Vessel Monitoring Plans (VMPs).

Participating captains have shown support for the project although the specific level of engagement varied from captain to captain. In general, participating captains need to become more aware of the importance of data quality from their vessel and how they can take actions to improve it. Increasing accountability for keeping the EM system on, the cameras clean and agreeing to a catch handling protocol through the VMP process will minimize the three most common reasons for poor data quality. Captains were compensated for collecting EM data which included a 30% bonus based on the level of engagement they showed. During this project all participants received the bonus as the focus has been on education. As the project moves forward, compensation has to reflect skipper efforts to have high data quality. Data completeness can be a good first step. A priority moving forward in the project should be to produce quarterly data quality reports for captains to be kept informed of data quality from their trips. We also recommend devoting efforts to reducing turnaround time of data quality assessment and data interpretation to speed up feedback.

An operational EM program can be designed to provide incentives for fishermen to provide high quality data. In programs where industry is responsible for EM data collection and interpretation costs, captains who have poor data quality could be made responsible for the additional costs of dealing with such data issues while keeping the overall program costs to a minimum for all other participants. Trips with high quality data could follow a streamlined process through EM data interpretation with little or no additional time needed to provide feedback whereas trips in which data quality issues are identified could follow a different path and additional time needed for investigation or feedback could be charged to the vessel. This requires transparent guidelines as to what kind and how much feedback and investigation are necessary. Another incentive to produce high quality data is if high data quality trips have processing priority over poor quality ones, which may delay a vessel from fishing.

Previous findings by McElderry et al. 2004 on-board NE groundfish longline and gillnet vessels showed that EM and observers collected catch in pieces within 6% of each other. Overall piece differences for Redfish, nk were 2.3% lower in EM, Atlantic Wolffish were 14.3% higher in EM and Ocean Pout had three pieces recorded by observer and six recorded by EM. Identification to species was identical between EM and observer for over 85% of the individual catch items recorded for Atlantic Cod, Haddock and Pollock. This work concluded that flounder and hake species were only closely matched between EM and observer data at the general species group category and not at the species level. Occurrence comparisons from this project generally concur with these previous findings. Flounder species and White Hake did not show similar comparisons while Atlantic Cod, Haddock Pollock, Redfish, nk, Ocean Pout and Wolffish showed similar occurrences in one or more gear types. Further work is needed to determine the minimum data quality requirements to identify all groundfish species. However this work must be based on detailed standards on acceptable differences between EM and observer data.

Because EM video data is a permanent record of the fishing activity that occurred at sea, catch interpretation through EM allows testing the replicability of catch estimates by an independent second review of the data. This aspect of EM allows pilot and operational programs to include secondary review as part of a thorough data quality process ensuring consistency in catch estimations and aiding in the training and regular certification of reviewers. In this project, groundfish species comparisons between primary and secondary reviews showed good precision in detecting groundfish pieces (correlations >0.98 and slopes between 0.99 and 1.04). Although there was high replicability of detection of flounder catch at the general species level, difficulties identifying flounders to species were apparent in the inconsistent counts at the flounder species level. Comparisons at the species level revealed good precision between different viewers for

Atlantic Cod, Haddock, Pollock, Redfish and Ocean Pout (correlation >92 and slopes between 0.87 and 1.2) likely because the features used to identify these species are generally readably visible in EM video data simply if the catch item is shown to the camera, with minimum need for the fishermen to handle the fish in a specific manner.

Secondary review results further highlighted the need for consistent catch handling behavior on board to improve detection of discards by EM. Large differences in piece counts between primary and secondary reviews were due to inconsistent discarding behavior by crew and/or observers. As discussed earlier, feedback and VMPs are being used to minimize these issues and operational programs have a wide range of tools to incentivize consistent catch handling and discarding exclusively within control points. A more stringent critique of data quality by reviewers will also aid in ensuring these issues are detected and reported.

Comparisons with observer data show that EM reviewers were very successful at detecting incidental takes. Observer data included one incidental take record that was not detected by EM reviewers while EM reviewers detected two takes that were not recorded by the observer. Identification of incidental takes was also good with nine of the thirteen items identified to species while the others were identified to the family level and one as an unidentified bird. These results show that EM can provide data on occurrences of incidental takes, including date, time, location, the gear used when caught (longline, gillnet, or trawl), and general description of the condition of the item.

4.2 FEASIBILITY OF IMPLEMENTING EM IN THE NE GROUNDFISH FISHERY

There are three main considerations when assessing the feasibility of implementing an EM based program to support sector management in the NE groundfish fishery: the reliability of the technology to collect data at sea; the cost-effectiveness of an EM based program, and the data that the program ultimately provides to enable sector managers to report to NMFS on their member's remaining balance ACE holdings (based on landed and discarded catch) and compliance and/or enforcement concerns.

Although an overall assessment of an EM based program will need to include all three, each of these considerations is examined separately to allow for focused discussion.

Technical Assessment of EM System

Overall, the equipment performed well with technical problems resulting in minimal data loss. Manually turning the EM systems off was the cause for all data gaps, incomplete data and data corruption in the project. Four vessels were consistently manually powering down the EM systems during transit to and from the fishing grounds and another three vessels did it occasionally resulting in 62% of the trips including both departure and return from port. Powering the system off at the fishing grounds was rare with 98% of the EM sensor data collected within trips. Data gaps were mostly concentrated on one vessel, which only powered the system on during hauls. These system performance results are consistent with results from several other EM applications around the world (Bryan et al., 2011; McElderry et al., 2010a; McElderry et al., 2010b; Dalskov et al., 2009).

