NORTHEAST FISHERIES SCIENCE CENTER

FISHERIES SAMPLING BRANCH ELECTRONIC MONITORING PROJECT SUMMARY 2010-2014

U.S. Department of Commerce
NOAA Fisheries Service
National Marine Fisheries Service
Northeast Fisheries Science Center
Fisheries Sampling Branch
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Woods Hole, MA 02543

The Fisheries Sampling Branch (FSB) of the Northeast Fisheries Science Center (NEFSC) has organized work completed during the Electronic Monitoring (EM) study into this reference document to support the development of EM programs. Operational methodologies, equipment and technical specifications, outreach documents, and project summary reports are compiled here to help promote a broader awareness of EM capabilities, to inform implementation planning activities, and to provide guidance for implementing EM standard applications and best practices.

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Introduction

The Fisheries Sampling Branch of the Northeast Fisheries Science Center conducted a multi-year Electronic Monitoring study to test the feasibility of EM technology to collect catch and fishing effort data aboard commercial vessels. The goal of the study was to evaluate the utility of EM as a means to monitor catch on a real-time basis to meet quota monitoring needs in the Northeast Multispecies fishery. EM data were collected from 2010-2013 and the study concluded in the spring of 2014. Participating vessels were based out of a variety of ports in the northeast to reflect variations in fishing activity over the geographic range and to assess the use of EM in sector-based management. Data obtained from EM were compared to traditional monitoring reporting sources (observer, vessel trip reports, etc.) to determine data compatibility, understand how EM data could be incorporated into the current data management structure, and to ascertain how the various monitoring tools would work collectively.

This document is a compilation of the work and results collected over the course of the study. Experimental work was conducted over three distinct but related project phases. Each project phase sought to address challenges identified in previous phases through experimental testing, modifications to data collection techniques, and adjustments in data management. The work performed under this study provided an evaluation of the reliability of EM, potential applications and feasibility of EM, and provided this information in scalable manner to facilitate the expansion and application of EM into other fisheries. Through this work, we have developed a better understanding of the capabilities and challenges associated with EM.

Information gained from the study can be used in the determination of EM as a suitable monitoring tool and to inform the implementation process. Specifically, work explored included; the identification of baseline data, standardized catch handling protocols, the application of discard control points, the identification of issues that impair video quality, weight estimation through standardized length-weight regressions and volumetric subsamples, data alignment techniques, captain feedback mechanisms to improve data, and efficiencies in species identification. That exploratory work provided valuable information which assisted in the evaluation and simulation of two potential EM applications suitable for Northeast fisheries. Results included a baseline framework of a functional EM program, including; supporting operational components and primary cost drivers.

The evaluation of EM as a potential monitoring tool in northeast fisheries is largely determined by the monitoring goals and data needs. Those elements drive both the program structure and costs. The study includes an initial assessment of EM and identifies critical program components to consider in the development and implementation processes. The evaluation process should be a collaborative progression among management, scientific agencies, the fishing industry, and stakeholders. Program development needs to align with current data collection tools, incorporate accountability measures, and supporting regulatory changes to create a cohesive and effectual monitoring program. Successful programs have a defined EM role and strike the right balance between monitoring needs and costs.

NOAA FISHERIES SERVICE

F/V Barbara L Peters – photo credit CR environmental

The Northeast Fisheries Science Center conducts ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf, to promote the recovery and long-term sustainability of these resources, and to generate social and economic opportunities and benefits from their use.

Electronic Monitoring: Documenting and Estimating Catch

Objectives Electronic Monitoring (EM) technologies hold promise as data collection resources and could be used as a monitoring tool by integrating the system with other data collection programs. The Northeast Fisheries Science Center (NEFSC) conducted a collaborative four-year study (in 3 phases) from 2010-2014 with Archipelago Marine Research, Ltd. and 13 participating fishing vessels. The goal of the study was to investigate the utility of EM to monitor fisheries and manage catch entitlements in the Northeast Multispecies Fishery.

The study has promoted broader awareness of EM capabilities to inform implementation planning activities and is used in consideration of developing EM standard applications and best practices. Through outreach meetings, presentations of findings, and simulation exercises, this project has brought operational experience to local fishermen, technicians, scientists, and regulators.

Phases I and II Phase I focused on building a foundation of data (detection, counting, species identification) specific to the needs of the Northeast Multispecies Fishery. Phase II focused on a series of dedicated experiments to improve methods for obtaining fish weight, with a known accuracy and precision, and to develop methods to increase species identification through catch handling practices. Results demonstrated there were efficiencies in weight estimation using standardized length/weight regressions and improvements in species identification among select species.

Phase III Phase III focused on developing and testing on-board methodologies (catch handling) to simulate an operational EM program. At-sea testing incorporated two EM models: 1) maximized retention of catch with EM monitoring for discard compliance; and 2) EM validation of allowed discards through vessel trip reports (discard audit). Incorporating techniques and information learned from previous work, each approach was tailored to meet specific program objectives. Results included identifying the necessary components to support an EM operational program and beneficial strategies for effective data collection.

Project Outcomes Information summarized in the Phase III report included: an inventory of data collected during Phase III, an examination on the two EM models tested (retention and audit), including procedural and logistical considerations and documented efficiencies for each, and a narrative of operational components necessary to support EM with a focus on the primary cost driver elements for management purposes. Project reports from the various phases of the study and other EM related information can be found on the Fisheries Sampling Branch (FSB) website (www.nefsc.noaa.gov/fsb/). To further support this work, NOAA fisheries is involved with the regional EM working group and is working with Fisheries Management Councils, the industry, EM service providers, and other stakeholders, to determine how to best incorporate EM into fisheries monitoring. For more information please visit the FSB website or contact Amy Martins at 508-495-2266 or at Amy.Martins@noaa.gov.

NEFSC Electronic Monitoring Study Final Contract Summary

Contract Information

Solicitation Number: EA133F-09-RQ-1074
Contract Number: EA133F-10-SE-0949
Contract Specialist: Roberta Smith
Service Provider: Archipelago Marine Research, Ltd.
Period of Performance: March 25, 2010 – May 31, 2014
Project Oversight: Amy S. Martins, Fisheries Sampling Branch
Contracting Officer's Technical Representative: Nichole Rossi, Fisheries Sampling Branch

Project Scope

The Fisheries Sampling Branch (FSB) of the Northeast Fisheries Science Center (NEFSC) conducted a multi-year pilot study in conjunction with Archipelago Marine Research (AMR) Ltd. to investigate the utility of electronic monitoring (EM) technology as a monitoring tool in the Northeast (NE) multispecies fishery.

The project incorporated a total of 13 volunteer vessels in the trawl, longline, and gillnet fisheries. The technology was tested on a representative range of vessels (size, fishing operation/boat set-up, etc.) in diverse geographies to effectively assess the applicability of the technology in sector-based management. Project goals focused on testing and evaluating EM as a viable alternative to human monitors/observers. Project objectives tested the ability of EM to monitor bycatch in real-time, effectively identify species (e.g., Annual Catch Entitlement species), and obtain an estimated weight utilizing length approximations.

The study involved a high level of collaboration between AMR and FSB staff. The FSB actively participated in every facet of the study (developed project objectives, EM field work, video reviewing, outreach, etc.). By playing a key role in the project, FSB was able to provide an impartial assessment on the aptitude of EM technology to help inform the evaluation and implementation processes.

The base term of the project was conducted over a 18-month period, which included three phases; pre-planning, data collection, and data analysis and report writing. Two additional option periods proceeded from the expiration of the base period.

Project Phases

- **Project Setup**; 3-month period (initiated 1 March 2010) involved finalizing project design, clarifying roles, responsibilities, and timelines, and formalizing the project team and participating vessels.

- **Data Collection**; 12-month period (initiated 1 May 2010) involving the collection of EM data on participating vessels. The FSB and AMR collectively reviewed data and employed a series of quality control measures to ensure data reviewing for both programs is comparable. Processing included examining sensor data, identifying fishing episodes, catch enumeration, and identifying species by catch disposition.

- **Analysis and Reporting**; 3-month period analyzing EM data and performing comparisons with other catch reporting sources (vessel trip reports, dealer reports, human At-Sea Monitor and Northeast Fisheries Observer Program data, and Study Fleet data). The final report will include at a minimum a project description, summary of observations, interpretations of results, and conclusions and recommendations for future use of EM.

Project Objectives

Primary objectives during the inaugural year were conservative. More progressive study objectives evolved as the data shaped the interpretation methodology and the study matured. The initial period of the study focused on primary objectives, as the project matured secondary objectives became primary.

Primary Objectives:

- To determine the time and location of trips and fishing events
- Ensure video recording during all catch handling events
- Determine retained and discarded catch identified to the lowest taxonomic level possible
- Ensure discarding is in the camera view

Secondary Objectives:

- Determine the length of discarded quota species
- Determine total catch volume

Study Participants

Thirteen vessels participated in the study. The FSB actively solicited study participants and worked with sector managers to obtain suitable vessels for participation. The FSB and AMR conducted three rounds of installations in 2010 (April 20th- April 28th, July 12th- July 23rd, and September 28th- October 8th). A fourth round of installations occurred April and June of 2011 to include 2 additional trawl vessels out of Maine.

Participating Vessels

Vessel	Port	Captain	Gear	Date Installed	Date Uninstall	Length
Barbara L Peters	Scituate	Frank Mirarchi	Trawl	4/22/2010	11/6/2013	55
David and Jenna II	Gloucester	John Greenleaf	Gillnet/Longline	10/4/2010	8/31/2011	35
Elizabeth Helen	Point Judith	Steve Arnold	Trawl	7/19/2010	1/7/2012	55
Leslie and Jessica	Port Clyde	Gary Libby	Trawl	4/21/2011	8/1/2013	51
Maria and Dorothy	Portland	Robert Odlin	Gillnet	10/6/2010	6/17/2011	43.9
Miss Fitz	Chatham	John Our	Gillnet/Longline	4/26/2010	10/24/2013	42
North Star	Portland	Vincent Balzano	Trawl	6/6/2011	11/1/2013	42.4
Ocean State	Point Judith	Bob Westcott	Trawl	7/22/2010	10/30/2013	72
Rugrats	Chatham	Bob St. Pierre	Gillnet/Longline	4/27/2010	8/20/2013	42
Toots	Gloucester	Bill Skrobacz	Gillnet	10/2/2010	11/5/2013	31
Virginia Marise	Point Judith	Rodman Sykes	Trawl	7/21/2010	11/19/2013	62.7
Alicia Ann	Dennis	Greg Willinski	Longline/Gillnet	6/23/2011	10/18/2013	35
Lori B	Gloucester	Mike Leary	Gillnet		12/21/2011	44

AMR sub-contracted EM field responsibilities with East West Technical Services (EWTS). Field technicians were responsible for hard drive retrievals, delivering data to FSB, addressing any equipment malfunctions, and conducting future installations.

Outreach Activities

FSB and AMR have conducted a series of outreach events geared toward the industry, study participants, sector managers, and NOAA staff. A comprehensive list of all outreach events (date, location, etc.) is archived on the Tech Park common drive. Below is a summary of the activities.

- Study Participants, Sector Managers, and Interested Stakeholder Meetings
    - Over 30 events in various ports within New England (2010-2013)

- National Observer Program Advisory Team; Electronic Monitoring Committee (EMC)
    - June 16, 2011, Woods Hole, MA
    - September 15, 2010, La Jolla, CA
    - September 12-16, 2011, Woods Hole, MA

- GARFO EM Study Lecture/Demo
    - Sector Manager's Workshops (August 2010 and 2011)
    - November 15, 2010, Gloucester, MA
    - June 19, 2013, Gloucester, MA (Field Staff Presentation)
    - February 20, 2014, Falmouth, MA (EM demo; WebEx)
    - March 13, 2014, Falmouth, MA (EM demo; WebEx)

- NEFSC EM Study Lectures
    - Northeast Fisheries Observer Program (NEFOP) and At-Sea Monitoring (ASM) trainings (ongoing since May 2010)
    - Advanced Sampling Technology Working Group Presentation, May 2011
    - End User Presentation, June 2011
    - SeaGrant Fellow EM Demonstration, April 13, 2012

- Equipment Display Demo
    - NEFMC Poster and equipment demo, November, 2010
    - Maine Fishermen's Forum (2011, 2012, 2014)
    - Commercial Marine Expo, June 13-14, 2012, New Bedford, MA

- Marine Resources Education Program (MREP)
    - November 17, 2011, Falmouth, MA
    - March 18, 2011, Falmouth, MA
    - March 29-30, 2012 Falmouth, MA
    - May 21, 2013, Falmouth, MA
    - April 8, 2014, Falmouth, MA

- Presentations/Panel Representation/Posters
    - American Fisheries Society (AFS), Southern New England Chapter, January 16, 2013
    - International Fisheries Observer & Monitoring Conference (IFOMC), April 8-12, 2013, Chile
    - Fisheries Dependent Information Symposium, March 3-6, 2014, Italy
    - National EM workshop, January 8-9, 2014, Seattle, WA
    - Northeast Fisheries Management Council, Electronic Monitoring Working Group, December 17, 2013, WebEx demo of EM data
    - International Collaborative Research Summit, October 1-2, Narragansett, RI
    - Northeast Region EM workshop, May 7-8, 2014, Portsmouth, NH

Project Documentation

FSB created the following outreach documents and resources (some in conjunction with AMR) for distribution to industry members, sector managers, study participants, council staff, affiliated NOAA staff, NEFOP observers and ASMs. Most of the resources listed below are available on the FSB website (http://www.nefsc.noaa.gov/femad/fsb/), documents that include proprietary or confidential information are not available for the general public. The following information (excluding presentations) is archived on the Tech Park common drive.

Document	Target Audience	Purpose
Vessel Installation Specifications	Vessel captain and crew (study participants)	Provide captain and crew with general vessel requirements for installing an EM system (i.e. power supply, wire run set up, camera views etc.).
Vessel Participant Letter	Vessel captain and crew (study participants)	Introductory letter for the EM study, stating participant reporting requirements and data confidentiality.
Electronic Monitoring Fact Sheet	Fishing industry, Sector Managers, NMFS staff, Council staff, NGOs, general public	Provides general information about the purpose of the EM study, identify project partners, and objectives of the three phases of the study.
Electronic Monitoring Fact Sheet (Fishermen)	Fishing industry	Provides general information about the EM study specifically geared toward fishermen. Includes information on frequently asked questions (such as data ownership and privacy)
Observer/At-Sea Monitor Electronic Monitoring Memo	Observers and At-Sea Monitors, Observer program staff	Introductory letter to observers/ASMs stating purpose of EM study, identifies participating vessels, changes to observer duties, and what observers can expect to see on vessels.
Observer/At-Sea Monitor On Deck Reference Guide for EM Vessels	Observers, At-Sea Monitors, Observer program staff, vessel captain and crew (study participants)	A reference guide for observers/ASMs to provide support for completing observer duties on an EM study vessel. Contains vessel specific catch handling protocols.
Electronic Monitoring FAQs	Fishing industry, Sector Mangers, NMFS staff, Council staff, NGOs, general public	Frequently asked questions and answers about EM.
Electronic Monitoring Newsletter	Fishing industry, Sector Mangers, NMFS staff, Council staff, NGOs, general public	Provides EM constituents with progress and activities related to the EM study.
Electronic Monitoring Photo Summary	NMFS staff, Congress	A collection of screen shots derived from the EM study video depicting various catch handling scenarios and issues with data quality.
Electronic Monitoring Data Schematic	NMFS staff, fishing industry	Illustration of hierarchy of EM data within a database including specific data field and reference source.
Electronic Monitoring Webpage (FSB website)	Fishing industry, Sector Mangers, NMFS staff, Council staff, NGOs, general public	Compiled information on the EM study including reports and findings.
Length Measurement Tool Description	Fishing industry, Sector Mangers, NMFS staff, Council staff, NGOs, general public	Summarizes how the length measurement tool is used in the EM software to acquire lengths of fish from video.
Data Request Form	Vessel captain and crew (study participants), EM service provider, fishing industry, Sector Mangers,	Formal request document for acquiring copies of video data from the EM study.
Vessel Monitoring Plan (Sample)	Fishing industry, Sector Mangers, NMFS staff, Council staff, NGOs, general public	Vessel specific document illustrating the roles and responsibilities of the crew, EM technicians, and NMFS staff. Includes EM set up specifications, camera views, and catch handling protocols for the vessel.

Total Project Costs

Project costs provided below are specific to costs incurred by the contractor and do not include costs associated with NEFSC staff. A detailed breakdown of AMR's costs was summarized in the EM Project Cost Estimate document (archived on Tech Park common drive). A summary of the project costs per contract period are included below. This contract was a firm-fixed price contract. Differences in monthly costs among performance periods (base and option) are the result of the following annual adjustments:

- Labor rates are adjusted annually and will increment by 4% between the option periods

- All other expense categories will increment by 3%
- Leased equipment is adjusted to reflect the full 18 month contract period

Contract Cost Summary

Performance Period	Period Timeline	Monthly Total	Monthly Payout	Funding Line	Funding	Funding Total
Base Period	3/25/10 - 9/24/11	18 months	$51,001.38	14.09.G8LFF20	FY2009	$236,092.00
				14.10.H8LAE19	FY2010	$681,932.84
						$918,024.84
Option Period I	9/25/11 - 3/24/13	18 months	$56,235.88	14.11.J8LAE19	FY2011	$1,012,245.84
						$1,012,245.84
Option Period I (6 month extension)	3/25/13 - 9/24/13	6 months	$56,235.88	14.13.L8LAE13	FY2013	$112,471.76
				14.13.L8LAE19	FY2013	$224,943.52
						$337,415.28
Option Period II	9/25/13 - 5/31/14	6 months	$50,000.00	14.13.L8LAE19	FY2013	$300,000.00
						$300,000.00
				Total Contract		**$2,567,685.96**

Following the completion of Option Period I, a 6-month extension was exercised. The extension was exercised as both a cost saving measure and to evaluate what additional information could be obtained from the project.

The SOW for option period II was modified to incorporate specific elements NMFS wanted included into the final report. AMR agreed to the changes and requested 6 six weeks for reporting writing, which was incorporated into the contract deliverables section. After consultation and more discussion on the final reports (after the contract negotiation process), AMR suggested breaking the information up into 3 separate but related reports as opposed to one final report. The information needs, as defined in the contract regarding the content of the final report did not change, however, it was decided (NMFS in agreement) 3 separate papers would be more beneficial for the public.

AMR requested additional time to complete the final report at no additional charge to the government. Our goal was to ensure the final product was an accurate and thorough assessment of the technology in order to provide management with the information they need to determine if EM is suitable for Northeast Fisheries. As a result FSB supported AMR's request to extend the contract by additional two months (April, May) with a completion date of May 31st. ERAD held the last payment until the final report was accepted and finalized.

Final Products

Phase I focused on building a foundation of data (detection, counting, species identification) specific to the needs of the Northeast Multispecies Fishery. Information gathered in Phase I was summarized in the Electronic Monitoring System Annual Report (August 2011), found on the FSB website.

Phase II focused on a series of dedicated experiments to improve methods for obtaining fish weight, with a known accuracy and precision, and to develop methods to increase species identification through catch handling practices. Results demonstrated there were efficiencies in weight estimation using standardized length/weight regressions and improvements in species identification among select species. Information collected in Phase II was summarized in the Weight Estimation and Species Identification Technical Report (September 2012), found on the FSB website.

Phase III focused on developing and testing on-board methodologies (catch handling) to simulate an operational EM program. At-sea testing incorporated two EM models: 1) maximized retention of catch with EM monitoring for discard compliance; and 2) EM validation of allowed discards through vessel trip reports (discard audit). Incorporating techniques and information learned from previous work, each approach was tailored to meet specific program objectives. Expected results include identifying the necessary components to support an EM operational program and beneficial strategies for effective data collection.

Information collected in Phase III is summarized in one single report with three specific subsections. Report subsections will consist of: 1) a summary of data collected during Phase III; 2) an examination on the two EM models tested (retention and audit), including procedural and logistical considerations and documented efficiencies for each; and 3) a narrative of operational components necessary to support EM and associated cost drivers. The New England Electronic Monitoring Project Final Report (July 2014) can be found on the FSB website.

Major Accomplishments

Electronic Monitoring technologies hold promise as data collection resources and could be used as a monitoring tool by integrating the system with other data collection programs. The NEFSC conducted a collaborative four-year study (in 3 phases) from 2010-2014 with Archipelago Marine Research, Ltd. and 13 participating fishing vessels. The goal of the study was to investigate the utility of EM to monitor fisheries and manage catch entitlements in the Northeast Multispecies Fishery.

This study has promoted broader awareness of EM capabilities to inform implementation planning activities and is used in consideration of developing EM standard applications and best practices. Through outreach meetings, presentations of findings, and simulation exercises, this project has brought operational experience to local fishermen, technicians, scientists, and regulators.

Information learned throughout this project has been used to help develop equipment specifications, data processing quality standards and protocols, performance standards for EM service vendors, and has informed an EM cost analysis report. FSB staff continues to utilize the knowledge gained throughout the study to help further the implementation of EM in northeast fisheries through a variety of outlets (working groups, summary reports, congressional inquiries, etc.).

To further support this work, NOAA fisheries is involved with the regional EM working group and is working with Fisheries Management Councils, the industry, EM vendors, and other stakeholders to determine how to best incorporate EM into fisheries monitoring.

Continuing Developments

Several fisheries (Bluefin Tuna, herring) in addition to the NE multispecies fishery have expressed an interest in utilizing EM to meet monitoring objectives. The FSB is actively involved in the implementation of EM in the northeast and provides technical and functional support to various programs.

The FSB has several resources (products and documents) we are actively working on to assist in implementation discussions and processes. The resources listed below are draft documents that have either been developed by FSB or have had FSB contributions.

- Electronic Monitoring Equipment Specifications (currently under peer review)
- Video Review Time Analysis
- Species Identification Training of NE Species for EM Service Providers
- Electronic Monitoring Training for EM Reviewers & Vessel Crew (under consideration)
- Comparison of At-Sea Monitoring and Electronic Monitoring Data Collection
- Electronic Monitoring Cost Analysis (in cooperation with GARFO)

Electronic Monitoring System Specifications

Background

Electronic Monitoring (EM) technologies hold promise as data collection resources and could be used as a monitoring tool by integrating the system with other data collection programs. The Northeast Fisheries Science Center (NEFSC) conducted a collaborative four-year study (in 3 phases) from 2010-2014 with Archipelago Marine Research, Ltd. and 13 participating fishing vessels. The goal of the study was to investigate the utility of EM to observe fishing behavior and monitor catch allocations in the Northeast Multispecies Fishery.

Information presented in this paper was based on NEFSC's data collection with EM systems, and incorporates information obtained through numerous EM service providers. The purpose of this paper is to inform implementation planning activities in the consideration of developing EM standards in an operational program.

Electronic Monitoring System

EM systems are designed for the automated collection of fisheries data while vessels are at sea. They collect high-frequency sensor data and closed-circuit television (CCTV) imagery during fishing or related activities which are then reviewed post-trip to provide data needed for fisheries management, compliance, and/or science. EM systems typically consist of a control center, a user interface (monitor and keyboard), a suite of sensors (GPS receiver, hydraulic pressure transducer, drum rotation sensor, etc.) and waterproof armored-dome CCTV cameras (analog or digital).

Electronic Monitoring Data Needs

EM system features are determined by program needs and objectives. Program needs will dictate the specific features an EM system must have in order to meet defined objectives. The objectives listed below are not an exhaustive list, but rather, a synopsis of program goals used throughout the study period.

- Identify, count, and assign a catch disposition (kept or discarded) for individual catch items,
- Obtain an estimated weight per catch item, species, or species group by haul
    - Individual fish, volumetric weight, scale or tote weight, etc.
- Obtain an estimated length per catch item (required to obtain a weight estimate),
- Monitor fishing activity (as defined by program needs),
- Monitor regulatory compliance (as defined by program needs), and
- Verify area fished.

The purpose of this paper is to identify specific product features needed to meet primary objectives tested in the NEFSC study. Additional product features may be needed for an operational program or will vary depending on the program data needs and objectives.

- Distinguish and identify commercially important species and/or common bycatch in the Northeast Multispecies Fishery.
- Maintain a running count of individual fish during a trip by species (trip duration estimated 1-15 days total).
- Provide a length estimate for each discarded item by species.
- Provide weight estimates (derived from length measurement) by species on a haul basis incorporating standardized length-weight regressions generated by the Northeast Fisheries Science Center.

- Monitor fishing activity, including; catch sorting, discarding, transit, towing gear, hauling gear, setting gear, and stowage of kept fish.
- Verify area fished through means of GPS data that corresponds to still shots, video clips, or video streams.
- Activate recording activity through the use of sensors or other means.
- Store data for retrieval by or transmission to NMFS or approved vendor.
- Meet data confidentiality standards of the Magnuson-Stevens Act.
- Meet chain of custody and data integrity needs for enforcement purposes.

Functional Requirements

An EM system consists of two major elements; hardware and software. The proposed specifications are based on the general EM program objectives included above. Incorporating more defined objectives (i.e., data timelines or turnaround, volumetric measurements, etc.) may negate or alter some of the specifications listed below.

Hardware

I. General

- Hardware should be adaptable and transferrable in application to enable deployment on a variety of fishing vessels (size, gear, target species).
- Hardware, including but not limited to wires, cameras, control box, and sensors, should be adequately shielded to prevent radio frequency interference (RFI) with Vessel Monitoring System (VMS) units. All vessel electronics need to work together simultaneously.
  - Degree of adequate shielding required to alleviate any interference issues between electronic units depends on the size and layout of the vessel, location of the EM control box and wire runs, and location of the VMS antenna.
  - Shielding may be achieved by the use of ferrite beads, coaxial cable with shielding added to the wiring, or other commonly utilized materials for this purpose.
  - Location of the control box and cables should be arranged so that the VMS antenna is positioned a sufficient distance from the EM equipment to eliminate the risk of RFI.
- The EM system should be compatible with NMFS approved VMS units (http://www.nmfs.noaa.gov/ole/docs/2015/040815_noaa_fisheries_service_type.pdf).

II. Power

- Ability to run off DC or AC power supply, inverters, or generators.
  - Power draw should be minimal (maximum of 30 Watts or 2.5 amps).
  - Power wires should be resistant to damage, water, weather, etc.
  - Provide safeguards to retain data in the event of electrical failure or power spikes.

III. Vessel Data Storage

- The system should have sufficient removable data storage capacity to store all video and sensor data for an entire month (minimum of 500 gigabytes storage capacity). Each frame of stored video data should record a time/date stamp in Eastern Standard Time (EST).
  - Data storage components should be adequately shielded to prevent interference with vessel electronics.
  - Data storage hardware should be resistant to damage and data loss.
- The system should must include a means of removing data from the EM unit, such as;
  - at least two external USB (1.1 or 2.0) ports.
  - removable storage device (e.g., hard drive) approved by NMFS.
  - other means to transferring data.

IV. Cameras and Review

- Cameras should be waterproof armored-dome closed-circuit television (CCTV) compatible (number of cameras will vary by vessel and program needs).
- Cameras should be capable of point-to-point or point-to-multipoint transmission (not openly transmitted) on a limited set of monitors.
- Cameras should operate continuously.
- Each camera should be compatible with a range of fixed focal length lenses to enable swapping of lenses to achieve monitoring goals.
- Cameras must be able to record continuously and provide the option to produce still images for enhanced species identification and measurement.
- Cameras must produce images compatible with zoom function for enhanced identification and measurement during video review.
- The system must provide cameras with sufficient resolution and field of view to observe all areas where fish could be sorted, processed, and discarded. Resolution must be sufficient to discern individual fish (detect, count, and identify).
    - Digital cameras must be capable of recording data at a resolution of 2.9 mm to 12 mm at minimum for analog and 3.6 mm to 6 mm for digital cameras.
    - System must record at a speed of no less than 10 frames per second shared among all cameras within the EM system.
- Cameras must produce color footage with the ability to revert to black and white video output when light levels become too low for color recognition.
    - Cameras must be capable of functioning during low light conditions to account for nighttime fishing activity. "Functioning" is defined as allowing video reviewers to count, identify, and measure individual fish and otherwise account for fishing activity and catch handling.
- A 12 volt, 16-bit or better color monitor, for viewing all areas where sorting or handling of fish or any species takes place. The monitor will also be used by vessel crew to confirm the system is operating properly. The video monitor must:
    - Display all cameras simultaneously;
    - Be at least 12 inches;
    - Operate at all times, including when fish are handled or sorted; and
    - Be securely mounted and readily accessible to the EM technician and captain and crew.
- If required, measurement grids (discard chute, sorting table panel, etc.) should be designed and tailored to each gear type and vessel size and compatible with common species caught by the vessel.
- Measurement grids should be capable of calibration to ensure data accuracy and precision.
    - Grids should have a continuous flow of water across their surface at a speed which is conducive to identification, counting, and measurement of catch.
    - Grids should be constructed of a material that allows catch to flow smoothly, without snagging.
    - Grids should be fixed in place during fishing activity and be resilient to standard vessel motions.
    - Grids should be of an appropriate size and shape and not impede or hamper normal fishing practices.
- A robust system must be capable of withstanding the extreme weather conditions (-45-40 degrees Celsius) listed below with minimal maintenance.
    - Extreme heat, freezing rain/spray, ice, snow, fog, and hail.
    - Waves ranging from spray inducing chop to damaging large waves.
    - Violent pitching or listing.

V. Sensors

- The system must include a minimum of at least two sensors to trigger camera recording.
    - Sensors may include a hydraulic sensor, drum sensor, motion triggered sensors, or other sensors (must be approved by NMFS).
        - Sensors must be compatible with standard vessel equipment.
- The system must include a GPS unit to produce track of vessel transit and fishing activity.
    - GPS unit must be installed at a distance (vessel specific) from existing vessel electronics to eliminate risk of RFI.