Captains manually turned off their EM systems for various reasons including trying to save recording space, narrowing the amount of data that needed to be reviewed by limiting data collection during fishing activities, and wanting privacy on deck during specific times. Outreach and feedback was directed at explaining the importance of a full data record for each fishing trip and how EM data interpretation was carried out efficiently without limiting data collection to fishing activity only. Also, captains were reassured that there was no risk of running out of data storage space. Deck privacy was achieved by briefly covering the cameras instead of manually turning the system off. The biggest risk from EM data gaps is that fishing and/or catch processing may occur while the system is powered off and it would not be possible to know. Comparisons between EM and observer haul records showed that at least nine hauls were not captured by EM data during the project.

Ensuring that EM video data for all catch processing is complete is a priority for EM based catch monitoring programs. EM video data during catch processing may be lost due to equipment issues or by catch processing occurring outside of the times the EM system was configured to automatically record video. Results from this project show that equipment issues resulting in EM video data loss were minimal. Equipment problems that resulted in video data loss occurred twice, both as the result of a camera not recording video. Equipment issues like these could be quickly resolved in an operational program with a mature service delivery infrastructure and requirements for immediate reporting of equipment problems by captains.

For longline and gillnet vessels in this project, the length of time that the video recording continued after hauling stopped was set longer than was usually necessary to ensure that all catch processing would be finished before the automatic video recording ended. EM systems for trawl vessels in this project had the configured port box area restricted to their home port harbor. In an operational program, a combination of adjusting EM video data recording configurations and program rules can be used to ensure that EM video data recording is available for all catch processing, even if some catch processing occurs outside of the automatic EM video data recording. For example, captains could be instructed to manually trigger recording of EM video data in the rare occasions when catch processing extends longer than the automatic recording time configured for longline or gillnet vessels or that catch is processed at port by trawl vessels.

Issues related to captain behavior must continue to be addressed through feedback and, in an operational program, through a mechanism of incentives and consequences and an avenue for fishermen to be able to explain legitimate reasons for EM data gaps and reporting EM equipment problems (by being able to call from sea to report issues for example).

Cost Considerations

The monitoring program in which EM would be used needs to be defined first before costs can be calculated. Once the program is designed, the factors that would determine costs can be evaluated. These factors include those related to how the fishery operates (external factors) and how the program itself could ultimately operate (internal factors) (Table 11). However, there are two critical elements in the examination of the feasibility of using EM in the NE groundfish fishery. One element is to examine the factors that will ultimately determine the actual cost of an EM based program. These factors can then be used in discussions regarding the design of an EM based program. The second element is to provide a rough order of magnitude estimate of cost. This estimate serves as an initial assessment of the relative cost-efficiency of an EM program.

It is important to note that although the same factors would need to be considered when structuring costs for any monitoring program, EM based or other, different programs have different degrees of sensitivity to a particular factor. For example, an EM program is less impacted by highly erratic fishing schedules due to the ability to ensure an operational EM system at all times and little to no cost to the program in the case of a cancelled trip. In contrast, EM program costs would be more sensitive to higher requirements for service decentralization due to the higher infrastructure requirements needed to service equipment and retrieve data.

Table 11. Factors that influence the cost structure of EM and observer programs.

Factors	Examples
External	
Fishery activity	Number of vessels, landing, fishing events and seadays
Port use patterns	Temporal and spatial distribution of the fishery
Internal	
Analysis and reporting requirements	Data product delivered
Overall maturity of data model	Integration of data from different sources and flow of monitoring data to quota system
Degree of program centralization	Management of the program operations centralized vs. replication necessary at various levels
Cost recovery method	Division of cost responsibilities between government and industry as well as within industry
Program responsiveness	Reporting timelines
Feedback and outreach processes	Reports, meetings, one-on-one feedback
Performance tolerances	Data quality requirements. If audit-based: additional interpretation required based on initial results
Audit method and coverage level *	Amount of data that requires interpretation as well as level of detail within interpreted data

* Only a factor for audit-based programs

The 2010 cost structure of the New England EM pilot project does not provide an accurate representation of EM based monitoring costs as the pilot project was structured very differently than a mature, operational EM program would be. The overall cost per trip of the pilot project would be much larger than the cost of an operational EM program for three main reasons. The first reason is that the current pilot project was staged from Canada and focused on building local capacity, which resulted in expensive travel and training costs as well as necessary duplication of labor between FSB, EWTS and Archipelago staff. These capacity building costs are expected to be the highest during pilot studies and decrease substantially as EM programs are implemented.

Equipment costs are the second reason that cost structures would be significantly different between a pilot project and an operational program. Equipment was leased for the entire duration of the project whereas in an operational program equipment is often purchased and, although upfront capital costs are high, the cost of equipment is amortized across the total seadays for the lifespan of the equipment. Given that EM systems have historically lasted for up to 10 years of operation and Archipelago conservatively advises clients to plan for the system to operate for 5 years, this amortization can be significant.

The third reason for differences in cost structure was that for this project, as is true for other pilot studies, reporting requirements were complex including in season data analysis and summaries and a formal final report. Once reporting requirements for an operational EM program are defined, reporting can be done in a standardized (and often automated) way reducing overall costs for the program.

Although final costs of an EM based program cannot be obtained until the program is defined, it is possible to examine to provide an idea on the relative cost effectiveness of an EM based program. For this we created an order of magnitude estimate based on the internal and external factors observed in New England during the 2010 season. The assumed basic parameters of fisheries management, fleet dynamics and operational structure are stated upfront and the potential costs were applied to come up with a yearly and per trip cost estimate. The assumed internal and external factors in our rough order of magnitude estimate are:

- Vessel fishes 100 trips a year (~2 trips per week and two weeks off).
- EM equipment is purchased
- EM data is retrieved weekly by a local EM field technician
- EM technicians are available locally but not at every port
- EM data interpretation is completed for 100% of the fishing events collected

The rough order of magnitude estimate is summarized in

Table 13 and a detailed description of each cost item is provided below:

Equipment Cost:

- The amortized price of an EM system bought in 2010 over its five year projected lifespan is about US$3,565 a year and includes 4% of the purchase price for maintenance costs and a 7% interest rate on the loan to buy a system.

EM Data Collection (Equipment servicing costs):

- Installing an EM system on a boat was estimated to take 9.5 hours. This is the average install time for 2010, which is much higher than the average 4-6 hours seen in other projects since almost every install event also contained training of local staff (both FSB and EWTS).
- Regularly scheduled services to retrieve EM data required 2 hours per week based on the average time billed by technicians in 2010. Again this is higher than the 0.75 hour average seen in other comparable fisheries.
- Non-scheduled services to follow up on potential issues do not occur regularly. In 2010, there were a total of 13 of these non-scheduled service events over an eight month period across ten vessels installed. Based on this, assuming one service event every other month would be conservative. Troubleshooting events in the first year of the NE EM project averaged 1 hour.
- Since technicians are not available in every port at this time, a drive time of 120 miles was chosen based on the mileage logged by service technicians in 2010. Furthermore it was expected that servicing would include at least one other vessel in the area, reducing the travel cost per vessel to half.

EM Data Interpretation:

- Fishing activity interpretation times were based on interpretation times for the data summarized in this report.
- Average hauls per trip were based on EM data interpretations summarized in this report.
- Viewing times per haul were based on those recorded in this project following the interpretation methods described in this report (Table 12).

Table 12. Average number of hauls per trip, viewing time, catch handling time and the resulting viewing to catch handling ratios for all hauls in 2010, by gear type.

Gear	Average Hauls per Trip	Average Viewing Per Haul (hours)	Average Catch Handling Per Haul (hours)	Viewing to Catch Handling Ratio
Longline	5.5	1.38	0.92	1.5
Gillnet	3.4	1.65	1.04	1.6
Trawl	3.0	2.79	0.87	3.2
All Gears	**3.5**	**2.27**	**0.91**	**2.7**

The total yearly cost estimated here based on 2010 data and the fishing activity level defined above would be $50,453, $39,643 and $53,978 for longline, gillnet and trawl boats respectively (

Table 13). This translates to a cost per trip of $505, $396, and $539. These estimates are considered in the high range due to differences between pilot projects and mature operational programs described above, mainly training and familiarization with the EM system, data interpretation, and general processes around the EM project. Gillnet trips resulted in the lowest estimated cost because the overall reviewing effort for gillnet trips in terms of total amount of time handling fish per trip was much lower than that for longline trips. This illustrates how different factors that affect cost interact in a monitoring program.

The $548 cost for install would only apply to the first year a vessel carried an EM system. In addition to the above there are costs that were not included. Supporting all this data collection is the required computing infrastructure and the positions associated with it. These costs were not included as they are highly dependent on as of yet unknown decisions on monitoring design; however these costs are not unique to EM based monitoring programs.

Any of these estimates are expected to change as the internal and external factors become further defined. For example, labor related to data collection and data interpretation constitutes >85% of total costs per trip. Program design decisions related to how often data needs to be retrieved, or whether this responsibility can rest on the captain, can impact costs significantly. Furthermore, because data collection and interpretation in an EM based program are separate, large amounts of data can be collected relatively inexpensively and more or less data may be reviewed to meet program objectives and design. Changes to catch interpretation could have a significant impact in the total cost given that catch interpretation costs are the single largest cost line item. The program design options available to affect the level of catch interpretation are wide ranging and include options such as changing the proportion of trips and/or fishing events need to be reviewed which would or changes to how catch data is reviewed which would affect the amount of time per haul.

The relative advantages of each monitoring model are open for discussion and well beyond the scope of this report, but it should be kept in mind that this list of options is far from exhaustive and that EM based programs allow great flexibility to incorporate a wide spectrum of highly effective monitoring models to support sector management.

Table 13. Estimated costs for a hypothetical fishery. Note that times have been rounded to the nearest quarter of an hour and all dollar amounts have been rounded up to the next full dollar except for millage costs.

Item	Associated effort	Estimated Billing Rate (USD)	Cost per Year (USD)
EM system (includes maintenance and loan interest)	NA	$3,565 per year	$3,565
EM data collection			
EM system installation (includes mileage)	9.50 hours	$45 per hour	$488
Data Retrievals	2.00 hours and 15 events	$45 per hour	$4,500
Service Events	1.00 hour event every other month	$45 per hour	$270
Field technician travel	60 miles for 56 events	$0.5 per mile	$1,680
EM data interpretation			
Fishing activity interpretation	0.25 hours per trip	$47 per hour	$1,175
Longline – Catch data interpretation	1.50 hours per haul and 5.5 hauls per trip	$47 per hour	$38,775
Gillnet - Catch data interpretation	1.75 hours per haul and 3.4 hauls per trip	$47 per hour	$27,965
Trawl - Catch data interpretation	3.00 hours per haul and 3.0 hauls per trip	$47 per hour	$42,300
Longline - Total			**$50,453**
Gillnet - Total			**$39,643**
Trawl - Total			**$53,978**

Data Considerations

Since procuring actual accurate weights while at-sea can be difficult, at sea monitoring programs often have to develop estimation methodologies to derive weights by species. Currently in the NE groundfish fishery, observer and ASMs have established acceptable methodologies to determine weights. EM technology reliably provides sensor and video data for a human reviewer to estimate catch from. What remains to be developed in order to implement an EM program for catch monitoring in the NE groundfish fishery is an acceptable method for estimating weight for discarded ACE catch by species that is parallel to the ASM methodology.