VI. Preferred Features

- The system should have electronic reporting capabilities and the option to link with eVTR software.
- Hard drives should be modern, robust drives that do not require extra care in handling or shipment when compared to commercially available drives.
- Hard drives should be pre-formatted for ease of use and to allow the captain to exchange hard drives readily.
- Digital cameras are preferred to analog cameras.
- Regular system upgrades as technology advances.

Software

I. EM Data Review

- The software must include basic video and navigation functions (at a minimum: record, start, stop, bookmarking, play, standard viewing capabilities, copy and save functions, etc.).
- Custom or licensed-based software must be supplied to the government for data processing purposes throughout the duration of program.
- Software should include the ability to accomplish the below functions;
    - Assess video quality based on standard requirements including but not limited to; complete sensor data (if applicable), camera functionality, presence of video gaps (missing or incomplete), clarity of images (are cameras dirty, focused, covered by salt spray, etc.), sufficient camera angle to monitor catch, species identification, and sufficient view of catch handling practices, etc.
    - Allow reviewers to identify each species caught or at minimum store images of unknown species for later identification and inclusion in the catch record.
    - Software must obtain a calculated weight from measured length.

II. Security

- Data encryption or tamper evident features (video and sensor).
- Software must be secure, have the ability to lock and protect data, and detect if the EM system was tampered with at any point during a fishing trip (tamper evident).

III. Compatibility

- Software must be compatible with:
    - Personal Computers (PC);
    - Windows-based operating systems; and
    - Internet Explorer and other commonly used browsers.
- Software must produce data in a file format such as .xls, or .xml that is compatible with an Oracle database.
- The system must use commercially available software or provide proprietary licenses.

IV. Pre-trip System Check

- Software must include a pre-trip test of the EM system to ensure any issues with system components are identified prior to trip start.
    - Test performance and results shall be recorded for use by the video reviewer at the start of each fishing trip.

V. Data Validation

- Software must include the ability to verify a complete trip (complete EM trip is defined as a trip where video was recording 100% of the time, trip start to trip end).
- Software should record and utilize the following data fields;
    - Vessel permit number, vessel name, VTR serial number, gear type, targeted species, sail date and time, land date, trip type, number of hauls/tows, statistical area fished, fish species (kept and discarded), disposition (kept or discarded), and an estimated weight by species.
    - Software shall include identifying timestamps, location, vessel name/number, and GPS unit to facilitate review.
    - Software should be capable of interfacing with NMFS approved eVTR software (FLDRS, etc.).
- Sensor data shall display vessel track, fishing start/end locations and times, transit locations and times, and provide a complete record of all fishing activity during a given trip.
    - Sensor data shall display data from the GPS as well as power to the EM system, and sensors used to trigger recording.

VI. Shoreside Data Storage

- System data should be stored for 5 years after collection and must include sufficient data backup features to protect data.

VII. Data Output

- Initial review results (preliminary data) should be made available to sector managers to facilitate weekly sector reporting timelines.
    - JPEG, video, sensor, and statistical data review methods should conform to this standard.
- Statistical data output shall be organized in such a way as to lend itself to comparison to still images and/or video data.
- End users should be able to load and query statistical data using Oracle.

VIII. Preferred Features

- Automated species ID, automated measurement, and automated weight estimate.
    - Software should be able to incorporate additional species for automated processing.
    - Able to handle automated ID of multiple fish at a time (i.e. not single file fish fed down a chute), multiple fish orientations, weather conditions, light conditions, etc.
- Remote transmission of EM data within 24 hours of vessel landing.
- Software must be easily modified to incorporate regional preferences.
- The system should be portable between platforms (fishing vessels) where peripherals (cameras, sensors) are static and core components (computer, software, discard chute) are transferred.
- The system should have electronic reporting capabilities and the option to link with eVTR software.

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.

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New England Electronic Monitoring Project
2010 Annual Report

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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.

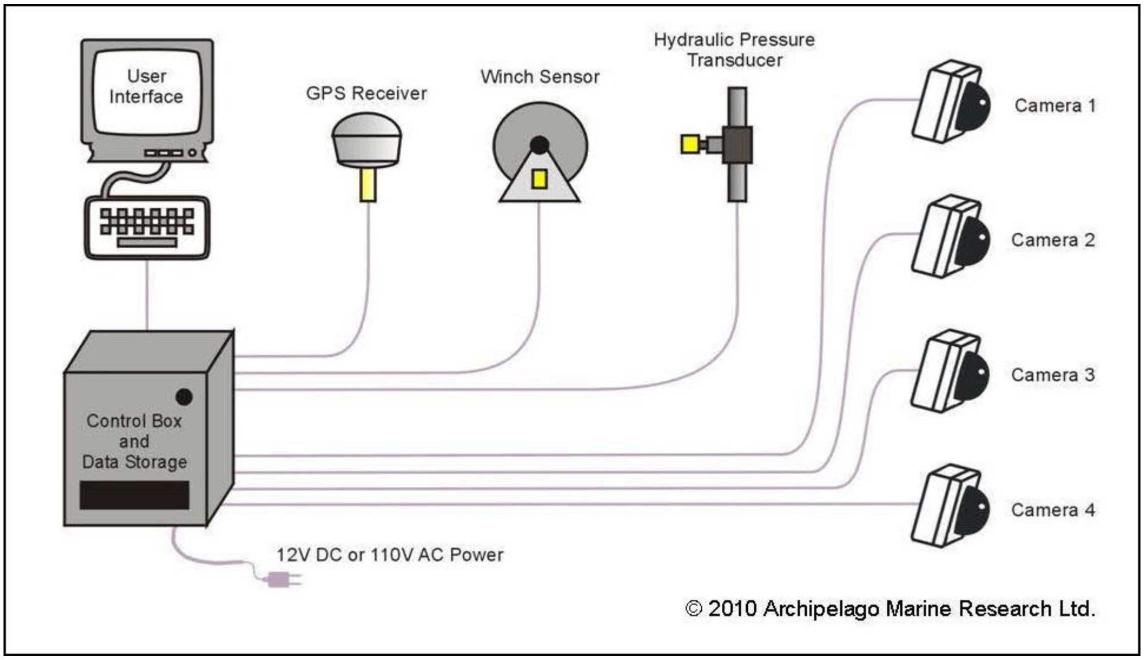

Figure 1. Schematic diagram of the electronic monitoring system, which can record video data from up to four cameras per vessel.

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.

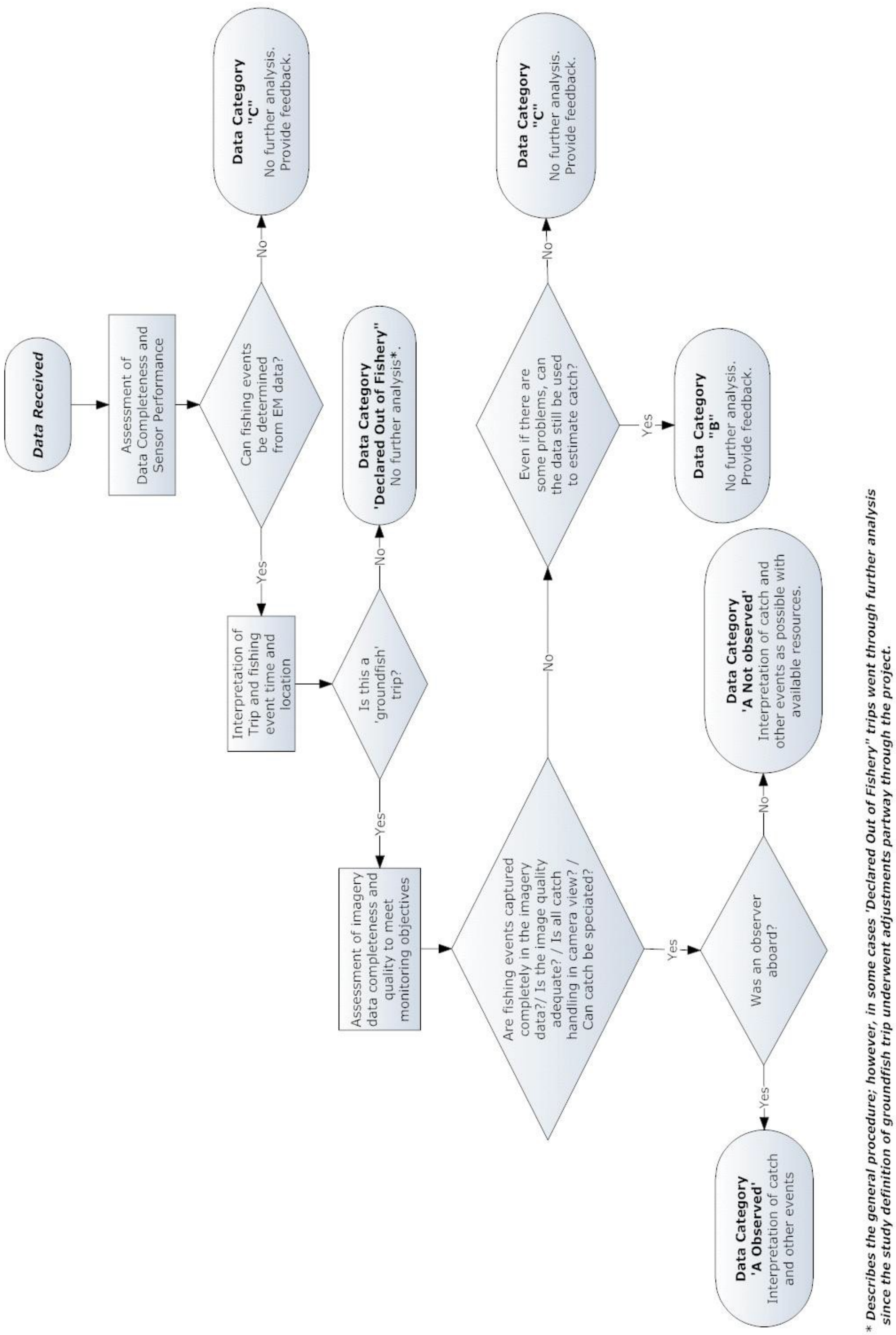

Figure 3. Conceptual model of EM data quality assessment and interpretation protocol.

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.

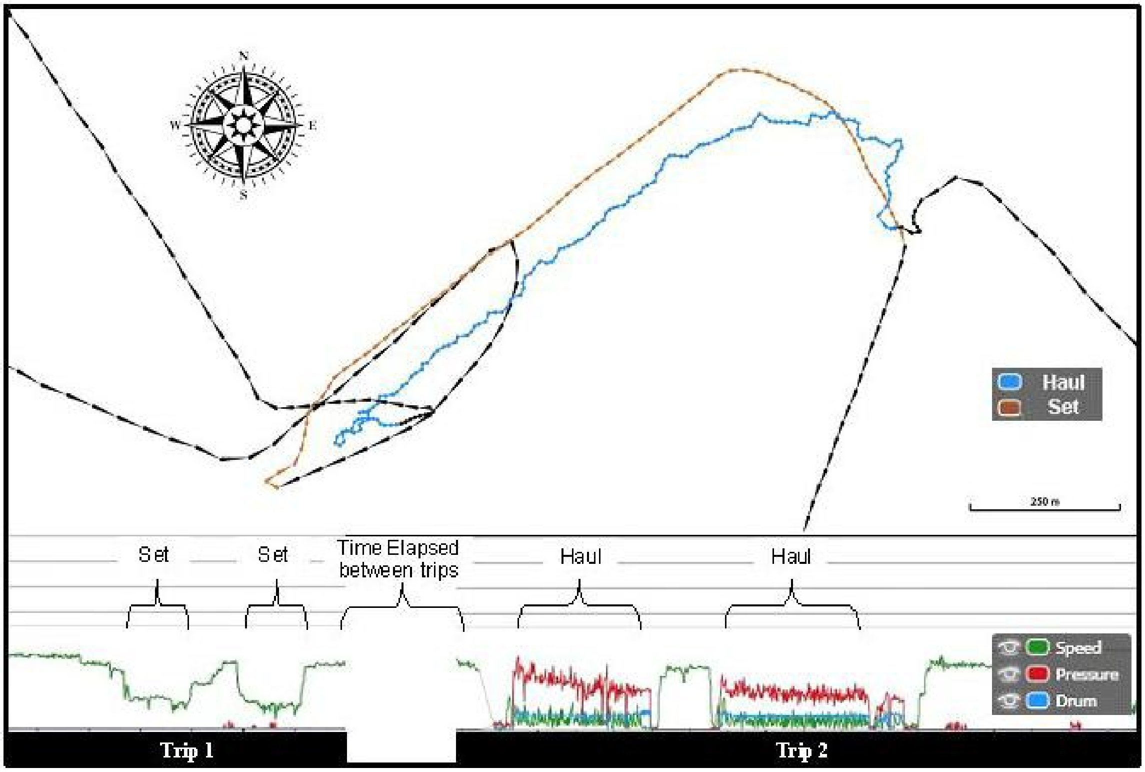

Figure 4. Example of gillnet sensor data from one of the project vessels for a trip, also representative of longline. The time series graph (lower) shows vessel speed, hydraulic pressure and winch rotations for two different trips. In longline and gillnet vessels gear was set on one trip and hauled the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

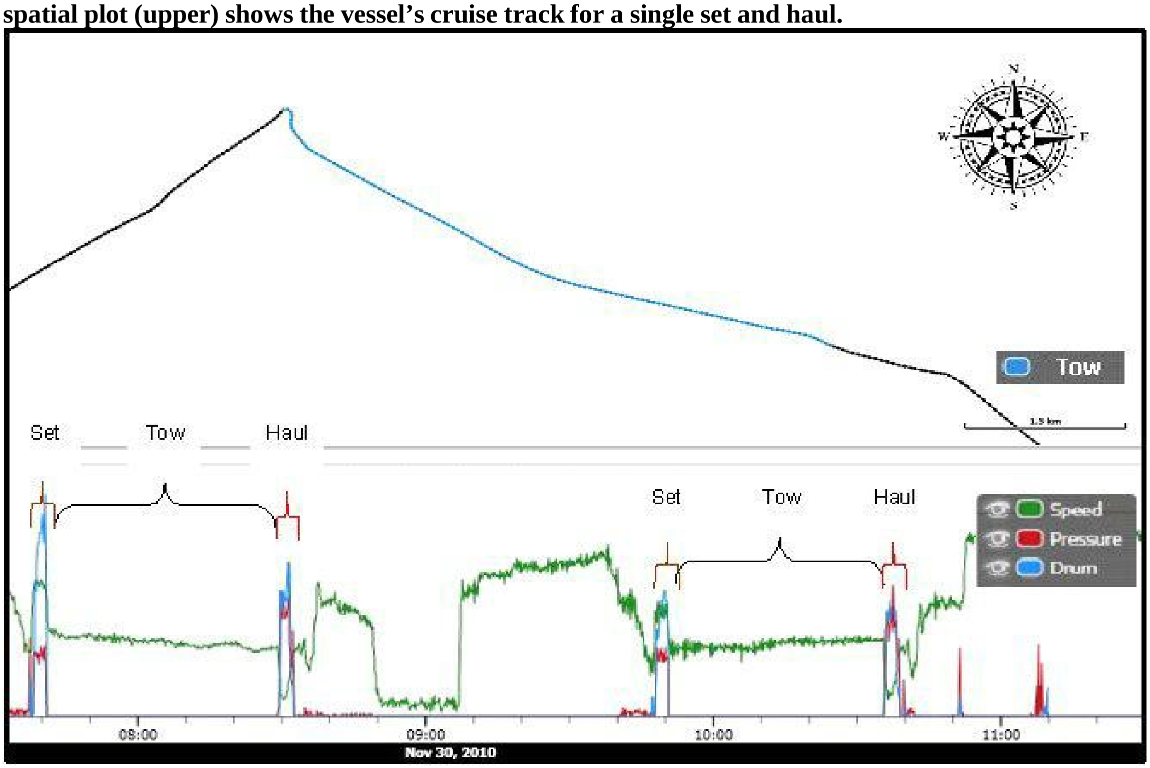

Figure 5. Example of trawl sensor data from one of the project vessels. The time series graph (lower) show vessel speed, hydraulic pressure and winch rotations. The spatial plot (upper) shows a single tow in blue.