Specific examples of how catch monitoring for quota management purposes using an EM based program have been achieved in a cost and logistically effective way can be found in the British Columbia, Canada hook and line groundfish fishery where the EM based program provides estimated weights for quota species by area (Stanley et al., 2011). Weights are derived by applying a species-specific average weight to the number of pieces counted. Although this approach can be done by monitoring 100% of the fishing events, a more cost efficient way was devised that involves auditing captain fishing log data for a randomly selected 10% of fishing events per trip. Using data for yelloweye rockfish, Stanley, et al. have shown that weight estimates from EM interpretations in this fishery not only provide an unbiased catch estimate in the fishery but that this estimate is virtually independent since the sample is randomly selected and the captains never know which single fishing event will be reviewed (Stanley et al. 2009).

A different approach to derive weights in an EM based program is used in the British Columbia inshore trawl fishery where total catch weight estimates are calculated through a volumetric catch estimate of the checker and discards are calculated through volumetric estimates of baskets sorted by species in camera view. These approaches have required active participation from captains and crew to ensure catch handling methods were consistent with EM catch interpretation methods.

Either of these approaches or a combination of both may be applicable in the NE groundfish fishery. The barrel count protocols used to interpret retained skate catch in directed skate trips in this project could be further explored and tested to provide weight using a volumetric estimate for other groundfish species. Based on t-tests results using 2010 retained EM piece counts and observer or NOAA survey average weights for four species, this methodology is worth further examination. Broad length categories for discard catch, legal and sublegal for example, could be applied to account for piece/weight variability. The NE EM project is currently preparing an experimental design to test the use of catch length estimates to derive weight using EM video data.

Another aspect that requires further examination is to ensure that catch estimates in an EM based program in the NE groundfish fishery can be provided for all ACE species, even those that are difficult to identify to species on EM video data, such as flounders and hake. Further work could concentrate on establishing the minimum EM video data quality requirements for reviewers to reliably identify these catch items to species, i.e. what would be required to capture the features that allow EM reviewers to identify each species. These could involve one or more of the following: changes to camera set-ups to allow better close up views, catch handling practices that ensure a catch item is shown in a certain way to a camera, etc.

Differences in overall catch volume, catch composition, and fishing methods and catch handling between gear types offer differing levels of difficulty in achieving catch monitoring. These differences by gear type must be taken into account to arrive at gear specific catch monitoring methodologies rather that trying to find a single solution that would be effective across gear types. In longline and gillnet vessels, relatively small catch volumes, lower species diversity in the catch and catch coming up one at a time on the gear make it feasible for captains to ensure that each catch item is shown to the camera in a way that facilitates enumeration and identification and standardized catch handling methods make it possible to determine disposition.

Trawl vessels represent a greater challenge due to large catch volumes, greater species diversity per haul, and more complex catch handling processes as all of the catch is brought onboard at once. A census approach for catch enumeration was possible in this study but required more effort on the vessel by streamlining catch handling and adjusting camera views and at the interpretation stage with longer reviewing times per hour of video than the other two gear types.

Having a clear mandate as to whether EM is to be used with the current ASM program rules and data model or whether a parallel EM based program is intended as well as the specific data standards required will help identify a detailed plan for developing catch interpretation methodology.

5 CONCLUSION AND RECOMMENDATIONS

The first year of the project was aimed at building local capacity to support future efforts in developing an EM based program to support sector management in the NE groundfish fishery. This was met by conducting outreach meetings for industry and NOAA staff, installing EM systems in ten vessels representative of the NE groundfish fleet; training local program staff to carry out EM field services through a subcontractor; training FSB staff to interpret data and introducing them to the operational aspects of an EM project; and beginning to define EM data quality requirement and interpretation methods.

There are three high level aspects to assess the feasibility of implementing an EM based catch monitoring program in the NE groundfish fishery to allow sector managers to report on their members' catch holdings: equipment reliability, cost effectiveness, and providing groundfish species catch weights. Results from this study confirm previous findings (Bryan et al., 2011; McElderry et al., 2010a; McElderry et al., 2010b; Dalskov et al., 2009) that EM equipment reliably collects data at-sea. A rough order of magnitude cost estimate of EM program operations suggests that EM could be able to provide a cost-effective at-sea monitoring option, although final costs will be dependent on the final program design. Further work is needed to resolve the issues around designing an EM based program that provides catch weights is the next step towards assessing the applicability of EM technology in the sector fisheries. The second year of the project should focus on this last aspect. For this we recommend the following priorities for the next steps of the project:

1- Establish the objectives of an EM program in the NE groundfish fishery and data standards.

Discussions with NEFOP will be needed to define what the ultimate goal of using EM in the fishery is. There are a wide range of options spanning from full replacement of the current ASM program to the introduction of EM for specific gears or sampling situations. An audit program could be applied in any of these options.

Given that the interpretation and nature of EM data are different from the ones currently collected by the ASM program, it will be critical to document the standards that must be met by EM program data. Standards should include how much variation is acceptable, at what level (for example trip or haul) and what the acceptable tolerances of error are. These standards can be described in parallel with those in the current observer and ASM programs.

An EM working group with representation from all stakeholders could be established to generate guiding principles and standards for an EM based catch monitoring program and discuss potential program designs that would fit the requirements of both fishery management and industry. A clear mandate and governance structure for this group would be needed.

2- Develop a methodology to use EM to provide estimates of catch weights for ACE species.

As management of the NE groundfish fishery under sector management requires accounting for total removals by species by stock for ACE managed species, an estimation methodology by species will need to be developed for the NE fishery. Given that EM is a monitoring tool that lends itself well to determining fishing location per haul, counting pieces of fish, doing volumetric estimates of containers of known dimensions (such as checkers or baskets), and verifying activities or behaviors onboard, it is feasible to develop a sampling program using these attributes. Further, EM also allows for the collection of other types of information using EM data such as length estimates which could also be investigated for this purpose.