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 totaled 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 totaled 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 totaled 146.

Species Name	Occurrence Comparison by Haul			Catch Percentage Within Matches		EM	Observer
	Match	*EM Only*	*Observer Only*	*EM Pieces*	*Observer Weight*	Pieces	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.

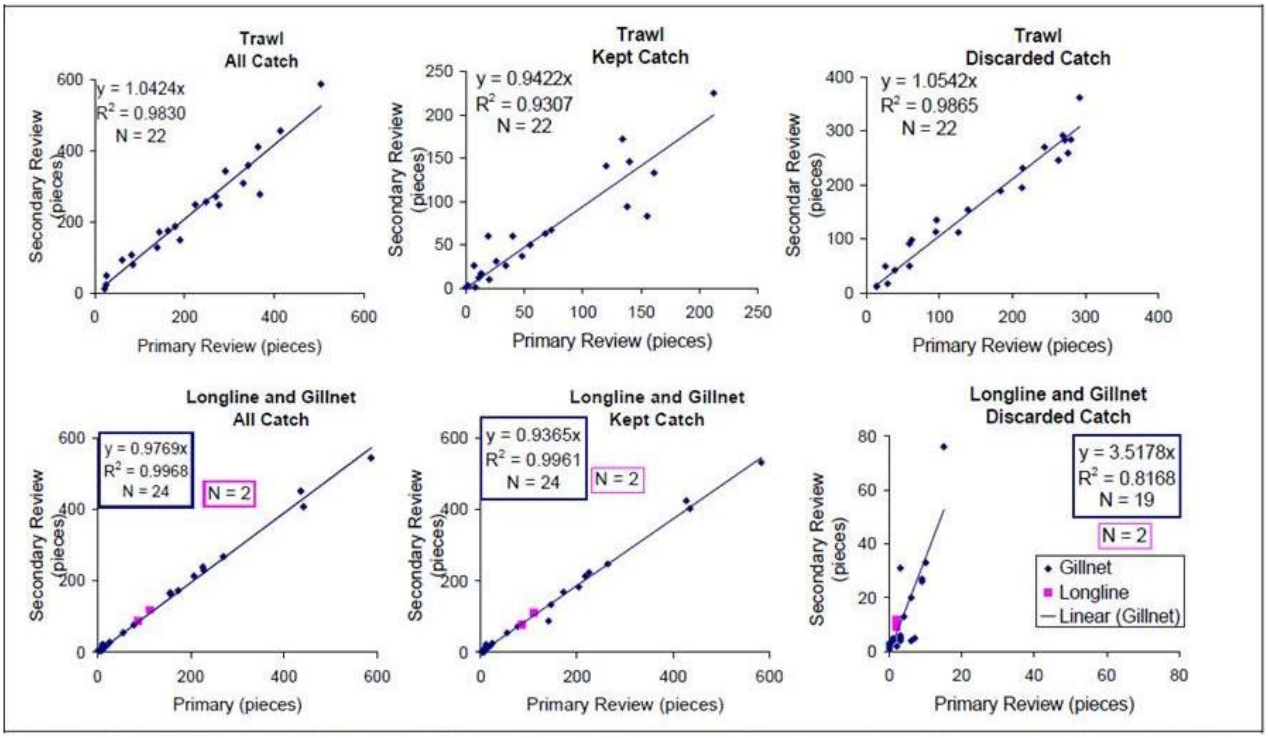

Figure 7. Scatter plots of total groundfish species catch counts of primary vs. secondary review data for trawl, gillnet and longline hauls. Best fit linear data for gillnet is shown inside blue boxes while longline sample size is shown inside pink boxes.

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.

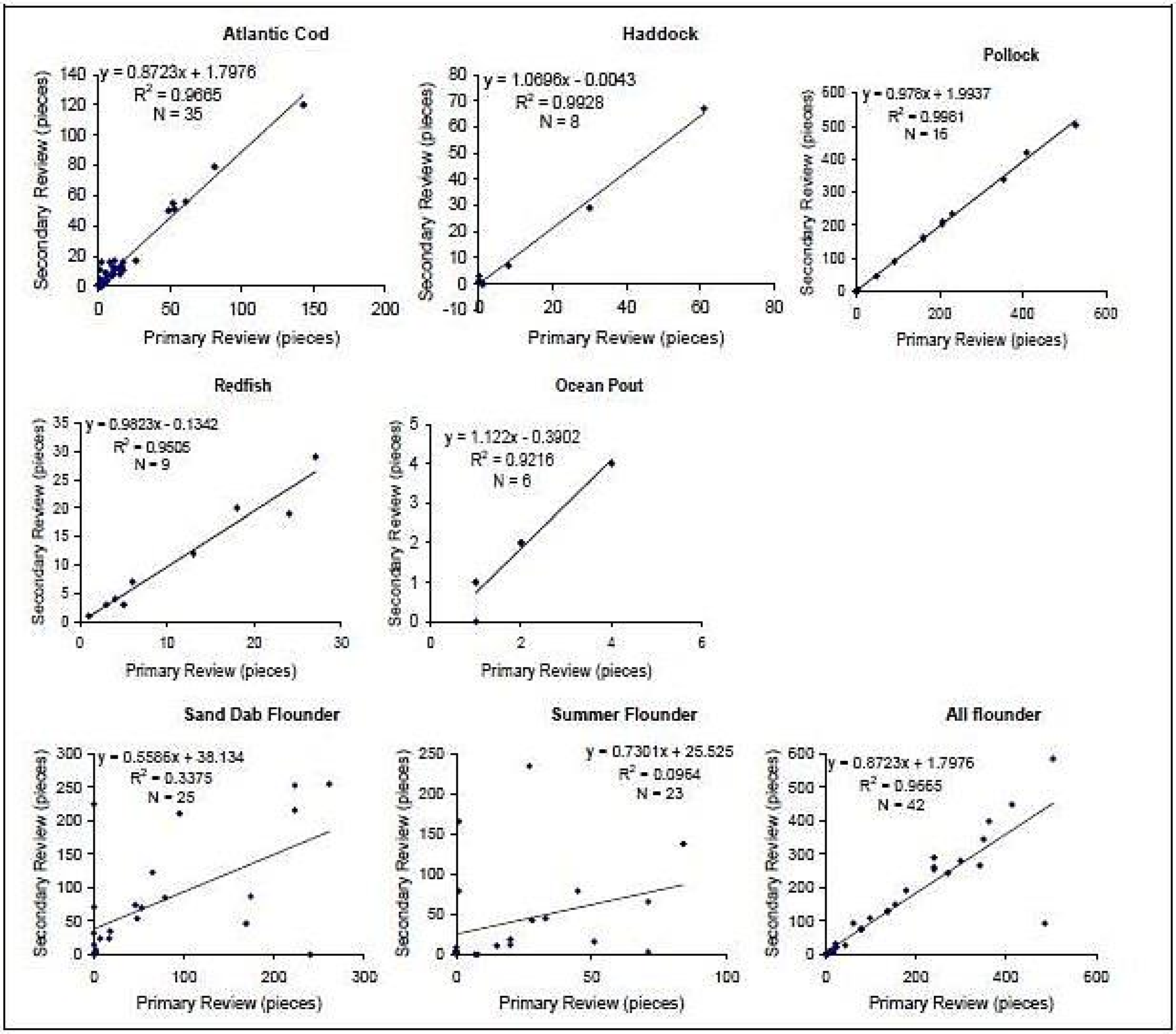

Figure 8. Scatter plots and linear regression of primary vs. secondary total pieces counts for Atlantic Cod, Haddock, Pollock, Redfish, nk, Ocean Pout, Sand Dab Flounder, Summer Flounder, and all flounder.

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 identified 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.

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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	38	34%
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**	

ESTIMATING WEIGHT AND IDENTIFYING SPECIES THROUGH ELECTRONIC MONITORING (EM):

A PRELIMINARY COMPARISON OF ELECTRONIC AND OBSERVER- BASED REPORTING

Interim Technical Review
Option Period I
Contract EA133F-10-SE-0949

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ABSTRACT

Exploratory experiments were carried out between November 2011 and May 2012 as part of the New England electronic monitoring (EM) pilot project to provide preliminary data on: 1) whether estimating weight using length-weight conversions and/or volumetric estimates should be pursued further and 2) whether EM data can be used to identify discarded fish species in the Northeast (NE) groundfish fishery.

Observers and EM systems were simultaneously in place and the experimental methods were intended to allow for comparisons of observer and EM reviewer data at the individual fish and basket level. EM data was analyzed by two independent reviewers, Reviewer A and Reviewer B.

Results from the length- weight experiments found no significant difference between weights calculated from observer lengths and actual weights collected by the observer (bootstrap mean difference of -0.3491 lbs and upper bound of 95% CI 0.2247 lbs). Bootstrapped mean differences between observer and reviewer calculated weights revealed a statistically significant difference between the measurements and, on average, flounder species were underestimated by 3.67% (Reviewer A) and 8.02% (Reviewer B). Atlantic cod was, on average, underestimated by 8.78% (Reviewer A) and overestimated by 12.20% (Reviewer B).

Volume experiment results showed that reviewers overestimated the weight of flounders compared to actual weights on average by 1.778 lbs (Reviewer A) and 0.872 lbs (Reviewer B) per basket using small baskets and by 4.850 lbs (Reviewer A) and 6.32 lbs (Reviewer B) per basket using bushel baskets. Gadids were overestimated on average by 1.79 lbs (Reviewer A) and 2.40 lbs (Reviewer B) by basket. Reviewers overestimated mainly due to very low volumes being rounded up to ¼ basket full estimates.

Species identification experiment results showed that Reviewer A and B had similar results for sand dab flounder, Atlantic cod and ocean pout, where reviewers matched observer identification in >90% of entries. American plaice flounder had 63% and 66% matched identification for Reviewer A and B respectively. American plaice flounder was difficult to identify whenever its mouth was not clearly visible. Yellowtail flounder and winter flounder had high matching success for Reviewer A (97% and 91% respectively) but Reviewer B had difficulties detecting the identifying characteristics on these species (66% and 19% matching success respectively). Expansion of the exploratory experiments is needed to include additional species and increase the sample sizes for others as well as to incorporate methodology changes to increase the identification success for American plaice and achieve greater consistency in identifying winter, and yellowtail flounder among reviewers.

The data collected during these exploratory experiments was sparse and the results presented in this report are preliminary. However, the preliminary results show that the use of length-weight relationships should be pursued further as it is a promising method for estimating discarded weight of some regulated species and that the EM video can be used by reviewers to consistently identify a variety of species, including some, but not all, flounders. Volumetric methods may not be well suited for accurate weight estimation

in applications with low catch volumes since reviewers overestimated weight mainly due to very low volumes being rounded up to ¼ basket full estimates. Overall the results are positive, especially considering that there was limited opportunity to improve the methodologies since the experiments spanned only 14 trips, and we do not see any obvious obstacles to working on resolving the outstanding issues identified through further work. This work should include expanding the experiments in order to collect data on more species, improve species identification and weight estimation as well as develop operational methodologies.

1. INTRODUCTION

In April 2010, the Fisheries Sampling Branch (FSB) of the Northeast Fisheries Science Center (NEFSC) of the National Oceanic and Atmospheric Administration (NOAA) contracted with Archipelago Marine Research Ltd. (Archipelago) on a multi-year project to test the applicability of electronic monitoring (EM) technology for collecting catch and effort data aboard vessels, and evaluating the utility of EM in monitoring catch in the Northeast multispecies fishery (also referred to as the NE groundfish fishery).

The first year of the project focused on building local capacity to support current and future EM efforts in the region and gathering an initial comparative data set with observer and EM data (Pria *et al.*, 2011). For this initial data set, observer and EM data were collected independently and used different methods which introduced too many external factors to be able to understand how species identification and weight estimation using EM data may differ from observer identification and weight collection.

To begin answering the question of how these weight estimation methodologies and species identification may compare between observers and EM reviewers, we carried out exploratory experiments that used observer data to ground truth the estimated weights and species identification gathered from EM. Given that weight cannot be determined directly from EM visual data, we chose to explore two methods for estimating weight from video data: using fish length and applying length-weight relationships, and using volumetric estimates and applying density factors.

The exploratory experiments had two independently tested objectives:

- To provide preliminary data to decide whether estimating weight using length-weight conversions and/or volumetric estimates should be pursued further, and
- To provide preliminary data on whether EM data can be used to consistently identify discarded fish species in the NE groundfish fishery.

The exploratory experiments were carried out on a commercial fishing operation so that the experiments would be based on real catch composition and at-sea environmental conditions. However the exploratory experiment design was as independent of vessel layout or gear type as possible and was based on a semi-controlled environment with the intention to maximize the alignment between the two data sources and limit external factors influencing the comparisons. The design was not intended to adhere to operational observer or EM on-board methodologies.

This report presents the work done during the exploratory experiments with the intention of identifying which methodologies are worth pursuing further. In addition, the report identifies some of the key methodology elements that would be required when developing operational applications.

2. MATERIALS AND METHODS

Vessel Selection

Vessels used for these exploratory experiments were selected from those participating in the New England EM pilot study. Vessels were selected based on the following criteria:

- Good track record for providing high quality EM data (complete EM data collection for the entire fishing trip with EM system powered from port to port).
- Actively targeting and discarding regulated species.
- Vessel captain agreeable to carrying observers and modifying catch-handling practices for the purpose of the experiments.

Data used in this report were from two day-trawlers, herein referred to as Vessel A and Vessel B.

Data Collection Timeframe

Exploratory experiment data collection took place between November 2011 and May 2012 (Table 1).

Table 1 Data collection periods by experiment for each of the two vessels

	Length	Volume	Species Identification
Vessel A	Nov 2011- Feb 2012	Nov 2011 – Mar 2012	Mar 2012
Vessel B	n/a	May 2012	May 2012

Due to the nature of the data collected for length and species identification experiments (catch had to be sorted by species for length experiment and randomly sorted for species identification experiment), length and species identification data could not be collected on the same haul. Volume data were collected on all experimental hauls. Observers concentrated on collecting length and volume data for the first part of the experimental data collection period and species identification and volume data for the second part.

The data collection period finished at the end of May.

Species Involved in the Experiment

The experiment concentrated on working with discarded regulated species. These species are prohibited or regulated through trip limit and ACE.

The species regulated through trip limit was Atlantic halibut (*Hippoglossus hippoglossus*) while those prohibited were Atlantic wolffish (*Anarhichas lupus*), ocean pout (*Zoarces americanus*) and sand dab flounder (*Scophthalmus aquosus*). ACE regulated species were:

- Atlantic cod (*Gadus morhua*)
- Haddock (*Melanogrammus aeglefinus*)
- Pollock (*Pollachius virens*)
- Redfish (*Sebastes* spp)
- White hake (*Urophycis tenuis*)

- American plaice flounder (*Hippoglossoides platessoides*)
- Winter flounder (*Pseudopleuronectes americanus*)
- Witch flounder (*Glyptocephalus cynoglossus*)
- Yellowtail flounder (*Limanda ferruginea*)

Overview of Experimental Design

Experimental design was based on collecting and reviewing EM data and comparing them to data collected by an observer. For this comparison to be meaningful, EM and observer data had to be collected in a manner that maximized alignment.

FSB project staff were on board each experimental trip to collect the data for the exploratory experiments. For the purposes of this report FSB staff on board experimental trips will be referred to as "observers." Observers collected standard at-sea monitor (ASM) program data as well as data specifically for comparison with EM reviewer data. Only experiment-specific data were used for comparison to EM reviewer data.

In all experimental hauls the observer and crew put aside all regulated species that were to be discarded. The observer then sorted this catch by species into baskets and took a weight of each basket, either using a Marel scale or a spring scale. Spring scales were used during hauls in which the motion-compensated scale could not be calibrated properly. The observer then collected data depending on the experiment being carried out (described in sections 2.1, 2.2 and 2.3).

Two independent reviewers examined all fishing events: one Archipelago reviewer (Reviewer A) and two FSB staff (grouped as Reviewer B). All reviewers were trained in NE groundfish identification and EM video review. No catch information from the observer data set was available to the reviewers ahead of video review.

The exploratory experiments assumed observer data and actual weights from observers to be accurate (i.e. no observer measurement error was calculated or considered in the data analysis). However, it is possible that errors within observer data introduced differences between the data sets.

EM System Description

The EM systems used to gather data consisted of a control centre, a user interface (monitor and keyboard), a suite of sensors (including GPS receiver, hydraulic pressure transducer, and a drum rotation sensor), and up to four waterproof armored-dome closed circuit television (CCTV) cameras (Figure 1).

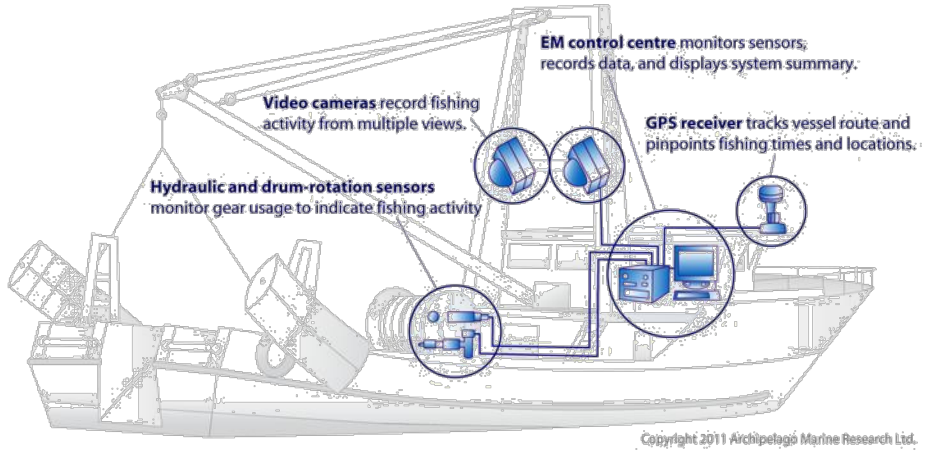

Figure 1 Schematic of the electronic monitoring system used in the experiments

EM Data Collection

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 left port to engage in fishing, to the vessel's return to port). Video recording started once the winch rotated or hydraulic pressure exceeded a threshold level after the vessel left port, and video recording ended when the vessel returned to port.

Camera Configuration

Two cameras were used for recording video data on each vessel (Table 2). One camera was set up to provide an orthogonal, close-up view of the discard area and the other provided a wide-angle view of the deck (Figure 2 and Figure 3). On Vessel A the wide-angle view was initially used for estimating basket fullness (for the first five hauls) but it was determined that a close-up view of the baskets was more appropriate. The wide-angle view was changed at the end of January to capture the observer working area and was used by the reviewer to be alerted when fish entered the close-up camera field of view, which made it easier to align the two data sets at the individual fish-level.

Table 2 Camera installation specifications. Distances are from the camera dome to the center of view. Distance for Vessel A wide-angle view camera corresponds to observer working area view

Vessel	Camera	Lens Size (mm)	Distance (m)	Location
Vessel A				
	Close-up	12.0	2.13	Wheelhouse overhang, starboard side.
	Wide-angle	8.0	3.81	Wheelhouse gantry starboard mast.
Vessel B				
	Close-up	12.0	1.93	Wheelhouse gantry lower crossbar.
	Wide-angle	6.0	3.96	Wheelhouse gantry 'A' frame port side.

Figure 2 Camera views from Vessel A: The top two examples display the initial wide-angle camera view for basket fullness estimation (top left), and the modified wide -angle view for context (top right). The bottom two examples are the close- up view of the discard area used for basket fullness estimation (bottom left) and length and species identification (bottom right)

Figure 3 Camera views from Vessel B: Wide-angle view (left) and close-up view (right)

On Vessel A, the close-up camera view of the discard chute was used for taking length measurements during the length experiments and for identifying catch during species identification experiments. It was also used for estimating basket fullness in ten out of fifteen hauls where volume experiments were carried out. The wide-angle view was used for estimating basket fullness in five out of fifteen hauls.

Similarly, the close-up camera view was used for basket fullness estimation on Vessel B and the wide angle view was used to alert the reviewer to baskets being placed on the close-up field of view.

2.1. Length experiment

All fish in the experiment were presorted by species (to avoid introducing error due to species identification). The fish moved one by one through the close-up view of the discard area, which for the vessel used was a half PVC pipe discard chute, and the discard chute and camera were fixed at a constant distance.

Length measurements were taken according to the NEFSC bottom trawl survey methods (center-line fork lengths for species with forked tails and center-line total lengths for species with round or square tails). The only exception was Atlantic halibut for which NEFSC bottom trawl survey collects forked length, but observers in this experiment collected total length.

Observers measured each fish to the nearest centimetre and placed the fish at the end of the conveyer belt for it to slide onto the discard chute. Fish length measurements were recorded in the same order that the fish were shown on the discard chute to facilitate alignment between the two data sets.

Reviewers determined fish length by measuring the fish in millimeters on the computer screen with a ruler. The screen measurements were then scaled using a multiplier calculated from the reference provided by the graduation marks on the discard chute. The multiplier was calculated by measuring the distance between the marks at the furthest left of the screen, the furthest right of the screen and at the center of the screen and averaging those three measurements. The marks were measured at the middle of the chute.

(Equation 1) Reviewer Length = screen length * multiplier

Graduation marks were adjusted throughout the course of the length experiment data collection period (Figure 4). At the beginning of the data collection period, observers were requested to mark the surface of the chute with regular markings five centimeters apart and on the same plane as that on which the fish were going to be when measured by the reviewers. Observers tried to fulfill this requirement for the first five trips but were unable to due to complications trying to mark the chute while the vessel was at sea. The faint and irregular markings from these trips were used to calculate the scale multiplier but may have affected the reviewer length accuracy for those trips. For the final trip, the captain of the vessel was then requested to mark the chute in a dry location on land, which provided regular 5cm markings.

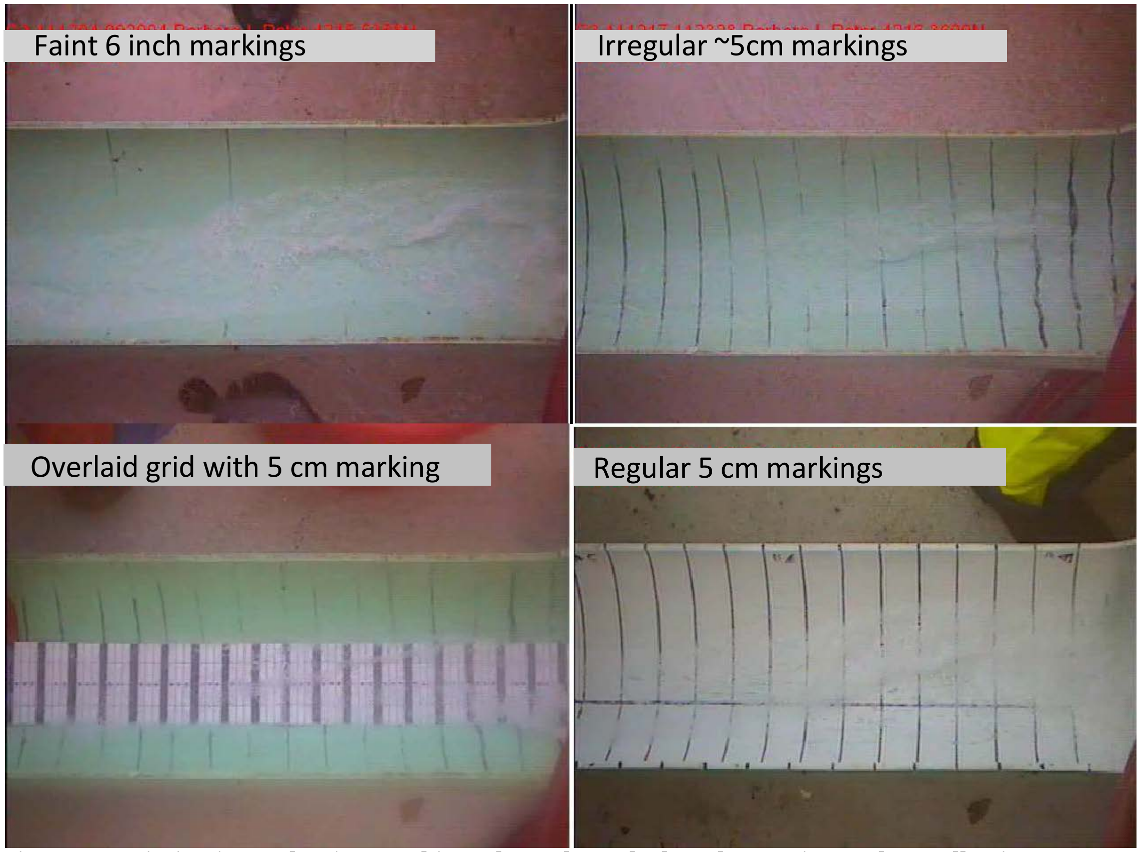

Figure 4 Variation in graduation markings throughout the length experiment data collection

In some instances, reviewers had difficulties measuring the fish length for reasons described below (Figure 5):

- Part of the fish was outside camera view in the images available (referred to as partial image)
- Low image quality caused edge of the fish to be difficult to discern
- Fish curled reducing the two dimensional length on the screen
- Part of the fish covered by the discard chute (chute interference)
- Part of the fish covered by the observer (observer interference)

Figure 5 Examples of reasons for identifying a measurement as "compromised" (measuring difficulties)

Observer and reviewer lengths were converted to weights using NEFSC length-weight relationships (Wigley *et al.*, 2003). Length-weight relationships were based on combined sex and on survey data which included winter data for all species, except Atlantic halibut (autumn) and redfish spp (spring/autumn). Fish identified to a species group (i.e. hake, nk or "not known") were not included in the weight comparisons since it was not possible to know which hake species length-weight relationship to apply.

The difference between observer and reviewer lengths and between observer and reviewer weights calculated from length-weight relationships was tested. Furthermore, the validity of the length- weight relationships was investigated by testing whether there was a difference between the observer actual weights and the sum of observer weights calculated from length-weight relationships. Finally, observer actual weights were compared to the total estimated reviewer weight to provide insight into whether this methodology can be applied in an operational setting.

2.2. Volume experiment

All fish were sorted by species into baskets of known volume and all baskets were shown in camera view.

Two types of baskets were used for all but the last exploratory experiment trip: bushel baskets and fish totes. While carrying out these experiments it was apparent that the overall volume of regulated species discards was very low and most of the baskets were not being filled. A third basket type, about half the size of a bushel basket, was sourced at the end of the data collection period and was only used on the last exploratory experiment trip. A description of the baskets and their volumes is provided in Table 3.

Observers and reviewers estimated the fullness of the baskets visually to the nearest ¼ based on how much the fish covered the side of the baskets. Because the bushel baskets had a conical shape and the fish totes had a trapezoidal shape, the volume that corresponded to each height estimate by the reviewer or observer was calculated using geometry.

For all three different types of baskets used, those filled with a small amount of fish were considered to be ¼ full rather than rounded down to 0 and baskets with a fullness height between ¼ and ⅓ were rounded down to ¼, which resulted in the average amount of fish for the "¼ basket estimate" to be 0.1875 rather than 0.25. For this reason the corresponding volume proportion for the "¼ basket estimate" was based on an estimated fullness height of 0.19 for all baskets.

Table 3 Description of the shape and size of the baskets used as well as the corresponding volume for each fullness level estimated by reviewers and observers

Basket Description	Estimated Fullness by Height	Corresponding Volume Proportion	Volume (ft^3)
NEFOP standard conical bushel basket			
	Full	1	1.49
	¾	0.71	1.05
	½	0.44	0.66
	¼	0.15	0.22
NEFOP standard trapezoidal fish tote			
	Full	1	2.69
	¾	0.74	2.00
	½	0.49	1.32
	¼	0.18	0.48
Rectangular small basket			
	Full	1	0.61
	¾	0.75	0.46
	½	0.5	0.31
	¼	0.19	0.12

Reviewer estimated volumes were converted to weights using approximate density factors using Equation 2. It was not possible to obtain independent density or average basket weights for regulated species. Actual weights from full baskets collected in the experiment were used to estimate an approximate density factor. Atlantic cod, haddock and pollock were grouped under "gadids" and were assumed to have the same density for the purpose of these exploratory experiments. Similarly, all flounders were assumed to have the same density. The rest of the species and species groups, including Atlantic halibut, were assumed to have significantly different densities to gadids and flounders and were not included in the volume experiment analysis because there were no full baskets to calculate their approximate density factors.

Equation 2 Weight = Density factor * Volume

The difference between observer and reviewer basket fullness estimates was tested as well as the difference between reviewer estimated weights and the observer actual weights.