As part of the project next steps, controlled experiments should be designed to determine weight estimation methodology and to ensure identification of catch by species. These experiments must be gear specific and include clear objectives and metrics to evaluate success.

3- Define standard requirements for data quality in order to maximize data quality across all vessels and gear types.

Guidelines for determining EM data quality need to become better defined in order to maximize the usability of EM data. A clearer definition of minimum data quality requirements followed by a continuation of feedback mechanisms between captains and field and data technicians is the first step to maximizing the proportion of high quality data collected in the project. Adopting the use of VMPs will ensure this process is formalized and transparent to captains, EM field and data technicians, and project coordination staff.

Activities related to EM data collection, local infrastructure development, and outreach should continue. EM systems have been installed on two additional vessels in the second quarter of 2011 and there is interest from two other vessels, which would bring the number of participating vessels to thirteen. Plans are being made for a participant meeting at the end of the 2011 summer. We continue to work with EWTS to build local technical know-how on how to support an EM program, transferring operational responsibilities to them as appropriate. This will ensure that prompt servicing can be achieved with a shorter turn around time in services and minimal data loss, which would in turn allow for quicker data quality assessment turn around time and more real time feedback to captains, observers and technicians. A VMP has been created for each vessel and includes a thorough documentation of the EM system set up, camera configuration and catch handling protocols specific to the vessel. One VMP has been distributed to a participating captain and others will be distributed in the near future. EM data quality assessments and interpretation has been streamlined with the introduction of EMI Pro 2.0 at the end of June 2011. These recent developments are anticipated to provide a strong foundation for the project's next phase.

6 ACKNOWLEDGMENTS

This project was funded by the Fisheries Sampling Branch (FSB) of the National Marine Fisheries Service. We are grateful for the co-operation and support from the captains and crews of all vessels involved in this project. Sector managers helped us reach out to interested fishermen and assisted us with outreach meeting organization, special thanks to Dan Salerno, Nick Brancaleone, Vito Giacalone, Meredith Mendelson, Cindy Smith, Jim Reardon, and Eric Brazer. We appreciate the offer from the Cape Cod Commercial Hook Fishermen Association to volunteer the use of two of their EM systems for this project. We are also appreciative to the New England Fisheries Council for accommodating us sharing a venue for a participant meeting during their Council Meeting.

The EM project team at FSB have been instrumental for this project at all stages, from project planning, developing objectives and methodologies and selecting participants to providing field support whenever necessary, interpreting EM data and providing invaluable advice and guidance in the analysis and reporting of data. The FSB project team is comprised of Amy Van Atten, FSB Branch Chief, Nichole Rossi, project lead, and Kelly Neville and Glenn Chamberlain, team members. Archipelago staff participating in this project included Randy McVeigh, Kim Astle, Coral Taylor, Chris Clarke, Kathryn Archibald, Conrad Carriere, Kim Mann, and Mike Turner.

7 REFERENCES

Bryan, J, Pria, M.J. and H. McElderry, 2011. Use of an Electronic Monitoring System to Estimate Catch on Groundfish Fixed Gear Vessels in Morro Bay California- Phase II. Unpublished report prepared for The Nature Conservancy by Archipelago Marine Research Ltd., Victoria British Columbia, Canada. 51 p.

Dalskov, J. & Kindt-Larsen, L. 2009. Final Report of Fully Documented Fishery. DTU Aqua report no. 204-2009. Charlottenlund. National Institute of Aquatic Resources, Technical University of Denmark. 49 p.

McElderry, H. 2008: At Sea Observing Using Video-Based Electronic Monitoring. Background paper prepared by Archipelago Marine Research Ltd. for the Electronic Monitoring Workshop July 29-30, 2008, Seattle WA, held by the North Pacific Fishery Management Council, the National Marine Fisheries Service, and the North Pacific Research Board: The efficacy of video-based monitoring for the halibut fishery. Available online at the following website: http://www.fakr.noaa.gov/npfmc/misc_pub/EMproceedings.pdf.

McElderry, H., M. Beck, M. J. Pria, S. A. Anderson. 2010a. Electronic Monitoring in the New Zealand Inshore Trawl Fishery: A Pilot Study. Unpublished report prepared for the New Zealand Department of Conservation by Archipelago Marine Research Ltd and Lat 37 Ltd., Victoria British Columbia, Canada. 46 p.

McElderry, H., M. Dyas, R. Reidy, and D. Pahti. 2007. Electronic Monitoring of the Cape Cod Gillnet and Longline Fisheries – A Pilot Study. Unpublished report prepared for the Cape Cod Commercial Hook Fishermen's Association (CCCHFA) by Archipelago Marine Research Ltd., Victoria BC Canada. 54 p.

McElderry, H., J. Illingworth, D. McCullough, and J. Schrader. 2004. Electronic Monitoring of the Cape Cod Haddock Fishery in the United States – A Pilot Study. Unpublished report prepared for the Cape Cod Commercial Hook Fishermen's Association (CCCHFA) by Archipelago Marine Research Ltd., Victoria BC Canada. 37p.

McElderry, H., M. J. Pria, M. Dyas, R. McVeigh. 2010b. A Pilot Study Using EM In The Hawaiian Longline Fishery. Unpublished report prepared for the Western Pacific Fishery Management Council by Archipelago Marine Research Ltd., Victoria British Columbia, Canada. 35 p.

Pria M.J., H. McElderry, S. Oh, A. Siddall, R. Wehrell, 2008. Use of a Video Electronic Monitoring System to Estimate Catch on Groundfish Fixed Gear Vessels in California: A Pilot Study. Unpublished report prepared for the National Marine Fisheries Service by Archipelago Marine Research Ltd., Victoria British Columbia, Canada. 46 p.