2.3. Species identification experiment

The observer mixed all the fish and then randomly took each fish from the basket, recorded the species and placed the fish at the end of the conveyer belt for it to slide onto the discard chute. Fish identification was recorded in the same order as the fish appeared on the discard chute to facilitate alignment between the two data sets. All fish in the experiment moved through the discard chute one by one.

Following NEFOP species identification guidelines, reviewers identified the fish to the lowest taxonomical level possible by using a minimum of two identifying characteristics and were free to use any characteristic they considered appropriate for that species. All reviewers used observer training resources to confirm identification characteristics including (Chase and Galbraith, 2004) as well as their previous experience. In addition Reviewer A used a variety of published resources (Gilbert and Williams, 1993; Douglas *et al*., 1999; Froese and Pauly, 2012). In cases where defining characteristics were not visible, the reviewers recorded the fish under the lowest species group for which identifying characteristics were discernible. Reviewers were asked to write down the characteristics used to identify the catch.

Observer catch entries were paired with each of the reviewer's catch entries to compare identification between the two at the individual catch entry level.

2.4. Data Source Pairing

Since the main goal of the exploratory experiments was to compare reviewer to observer at the catch-item or basket level, it was important to appropriately pair the two data sets. Analysis of individual fish or basket data required a data pairing process since the observer and reviewer data sets sometimes did not match up item-to-item. These mismatches were caused when either the reviewer or the observers did not record a fish or basket that was seen by the other data source. Any records that could not be reconciled between the two data sets were excluded from the analysis.

3. RESULTS

3.1. Length Experiment

3.1.1. Data Inventory

Fish length data were collected throughout seven trips comprised of fifteen hauls in total and included eleven regulated species and one species group (hake, not known). There were 74 actual weights collected by observers throughout the length experiment.

Observers collected 1,462 fish lengths and each reviewer collected 1,463. Individual observations were paired between the observer and reviewer data sets, and pairs where measurements were compromised were excluded from the final sample used in comparisons between observer and reviewer data for calculated weight and fish lengths (this process is summarized in Table 4.).

The pairing of observer to each of the reviewer data sets resulted in a total 1,443 length matching pairs between observer and Reviewer A, and 1,444 length matching pairs between observer and Reviewer B (shown under "Total" in Table 4; the "No Measuring Difficulties" column includes the data pairs for which the reviewers did not highlight any problem measuring the fish length).

Finally, the final sample excluded 166 of Reviewer B fish lengths of species with forks (Atlantic cod, haddock and Atlantic halibut) which were measured as total lengths instead of fork lengths. In addition, the total sample also excluded outliers caused by data entry errors (three from the Reviewer A data set and two from the Reviewer B data set). Comparisons between observer and reviewer fish lengths and calculated weights were based on this final sample of matching pairs which excluded all measurements that had measuring difficulties and those where the reviewer recorded the incorrect length type (total length instead of fork length).

Measurements with no difficulties highlighted comprised 75% and 80% of records for Reviewer A and Reviewer B length measurements respectively. In both reviewer data sets the majority of measuring difficulties were due to only part of the fish being captured on the video as it traveled down the discard chute (Table 5). Reviewer A marked more lengths as difficult to measure compared to Reviewer B, and most of the differences between the two were under the "low image quality" category. "Curled fish" was the second most common measuring difficulty for Reviewer B and the third for Reviewer A but did not represent a large proportion of the total measurements (5% and 4% for Reviewer A and Reviewer B respectively).

Table 4 Length data pairs available for comparison by species or species group

Species	Original Observer Sample	Observer- Reviewer A Matching Pairs			Observer- Reviewer B Matching Pairs		
		Total	No Measuring Difficulties	Final Sample	Total	No Measuring Difficulties	Final Sample
Yellowtail flounder	588	587	459	459	587	510	510
Sand dab flounder	366	361	288	288	362	326	326
Atlantic cod	352	352	223	221	352	210	47
American plaice flounder	72	65	61	61	65	62	62
Winter flounder	58	57	51	51	57	53	53
Ocean pout	11	11	4	4	11	4	4
Haddock	9	4	4	4	4	4	1
Atlantic halibut	2	2	2	2	2	2	1
Hake, not known	1	1	1	1	1	1	1
Witch flounder	1	1	1	1	1	1	1
White hake	1	1	1	0	1	1	0
Redfish	1	1	0	0	1	0	0
Total	**1462**	**1443**	**1095**	**1092**	**1444**	**1174**	**1006**
Total as percentage of original observer sample		**99%**	**75%**	**75%**	**99%**	**80%**	**69%**

Table 5 Number of observations removed from the reviewer data sets due to compromised measurements, out of a total of 1443 and 1444 matching pairs for the Reviewer A and Reviewer B data sets respectively

Measuring Difficulty	Reviewer A		Reviewer B	
	Number of Observations	Percent of Total Pairs	Number of Observations	Percent of Total Pairs
Partial image	183	13%	200	14%
Low image quality	77	5%	4	0%
Curled fish	71	5%	56	4%
Chute interference	9	1%	0	0%
Observer interference	8	1%	10	1%
Total	**348**	**25%**	**270**	**19%**

3.1.2. Comparisons

Haul-Level Comparisons of Observer Calculated Weights and Actual Weights
Actual haul weights taken by the observers were compared with the sum of the calculated weights from observer length measurements to test the applicability of the length- weight relationships for estimating discarded weight. Both a histogram of the differences and a scatter plot show the haul weights by species were similar between the two methods (Figure 6).

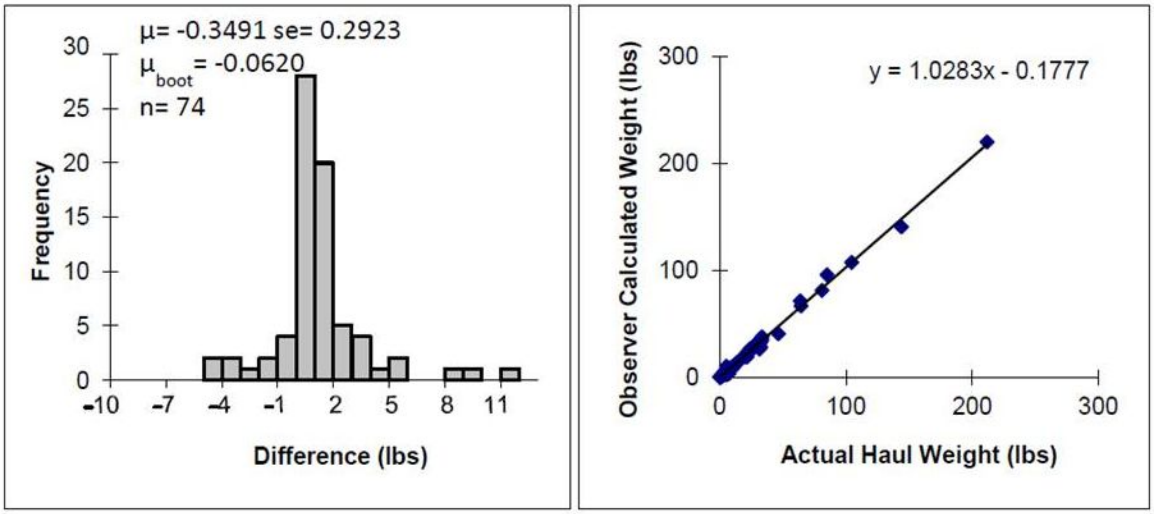

Figure 6 Comparisons of observer-calculated weights and actual weights: the histogram (left) depicts the difference between the observer- calculated weights by species by haul and the actual weights, and the scatter plot (right) illustrates the actual weights and observer calculated weights.

The data were not normally distributed (Shapiro-Wilk p-value<0.01) and could not be transformed using typical functions such as log transform, inverse or cube root. A non-parametric bootstrapping technique and corresponding 95% normal confidence interval could be used in hypothesis testing (Crowley, 1992). In this report it was used for testing for a difference from zero for the means.

There was no evidence of a significant difference on average between observer-calculated weights and the actual deck weights; the bootstrapped haul weight mean difference was -0.3491 lbs with an approximate 95% confidence interval that included zero (-0.9265 lbs, 0.2247 lbs).

Individual Fish Comparisons of Observer and Reviewer Calculated Weights Having established that the length-weight relationships were an appropriate way of estimating discarded weight by confirming that there was no significant difference between observer calculated and actual weights, comparisons were made between the individual fish weights calculated using length-weight relationships from the observer length data set and each of the reviewer length data sets. Hake, not known was not used for these analyses since a length-weight relationship could not be applied to a species group.

Initial inspection of the data revealed that they were closely correlated (Reviewer A adjusted R squared 0.939; Reviewer B adjusted R squared 0.949) with slopes close to one (Reviewer A slope 0.884; Reviewer B slope 1.135) (Figure 7). Furthermore the distributions of fish weight differences were centered around zero (Figure 7).

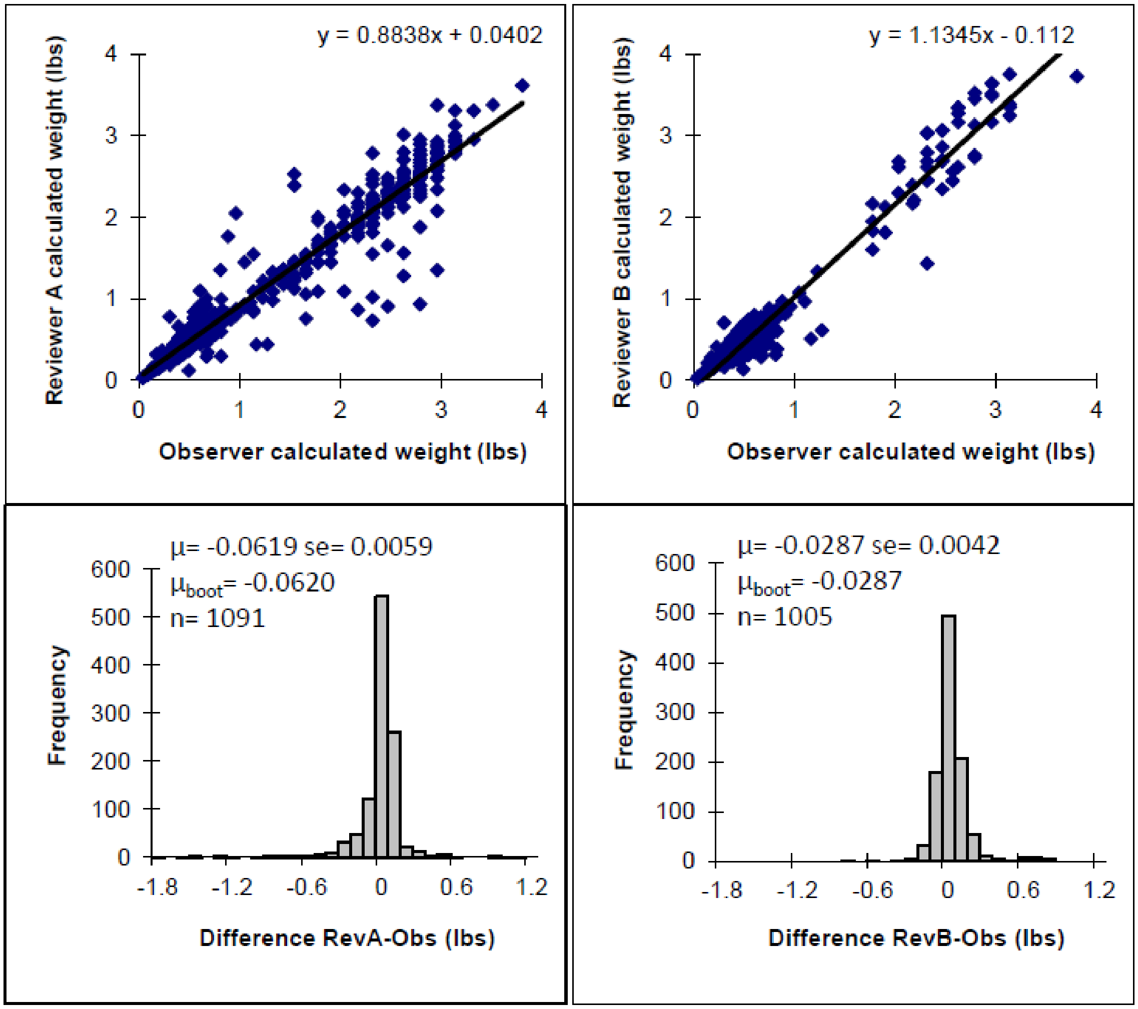

Figure 7 Comparisons of observer and reviewer calculated weights for each reviewer data set (Reviewer A data comparisons displayed on the left and Reviewer B comparisons on the right): The scatter plots (top) show observer and reviewer-calculated fish weights. The histograms (bottom) show the difference between the observer and reviewer-calculated weights.

The differences between reviewer and observer calculated weights were not normally distributed (Shapiro-Wilk p-value<0.01) and could not be transformed. A difference from zero for the means between weights was tested for using the same non-parametric bootstrapping technique as with the haul-level comparisons of observer calculated weight and actual weights. Bootstrapped confidence intervals for Reviewer A and B did not include zero, which provided significant evidence at an alpha level of 0.05 that Reviewers A and B are underestimating fish weight on average (upper bound of confidence intervals were -0.0505 lbs and -0.0203 lbs for Reviewer A and B respectively) (Table 6).

Using only species for which there were more than five records, the results from Kruskal-Wallis one way analysis of variance were significant (Reviewer A H=240.631 and Reviewer B H=94.797, 4 d.f., P<0.001) meaning that the median difference between observer and reviewer calculated weights were different among the five species for both reviewer data sets. This effect was further confirmed using a linear regression model (complete test results included as Appendix I) where there was a major difference between the line of best fit for Atlantic Cod compared to the rest of the species in both Reviewer A and Reviewer B data sets. Furthermore there was no evidence of a major difference among flounder species in both the Reviewer A and Reviewer B data sets suggesting that for all flounder species the measurement bias was approximately the same and these species may be grouped when calculating weight differences between observer and reviewers.

Based on these results, a bootstrapping technique was used to estimate the mean weight difference per fish between observer and reviewer-calculated weights of Atlantic cod and of flounders, which included yellowtail flounder, American plaice flounder, sand dab flounder and winter flounder. Both reviewers underestimated flounder weight as compared to observer calculated weight; Reviewer A by 0.021 lbs, or 3.66% and Reviewer B by 0.045 lbs, or 8.02% per flounder (Table 6).

Atlantic cod was underestimated on average by 0.2172 lbs per fish (or 8.78%) by Reviewer A while it was overestimated by 0.3051 lb per fish (or 12.20%) by Reviewer B.

Table 6 Weight differences per fish calculated from observer and reviewer data sets bootstrapped means and confidence intervals

Species Type	Reviewer A			Reviewer B		
	Mean	Lower 95%	Upper 95%	Mean	Lower 95%	Upper 95%
Overall - lbs	-0.0620	-0.0736	-0.0505	-0.0287	-0.0371	-0.0203
Atlantic cod - lbs	-0.2172	-0.2636	-0.1708	0.3051	0.2130	0.3973
Atlantic cod - %	-8.782	-11.370	-6.193	12.200	8.425	15.980
flounders - lbs	-0.0214	-0.0270	-0.0159	-0.0454	-0.0511	-0.0397
flounders - %	-3.658	-4.656	-2.661	-8.022	-9.044	-7.001

A second Kruskal-Wallis one way analysis of variance, which used fishing trip as the factor to be tested, detected a statistical significant difference between observer and reviewer calculated weight among fishing trips for both Reviewer A and Reviewer B data sets (Reviewer A H=392.299 and Reviewer B H=608.335, 6 d.f., P<0.001).

Individual Fish Comparisons of Observer Lengths and Reviewer Lengths

Comparisons between observer fish lengths and reviewer fish lengths had very similar results as those for the comparisons of calculated weights. Initial inspection of the data revealed that they were closely correlated (Reviewer A adjusted R squared 0.950; Reviewer B adjusted R squared 0.927) with slopes close to one (Reviewer A slope 0.931; Reviewer B slope 1.055) (Figure 8). Furthermore the distributions of fish length differences were centered around zero (Figure 8).

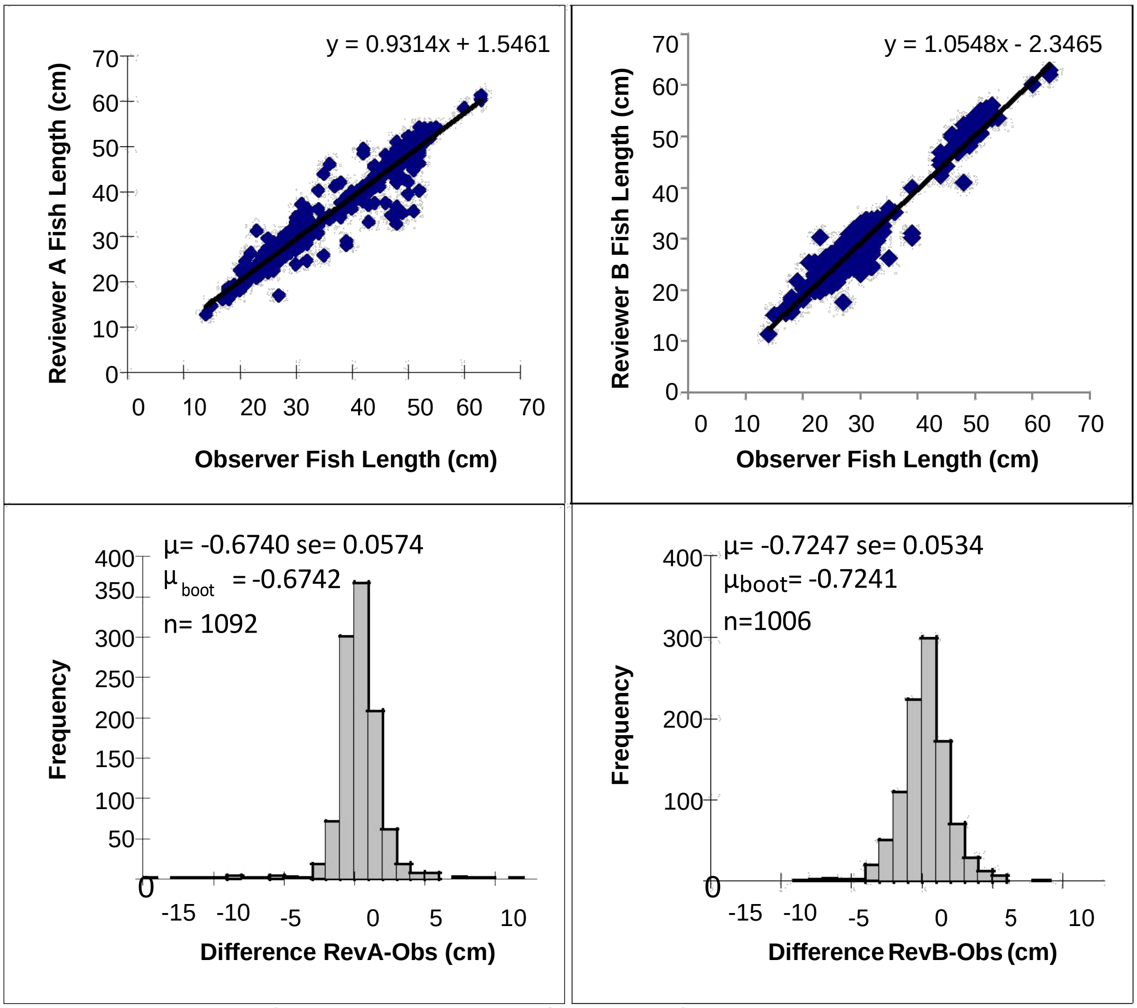

Figure 8 Comparisons of observer and reviewer fish lengths for each reviewer data set (Reviewer A data comparisons shown on the left, and Reviewer B comparisons on the right): The scatter plots (top) show observer and reviewer fish lengths. The histograms (bottom) show the difference between the observer and reviewer fish lengths

The differences between reviewer and observer fish lengths were not normally distributed (Shapiro-Wilks p- value<0.01) and could not be transformed. There was evidence at alpha level 0.05 that the observer and reviewer lengths were statistically significantly different (upper bound of confidence intervals were -0.5620 cm and -0.6183 cm for Reviewer A and B respectively) (Table 7).

Table 7 Difference from measured lengths by observers and reviewers bootstrapped means and confidence intervals

Reviewer	Mean (cm)	Lower 95% (cm)	Upper 95% (cm)
Reviewer A	-0.6742	-0.7865	-0.5620
Reviewer B	-0.7241	-0.8299	-0.6183

Individual Fish Comparisons of Reviewer A and Reviewer B Lengths
Data from the two independent reviews were different. The bootstrapped mean difference between the two independent reviews was -1.3896 cm with a 95% confidence interval of (-1.5234 cm, -1.2561cm).

3.2. Volume Experiment

3.2.1. Approximate Density Factor Calculation

Atlantic cod had 11 baskets estimated as full by reviewers while sand dab flounder and yellowtail flounder each had two. The actual weights of these baskets were used to calculate an estimated basket weight for gadids and flounders and, using the known volume of the baskets, calculate an approximate density for gadids and flounder species groups (Table 8). Since none of these baskets were filled completely, the volume was estimated based on 95% fullness. There were no full baskets for any of the other species and species groups to calculate density and these species were not included in any volume experiment weight comparisons.

Table 8 Approximate basket density for gadids and flounders calculated from average actual weights of full baskets estimates

Species Type	Full Baskets	Mean Basket Weight (lb)	Basket Volume (ft^3)	Approximate Density (lb/ft^3)
Gadids	11	74.92	1.399002	53.55
Flounders	4	79.8	1.399002	57.04

3.2.2. Data Inventory

Volumetric estimate data using bushel baskets were collected throughout 14 trips and 38 hauls and included 11 regulated species, and one species group (hake, not known).

Observers collected 188 volumetric estimates and basket weights using bushel baskets. Reviewer A collected 187 and Reviewer B collected 188 volumetric estimates on bushel baskets. Individual bushel basket observations were paired between the observer and reviewer data sets resulting in a total 183 volumetric estimate pairs between observer and Reviewer A and 185 volumetric estimate pairs between observer and Reviewer B (shown under total matching pairs in Table 9).

Volumetric estimates using fish totes were collected on one trip throughout two hauls for two regulated species. The observer and Reviewer A collected two volumetric estimates and Reviewer B collected one, which resulted in two volumetric estimate pairs between observer and Reviewer A and one volumetric estimate pairs between observer and Reviewer B (shown under total matching pairs in Table 9).

Volumetric estimate data using small rectangular baskets were collected throughout one trip and six hauls and included four regulated species, including redfish. The observer collected 14 volumetric estimates and basket weights. Reviewers also collected 14 volume estimates. Individual basket observations were paired between the observer and reviewer data sets resulting in a total of 14 volumetric estimate pairs between observer and each reviewer (shown under total matching pairs in Table 9).

Weight comparisons were only conducted on gadids and flounder volume estimates excluding full baskets because these were used to approximate a volume estimate.

Table 9 Volume estimates data pairs available for comparison by basket type and species or species group

Basket Type	Species / Species Groups	Fish Type	Observer- Reviewer A Matching Pairs		Observer- Reviewer B Matching Pairs	
			Total	Weight Comparison	Total	Weight Comparison
Bushel Basket						
	Atlantic cod	gadids	37	26	38	27
	Haddock	gadids	3	3	3	3
	Sand dab flounder	flounders	33	31	33	30
	Yellowtail flounder	flounders	31	29	32	29
	Winter flounder	flounders	31	31	31	31
	American plaice flounder	flounders	25	25	25	25
	Witch flounder	flounders	3	3	3	3
	Ocean pout	other	15	n/a	15	n/a
	Hake, not known	other	2	n/a	2	n/a
	White hake	other	1	n/a	1	n/a
	Atlantic halibut	other	1	n/a	1	n/a
	Redfish	other	1	n/a	1	n/a
	Total for bushel basket		**183**	**148**	**185**	**148**
Fish Tote						
	Atlantic cod	gadids	1	n/a	1	n/a
	Atlantic halibut	other	1	n/a	0	n/a
	Total for fish tote		**2**	**n/a**	**1**	**n/a**
Small Basket						
	Witch flounder	flounders	6	6	6	6
	American plaice flounder	flounders	6	6	6	6
	Redfish	other	1	n/a	1	n/a
	Atlantic halibut	other	1	n/a	1	n/a
	Total for small basket		**14**	**12**	**14**	**12**

Discard volumes by species throughout the experiment were very low, resulting in ~78% of baskets being estimated as ¼ full by observer and reviewers (Figure 9). It was not possible to quantify how many entries were rounded up with the data collected but by using data collected for the other experiments the median number of fish in each basket estimated as ¼ full was four, which indicated that over half of the ¼ full baskets were rounded up.

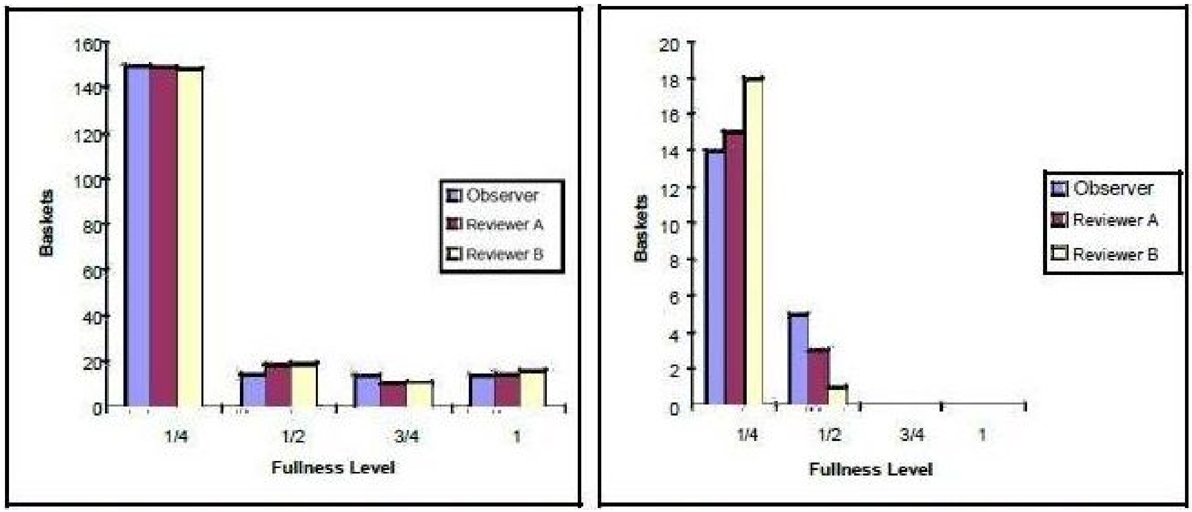

Figure 9 Number of baskets by fullness level from observer and reviewer data sets for Vessel A (left) and Vessel B (right)

3.2.3. Comparisons

Basket Fullness Comparison of Observer and Reviewers Estimates

Bushel baskets fullness estimates between observer and reviewers were identical for 93% and 91% of paired volumes for Reviewer A and Reviewer B respectively (Table 10). Small basket volumes were identical for 71% of paired volume estimates for both reviewers.

Table 10 Frequency of differences between observer and reviewer volume estimates by basket type for each reviewer

	Reviewer A		Reviewer B	
Reviewer - Observer Fullness Difference	**Bushel Basket**	**Small Basket**	**Bushel Basket**	**Small Basket**
-0.25	4%	21%	3%	29%
0	92%	71%	90%	71%
0.25	3%	8%	5%	
0.5			1%	
0.75	1%		1%	
Total	**183**	**14**	**185**	**14**

Basket Weight Comparison of Actual Weights and Reviewer-Estimated Weights

Both reviewers on average overestimated weight as compared to actual weights for gadids and flounders in both vessels (Figure 10). Both reviewers overestimated weight compared to actual weights for gadids and flounders in both container types. Mean weight differences were greatest for flounders using bushel baskets (5.469 lbs per basket for Reviewer A and 6.323 lbs per basket for Reviewer B). The mean difference was much smaller when the small rectangular baskets were used (1.778 lbs per basket for Reviewer A and 0.872 lbs difference per basket for Reviewer B).