Stanley R.D., H. McElderry, T. Mawani, J. Koolman. 2011. The advantages of an audit over a census approach to the review of video imagery in fishery monitoring. *ICES Journal of Marine Science.* DOI:10.1093/icesjms/fsr058

Stanley R.D., N. Olsen, A. Fedoruk, 2009. Independent validation of the accuracy of yelloweye rockfish catch estimates from the Canadian groundfish integration pilot project. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science.* DOI: 10.1577/C09-005.1. pp. 354–362

APPENDIX I – EM SYSTEM SPECIFICATIONS

Table 14. EM V4.2 System specifications

Specifications
EM control box (v4.2)
Size: 8” x 8” x 13” (20 x 20 x 31cm.) Weight: 11lbs. (5.2kg.) Casing: aluminum anodized (splash proof) Capacity: 500GB removable hard drive Recording time: up to 1,000 hours Recording channels: 4 Video resolution: VGA 640 x 480
Power and battery
DC power: 12 to 16 VDC AC power (adaptor): 90 to 240 VAC Operating current: 5 amps at 12 volts Protection: 20 amp fuse, battery deep-discharge prevention, low current (20 mA) sleep mode
Camera
Housing: powder-coated cast aluminum, sealed to IP66 Power: 12 VDC Aiming: fixed aim, internally adjustable for pan, tilt and rotation
Sensors and inputs
GPS receiver, sensors (pressure, rotation, contact closure), power supply monitor
Options
RFID tag reader, acoustic receiver, satellite modem (ship to shore)

APPENDIX II – DATA QUALITY CHECKLIST

	TRIP			
Sensor Data	01	02	03	04
Are all sensors working? **(1 = Complete, 2 = Incomplete, 3 = No Data, 4 = Not Installed)**				
GPS	1	1	1	1
Hydraulics (Pressure)	1	1	1	1
Winch (Drum)	1	1	1	1
Are there sensor time gaps? **(Y/N)**	N	N	N	N
Can fishing events be determined from sensor data? **(Y/N)**	Y	Y	Y	Y
Video Data				
Is there an observer on board or is this a study fleet trip? **(Obs, SF, No)**	Obs	SF	No	No
Are all cameras working? **(Y/N)**	Y	Y	Y	Y
Is the video triggering properly? (i.e. during start of fishing activity) **(Y/N)**	Y	Y	Y	Y
Are there time gaps during fishing operations? **(Y/N)**	N	N	Y	Y
Do the camera angles cover typical catch handling areas? **(Y/N)**	Y	Y	Y	Y
Are the cameras clean and focused? **(Y/N)**	Y	Y	Y	Y
Does the camera setup enable a reasonable standard of species identification? **-- see note below (Y/N)**	Y	Y	Y	Y
Is catch handling (observers, etc.) completed in camera view? **(Y/N)**	N	N	N	N
OVERALL RATING OF DATA				
Priority of data? (1, 2, 3 or 4) *where 3 & 4 will require feedback	1	2	3	4
OTHER INFORMATION				
Was a functionality test performed? **(Y/N) -[Use EMI - View\Event types\Functionality Tests]**	**Y**	**Y**	**Y**	**Y**
Was a feedback form filled in?	**NO**	**NO**	**YES**	**YES**

APPENDIX III – GROUNDFISH SPECIES LIST

Table 15. List of groundfish species in the NE groundfish fishery.

Species Common Name	Scientific Name / Taxonomic Groups
Managed through ACE (referred to as ACE species)	
Atlantic Cod	*Gadus morhua*
Haddock	*Melanogrammus aeglefinus*
Pollock	*Pollachius virens*
Redfish, Nk (Ocean Perch)	Family Scorpaenidae
White Hake **	*Urophycis tenuis*
American Plaice Flounder *	*Hippoglossoides platessoides*
Winter Flounder (Blackback) *	*Pseudopleuronectes americanus*
Witch Flounder (Grey Sole) *	*Glyptocephalus cynoglossus*
Yellowtail Flounder *	*Limanda ferruginea*
Prohibited Species	
Atlantic Halibut *	*Hippoglossus hippoglossus*
Atlantic Wolffish	*Anarhichas lupus*
Ocean Pout	*Zoarces americanus*
Sand Dab Flounder (Windowpane)	*Limanda limanda*
General Species Groups	
Flounder, nk *	Families Pleuronectidae, Paralichthyidae, and Scophthalmidae
Red/White hake mix **	*Urophycis chuss* and *Urophycis tenuis*
Hake, nk **	*Urophycis sp., Phycis sp.,* and *Merluccius sp.*

* Included in 'All Flounder'
** Included in 'All Hake'

APPENDIX IV - OVERALL INVENTORY OF ALL SPECIES RECORDED IN EM DATA

Table 16. Total catch by species or species group recorded by EM in 74 longline hauls as well as percent of hauls in which they occurred. Catch sorted descending number of pieces recorded.

Species Name	Taxonomic group	Pieces	Percent Occurrence
Haddock	*Melanogrammus aeglefinus*	13,062	100%
Skate, Nk	Several Genera in Order Rajiformes	7,466	81%
Cod, Atlantic	*Gadus morhua*	4,616	97%
Skate, Little	*Leucoraja erinacea*	2,997	30%
Fish, Nk	Phylum Chordata	2,796	68%
Dogfish, Spiny	*Squalus acanthias*	1,197	42%
Skate, Winter (Big)	*Leucoraja ocellata*	995	41%
Ocean Pout	*Zoarces americanus*	309	62%
Scallop, Nk	Several Genera in Family Pectinidae	297	15%
Sculpin, Nk	Several Genera and Families in Order Scorpaeniformes	198	46%
Dogfish, Nk	Several Genera and Families in Order Squaliformes	142	8%
Pollock	*Pollachius virens*	103	15%
Scallop, Sea	*Placopecten magellanicus*	102	9%
Flounder, Nk	Order Pleuronectiformes	88	51%
Cunner (Yellow Perch)	*Tautogolabrus adspersus*	69	12%
Sculpin, Longhorn	*Myoxocephalus octodecemspinosus*	38	8%
Clam, Nk	Several Genera and Families in Class Bivalvia	10	3%
Cusk	*Brosme brosme*	9	7%
Flounder, Winter (Blackback)	*Pseudopleuronectes americanus*	6	5%
Skate, Barndoor	*Dipturus laevis*	5	3%
Flounder, Yellowtail	*Limanda ferruginea*	3	4%
Flounder, Summer (Fluke)	*Paralichthys dentatus*	2	3%
Lobster, American	*Homarus americanus*	2	3%
Monkfish (Angler, Goosefish)	*Lophius americanus*	2	3%
Crab, Cancer, Nk	*Cancer sp.*	2	1%
Bass, Striped	*Morone saxatilis*	1	1%
Dogfish, Smooth	*Mustelus canis*	1	1%
Hake, Silver (Whiting)	*Merluccius bilinearis*	1	1%
Herring, Nk	Several Genera in Family Clupeidae	1	1%
Shark, Porbeagle (Mackerel Shark)	*Lamna nasus*	1	1%
Tautog (Blackfish)	*Tautoga onitis*	1	1%
Total		**34,522**	

Table 17. Total catch by species or species group recorded by EM in 95 gillnet hauls as well as percent of hauls in which they occurred. Catch sorted descending number of pieces recorded.

Species Name	Taxonomic group	Pieces	Percent Occurrence
Pollock	*Pollachius virens*	6,385	56%
Dogfish, Spiny	*Squalus acanthias*	5,793	75%
Skate, Winter (Big)	*Leucoraja ocellata*	2,248	17%
Cod, Atlantic	*Gadus morhua*	2,071	69%
Monkfish (Angler, Goosefish)	*Lophius americanus*	961	41%
Fish, Nk	Phylum Chordata	956	75%
Redfish, Nk (Ocean Perch)	Family Scorpaenidae	895	29%
Skate, Barndoor	*Dipturus laevis*	635	13%
Skate, Nk	Several Genera in Order Rajiformes	569	61%
Hake, Nk	*Urophycis sp., Phycis sp.,* and *Merluccius sp.*	380	20%
Dogfish, Nk	Several Genera and Families in Order Squaliformes	368	7%
Haddock	*Melanogrammus aeglefinus*	251	34%
Lobster, American	*Homarus americanus*	199	46%
Flounder, Nk	Families Pleuronectidae, Paralichthyidae, and Scophthalmidae	173	43%
Crab, Cancer, Nk	*Cancer sp.*	97	17%
Shad, American	*Alosa sapidissima*	59	17%
Hake, White	*Urophycis tenuis*	50	11%
Flounder, Summer (Fluke)	*Paralichthys dentatus*	32	5%
Bluefish	*Pomatomus saltatrix*	32	4%
Raven, Sea	*Hemitripterus americanus*	30	21%
Hake, Red/White Mix	*Urophycis sp.*	29	13%
Crab, Nk	Several Genera	25	12%
Cusk	*Brosme brosme*	21	13%
Crab, Northern Stone	*Lithodes maja*	20	9%
Sculpin, Nk	Several Genera and Families in Order Scorpaeniformes	10	7%
Flounder, Winter (Blackback)	*Pseudopleuronectes americanus*	10	6%
Flounder, Yellowtail	*Limanda ferruginea*	8	5%
Shark, Porbeagle (Mackerel Shark)	*Lamna nasus*	7	7%
Herring, Nk	Several Genera in Family Clupeidae	6	2%
Starfish, Seastar, Nk	Class Asteroidea, Phylum Echinodermata	6	3%
Hake, Silver (Whiting)	*Merluccius bilinearis*	5	4%
Ray, Torpedo	*Torpedo nobiliana*	5	4%
Crab, Lady	*Ovalipes ocellatus*	5	2%
Wolffish, Atlantic	*Anarhichas lupus*	3	3%
Crab, Jonah	*Cancer borealis*	3	2%
Mackerel, Nk	Several Genera	2	2%
Flounder, Witch (Grey Sole)	*Glyptocephalus cynoglossus*	2	2%
Flounder, American Plaice	*Hippoglossoides platessoides*	2	2%
Scup	*Stenotomus chrysops*	2	2%
Bass, Striped	*Morone saxatilis*	2	2%
Anemone, Nk	Several Genera	1	1%

Table 17. Continued.

Species Name	Taxonomic group	Pieces	Percent Occurrence
Debris, Rock		1	1%
Skate, Thorny	*Amblyraja radiata*	1	1%
Halibut, Atlantic	*Hippoglossus hippoglossus*	1	1%
Shearwater, Nk	Several Genera in Family Procellariidae	1	1%
Sturgeon, Atlantic	*Acipenser oxyrhynchus*	1	1%
Porpoise, Harbor	*Phocoena phocoena*	1	1%
Eel, Nk	Several Genera	1	1%
Shark, Basking	*Cetorhinus maximus*	1	1%
Sculpin, Longhorn	*Myoxocephalus octodecemspinosus*	1	1%
Seaweed, Nk	Kingdom Protista	1	1%
Cunner (Yellow Perch)	*Tautogolabrus adspersus*	1	1%
Seal, Harbor	*Phoca vitulina*	1	1%
Shark, Nk	Superorder: Selachimorpha	1	1%
Total		**22,371**	

Table 18. Total catch by species or species group recorded by EM in 232 trawl hauls as well as percent of hauls in which they occurred. Catch sorted descending number of pieces recorded.

Species Name	Taxonomic group	Pieces	Percent Occurrence
Skate, Nk	Several Genera in Order Rajiformes	211,977	95%
Flounder, Nk	Families Pleuronectidae, Paralichthyidae, and Scophthalmidae	29,973	88%
Scup	*Stenotomus chrysops*	13,207	53%
Flounder, Yellowtail	*Limanda ferruginea*	8,390	26%
Butterfish	*Peprilus triacanthus*	7,532	38%
Fish, Nk	Phylum Chordata	7,258	80%
Dogfish, Nk	Several Genera and Families in Order Squaliformes	5,265	40%
Hake, Nk	*Urophycis sp., Phycis sp.,* and *Merluccius sp.*	4,974	31%
Flounder, Sand Dab (Windowpane)	*Limanda limanda*	4,529	43%
Cod, Atlantic	*Gadus morhua*	3,815	27%
Dogfish, Spiny	*Squalus acanthias*	3,760	42%
Flounder, Summer (Fluke)	*Paralichthys dentatus*	3,692	64%
Crab, Nk	Several Genera	3,551	32%
Skate, Winter (Big)	*Leucoraja ocellata*	3,092	62%
Sculpin, Longhorn	*Myoxocephalus octodecemspinosus*	2,590	28%
Hake, Silver (Whiting)	*Merluccius bilinearis*	2,344	34%
Flounder, Witch (Grey Sole)	*Glyptocephalus cynoglossus*	2,266	28%
Lobster, American	*Homarus americanus*	1,883	63%
Flounder, Winter (Blackback)	*Pseudopleuronectes americanus*	1,684	37%
Scallop, Sea	*Placopecten magellanicus*	1,613	13%
Sea Robin, Nk	*Prionotus sp.*	1,294	35%
Skate, Little	*Leucoraja erinacea*	1,189	12%
Redfish, Nk (Ocean Perch)	Family Scorpaenidae	1,172	6%
Crab, Cancer, Nk	*Cancer sp.*	787	10%
Clam, Nk	Several Genera and Families in Class Bivalvia	620	9%
Sculpin, Nk	Several Genera and Families in Order Scorpaeniformes	604	19%
Invertebrate, Nk	Several Phyla	551	2%
Scallop, Nk	Several Genera in Family Pectinidae	551	11%
Hake, Red/White Mix	*Urophycis sp.*	461	10%
Monkfish (Angler, Goosefish)	*Lophius americanus*	396	33%
Starfish, Seastar,Nk	Class Asteroidea, Phylum Echinodermata	383	4%
Sea Robin, Northern	*Prionotus carolinus*	316	12%
Raven, Sea	*Hemitripterus americanus*	315	34%
Skate, Barndoor	*Dipturus laevis*	306	15%
Sea Bass, Black	*Centropristis striata*	217	19%
Bluefish	*Pomatomus saltatrix*	200	27%
Squid, Nk	Several Families in Order Teuthida	188	14%
Crab, Horseshoe	*Limulus polyphemus*	111	7%
Hake, Red (Ling)	*Urophycis chuss*	100	1%
Haddock	*Melanogrammus aeglefinus*	95	10%
Ocean Pout	*Zoarces americanus*	94	8%

Table 18. Continued.

Species Name	Taxonomic group	Pieces	Percent Occurrence
Flounder, American Plaice	*Hippoglossoides platessoides*	88	9%
Bass, Striped	*Morone saxatilis*	68	15%
Dogfish, Smooth	*Mustelus canis*	65	13%
Crab, Jonah	*Cancer borealis*	48	5%
Pollock	*Pollachius virens*	31	6%
Shell, Nk	Phylum Mollusca	30	4%
Debris, Nk		25	2%
Skate, Thorny	*Amblyraja radiata*	25	2%
Flounder, Fourspot	*Hippoglossina oblonga*	20	3%
Stingray, Nk	Order Myliobatiformes	12	2%
Halibut, Atlantic	*Hippoglossus hippoglossus*	12	4%
Wolffish, Atlantic	*Anarhichas lupus*	12	4%
Herring, Nk	Several Genera in Family Clupeidae	11	2%
Ray, Torpedo	*Torpedo nobiliana*	9	4%
Ray, Nk	Superorder: Batoidea	7	2%
Sea Bass, Nk	Several Genera in Family Serranidae	5	2%
Sponge, Nk	Phylum Porifera	5	1%
Weakfish (Squeteague Sea Trout)	*Cynoscion regalis*	4	1%
Tautog (Blackfish)	*Tautoga onitis*	4	2%
Sea Robin, Striped	*Prionotus evolans*	3	1%
Crab, Lady	*Ovalipes ocellatus*	3	1%
Debris, Plastic		3	1%
Shad, American	*Alosa sapidissima*	3	1%
Debris, Fishing Gear		3	1%
Ray, Bullnose	*Myliobatis freminvillii*	2	1%
Squid, Atl Long-Fin	*Loligo pealeii*	2	1%
Debris, Glass		1	0%
Debris, Rock		1	0%
Crab, Spider, Nk	Several Genera in Family Majidae	1	0%
Halibut, Greenland	*Reinhardtius hippoglossoides*	1	0%
Anemone, Nk	Several Genera and Families in Order Actiniaria	1	0%
Debris, Metal		1	0%
Skate, Clearnose	*Raja eglanteria*	1	0%
Quahog, Hard Shell Clam	*Mercenaria mercenaria*	1	0%
Cusk	*Brosme brosme*	1	0%
Snail, Nk	*Class Gastropoda*	1	0%
Hake, White	*Urophycis tenuis*	1	0%
Skate, Smooth	*Malacoraja senta*	1	0%
Skate, Rosette	*Leucoraja garmani*	1	0%
Herring, Atlantic	*Clupea harengus*	1	0%
Total		**333,859**	