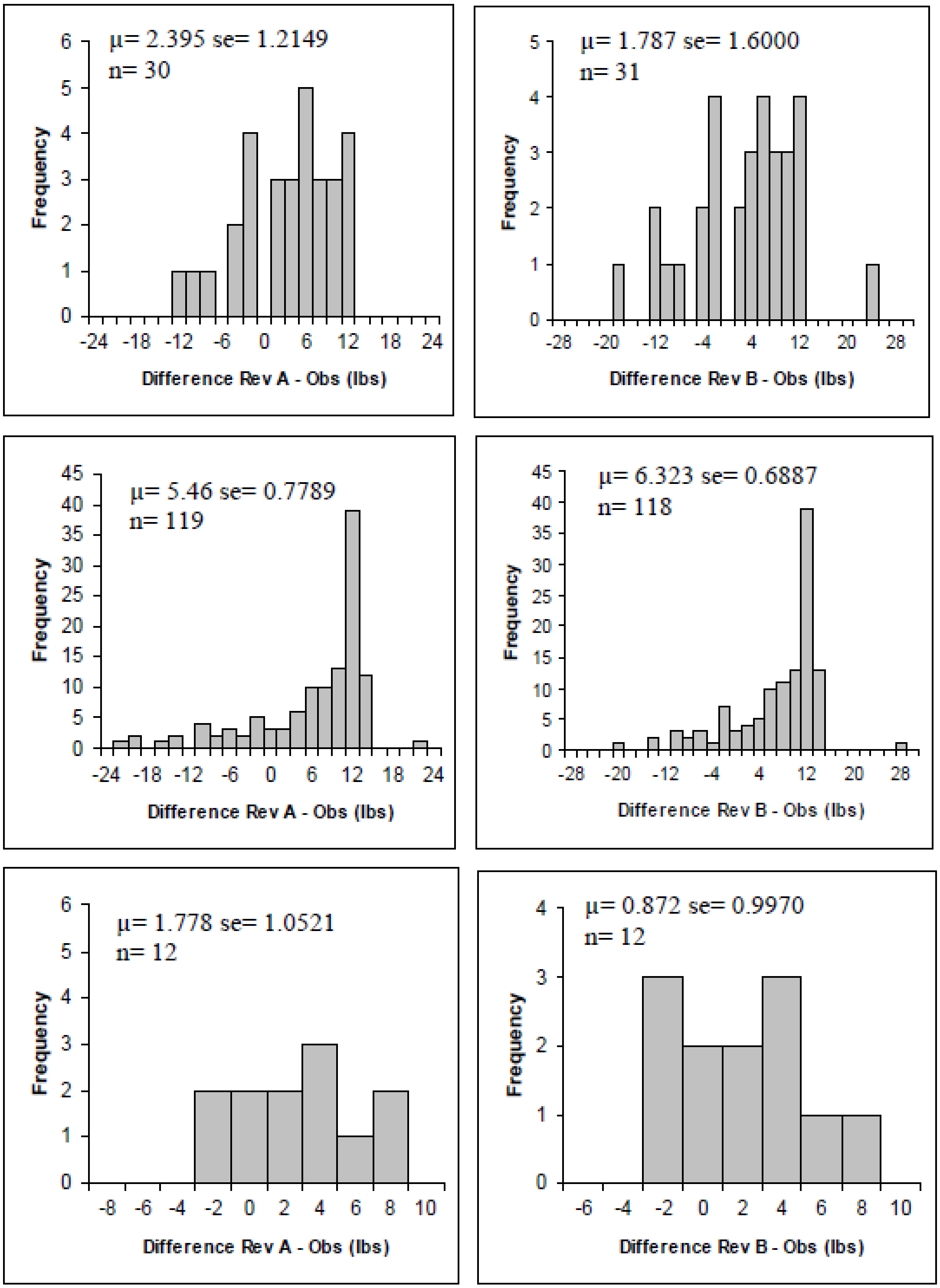

Figure 10 Histograms of the difference between Reviewer A (left) and Reviewer B (right) estimated weight and actual weights (lbs). Bushel baskets gadids (top), bushel baskets flounders (center), small baskets flounders (bottom)

Basket Fullness Comparison of Reviewer A and Reviewer B Estimates

Comparison results of basket fullness estimation between reviewers show a very similar distribution as observer and reviewer comparisons with most paired estimates being identical for both reviewers: 95% of the bushel basket paired entries and 86% of the small basket paired entries (Table 11).

Table 11 Frequency of differences between reviewers basket fullness estimates by vessel.

Reviewer A – Reviewer B Fullness Difference	Bushel Basket	Small Basket
-0.75	1%	
-0.25	3%	
0	95%	86%
0.25	1%	14%
0.5		
0.75		
Total	**185**	**14**

3.3. Species Identification Experiment

3.3.1. Data Inventory

Species identification data were collected on Vessel A throughout six trips consisting of 19 hauls in total. Observers identified 2,973 fishes, Reviewer A identified 2,993 and Reviewer B identified 2,976 (Table 12). Reviewer A had approximately 20 entries more than the observer and Reviewer B because Reviewer A recorded data for a group of sand dab flounder that were accidentally discarded en masse by the observer, while the observer and Reviewer B did not collect data for these.

Observer data included seven regulated species, three non-regulated species and one species group, Hake, not known, which encompassed *Urophycis* , *Merluccius* and *Physiculus* sp (including red, white and silver hake) (Table 12). Reviewer data included the same species and species groups as the observer, except Reviewer B data did not include four spot flounder. In addition, both reviewer data sets included three additional species groupings, which were flounder, not known for catch identified to the flounder level, groundfish, not known for catch identified no further than as a regulated groundfish species, and fish, not known for catch that could not be identified to any taxonomic level higher than a fish. These additional species groups accounted for 2.4% of Reviewer A and 16.7% of Reviewer B catch entries.

Table 12 Data entries from observer, Reviewer A and Reviewer B by species or species group (regulated species or groups that include only regulated species are marked with an asterisk)

Species/ Species Group	Observer Entries	Reviewer A Entries	Reviewer B Entries
Yellowtail flounder *	1264	1242	871
Sand dab flounder *	1161	1179	1150
Atlantic cod *	280	277	274
Winter flounder *	113	103	25
American plaice flounder *	95	61	100
Ocean pout *	34	34	35
Hake, silver	11	17	17
Hake, not known *	11	4	2
Witch flounder *	2	2	3
Four spot flounder	1	1	0
Monkfish	1	1	1
Flounder, not known	0	64	488
Fish, not known	0	7	9
Groundfish, not known *	0	1	1
Total	**2973**	**2993**	**2976**

The pairing of observer to each of the reviewer data sets resulted in a total 2,918 species matching pairs between observer and Reviewer A and 2,917 species matching pairs between observer and Reviewer B.

3.3.2. Comparisons

Individual Fish Identification by Observer and Reviewers

Catch pairs between observer and reviewer catch entries were compared for identification matches. Observer and Reviewer A comparisons for sand dab flounder and Atlantic cod had identical identification in 100% and 99% of observer entries respectively while yellowtail flounder and ocean pout were matched for 97% and winter flounder for 91% of observer entries. American plaice flounder was only matched for 63% of the observer entries (Table 13). Table 14 shows that 23 of the 29 non-matching American plaice flounder entries between observer and Reviewer A data were entered as flounder, not known, indicating that they could not be identified as a specific flounder species. Anecdotal information from the reviewer suggests that in many of these cases the reviewer was able to narrow identification down to American plaice flounder or yellowtail flounder but further identification was not possible because the mouth was not clearly visible, nor was the yellowtail flounder distinctive yellow colored ventral caudal peduncle area. A complete list of identification features used by reviewers, and the frequency with which they were used, are included as Appendix II.

Reviewer B comparisons to observer identification for Atlantic cod , sand dab flounder and ocean pout had a high proportion of matches with 99%, 98% and 94% observer entries matched respectively, which were within one and three percent points of the Reviewer A comparison results for these species. American plaice flounder comparisons for Reviewer B data also had similar results as Reviewer A with 66% of observer entries matched. Furthermore, Table 15 shows a similar distribution of un-matched American plaice observer entries with 18 out of 26 non-matched observer entries identified as flounder, not known by Reviewer B.

Reviewer B to observer identification comparisons had had very different results to Reviewer A to observer comparisons. While Reviewer A identification of yellowtail flounder and winter flounder matched 97% and 91% of observer entries for each species respectively, Reviewer B matched 66% of yellowtail flounder and 19% of winter flounder observer entries. Table 15 shows that 62 out of 88 (or 70%) of the non-matched winter flounder and 382 out of 423 (or 90%) of the non-matched yellowtail flounder were entered as flounder, not known.

Results from hake, not known, witch flounder, silver hake, and four spot flounder comparisons are inconclusive because these species had less than a dozen entries compared; however, the data suggested that reviewers had difficulties identifying hake, not known which is consistent with anecdotal information provided by reviewers that the specimens identified as fish, not known were likely to be very small hake, not known (~10 cm) for which identifying characteristics were not discernible (Figure 11).

Table 13 Number of paired observer entries by species/species group with the corresponding number of reviewer identification matched entries (Percentages of paired observer entries matched by reviewer are shown for species/species groups with over 30 entries)

Species / Species Group	Reviewer A			Reviewer B		
	Paired Observer Entries	Reviewer ID Matches	%	Paired Observer Entries	Reviewer ID Matches	%
Yellowtail flounder	1253	1220	97%	1255	832	66%
Sand dab flounder	1150	1147	100%	1151	1124	98%
Atlantic cod	277	274	99%	275	272	99%
Winter flounder	110	100	91%	109	21	19%
American plaice flounder	78	49	63%	76	50	66%
Ocean pout	34	33	97%	34	32	94%
Hake, not known	10	4		11	2	
Witch flounder	2	2		2	2	
Silver Hake	3	2		3	3	
Four Spot flounder	1	1		1	0	
Total	**2918**	**2832**	**97%**	**2917**	**2338**	**80%**

Table 14 Catch identification matrix between observer and Reviewer A matched pairs

Observer \ Reviewer A	Atlantic cod	American plaice flounder	Four Spot flounder	Sand dab flounder	Winter flounder	Witch flounder	Yellowtail flounder	Hake, not known	Silver Hake	Ocean pout	Fish, not known	Flounder, not known	Groundfish, not known	Total
Atlantic cod	274						1			1			1	277
American plaice flounder		49					6					23		78
Four Spot flounder			1											1
Sand dab flounder				1147			2					1		1150
Winter flounder					100		3					7		110
Witch flounder						2								2
Yellowtail flounder		1		6			1220					26		1253
Hake, not known								4			6			10
Silver Hake									2		1			3
Ocean pout	1									33				34
Total	275	50	1	1153	100	2	1232	4	2	34	7	57	1	2918

Table 15 Catch identification matrix between observer and Reviewer B matched pairs

Observer \ Reviewer B	Atlantic cod	American plaice flounder	Sand dab flounder	Winter flounder	Witch flounder	Yellowtail flounder	Hake, not known	Silver Hake	Ocean pout	Fish, not known	Flounder, not known	Groundfish, not known	**Total**
Atlantic cod	272					1					1	1	275
American plaice flounder		50	1	1		6					18		76
Four Spot flounder					1								1
Sand dab flounder		1	1124			5					21		1151
Winter flounder		4	5	21		17					62		109
Witch flounder					2								2
Yellowtail flounder		32	7			832			2		382		1255
Hake, not known							2		1	8			11
Silver Hake								3					3
Ocean pout			2						32				34
Total	272	87	1139	22	3	861	2	3	35	8	484	1	2917

Species identification difficulties were not annotated into the data record by the reviewers in a standardized manner that would allow a quantitative analysis. However reviewer comments and post-review interviews revealed that the main factor that prevented discerning identifying characteristics in catch was the effect caused by the water pushing the fish down the discard chute. Sometimes the water flow would make the fish seem blurry or be strong enough to cause foam to form on the discard chute and cover parts of the fish. Flounders and smaller round fish were affected the most by this. For some flounders, species identification was not possible if the size and shape of the mouth was not visible to the reviewer. Reviewers also commented that increasing the resolution of the images would facilitate species identification.

Figure 11 Example images of fish where water flow obscured identifying characteristics (left) and where water flow did not have a detrimental effect on identification (right)

4. DISCUSSION

The results show that the methodology of using length-weight relationships to estimate the weight of regulated groundfish species using EM data deserves further investigation. Although the weights were statistically different, the differences were on average within 4% to 8% for flounders and within 8% to 12% Atlantic cod. Furthermore, there was evidence that using observer fish lengths and length-weight relationships to calculate weight is comparable to actual weights taken by observers, since there was no statistical difference between observer calculated weights and actual weights.

The preliminary estimates of the difference between observer weights and reviewer weights using length-weight relationships for flounders and Atlantic cod may be used to understand the potential impact of these differences in the context of estimating discard weights for a NE groundfish vessel. Throughout the experimental trips, Vessel A discarded approximately 49 pieces of Atlantic cod per trip which would represent a weight difference of -10 lbs to +15 lbs on average per trip (using Reviewer A and Reviewer B mean weight differences respectively). Assuming that the vessel does 80 trips in a fishing season, discarded weight from reviewer length measurement data would roughly represent a difference of -800 lbs to 1,200 lbs compared to observer actual weights. Vessel A discarded approximately 285 flounders per trip which would represent a weight difference of -6 lbs or -13 lbs on average per trip and could translate to underestimating discarded catch by about 480 lbs to 1,040 lbs compared to observer actual weights over 80 trips in a fishing season.

It is worth noting that not all measurements were incorporated in the analysis. The estimated weight differences using length-weight relationships were based on instances where the reviewers were successful at obtaining a full length measurement of the fish. This would be an issue for calculating the total weight using reviewer lengths as the weight from these fish could be grossly underestimated. In an operational program these instances would have to be eliminated or their impact mitigated by, for example, applying sampling techniques using the complete length measurement data.

Instances when reviewers could not measure the full length of the fish were mostly due to partial images, which affected approximately 14% of the reviewer measurements. This issue could be minimized through a combination of changes to increase the success of having the entire length of the fish in the camera view. These changes could include: increasing the amount of frames per second recorded in the EM video, changing the catch handling process (such as slowing down the flow of the fish or holding the fish in camera view instead of sliding it) or modifying camera set-up to cover a larger area (in effect increasing the time the fish would be in camera view).

There were two main types of variation in the differences between reviewer and observer calculated weights using length-weight relationships: among reviewers and among fishing trips. Differences between reviewer estimates were particularly evident in Atlantic cod estimates, which were underestimated by Reviewer A and overestimated by

Reviewer B. It was not possible to identify the source of the difference although it was likely caused by differences in reviewer technique.

It is likely that differences between fishing trips were at least partially caused by inconsistency in the quality of the graduation marks, which varied over the course of the experiments. Furthermore, poor quality graduation marks could have been a factor affecting reviewer to observer comparisons.

Catch volume per species per haul was too low throughout the experiment to be able to apply a volumetric technique successfully. The mean weight differences using bushel baskets were relatively low (within two pounds for gadids and within six pounds for flounders) per basket (and hence per haul); however, the distribution of the differences had a wide spread and was not centered on the mean. For example, approximately one third of reviewer flounder weight estimates using bushel baskets overestimated the basket weight by 12 pounds. This was mostly due to over half of the basket fullness estimates being rounded up to ¼ full when they had four or less fish in them.

Using the small baskets reduced the weight difference between reviewer-estimated weight and actual weights (mean and spread) compared to the larger bushel baskets, even though with the smaller baskets there was greater disagreement estimating volume between ¼ and ½ fullness between observer and reviewers as well as amongst reviewers.

The exploratory experiment results for one of the reviewers established that it is possible for a reviewer to successfully identify discarded yellowtail flounder, Atlantic cod, sand dab flounder, winter flounder and ocean pout from EM data up to 91% to 100% of the time, based on the Reviewer A data set. However, there were differences between reviewers identification success. While Reviewer A was successful at identifying yellowtail flounder 97% and winter flounder 91% of the time, Reviewer B's success rate was 66% and 19% respectively. Furthermore, Reviewer A used the general species grouping flounder, not known for 2% of catch entries compared to 16% for Reviewer B; suggesting differences in success finding identifying characteristics on the video data. The differences in identification success rate between reviewers could be due to a combination of differences in experience identifying catch on video between reviewers and the characteristics selected by each reviewer. Fish identification through video often requires recognizing characteristics differently than an observer handling the fish would.

Consistent identification of American plaice flounder was difficult for both reviewers (63% and 66% matching identification for Reviewer A and Reviewer B respectively). A large mouth is one of the main identifying characteristics for distinguishing American plaice from yellowtail flounder. Reviewer A reported that the main issue preventing consistent identification of American plaice was that the video data did not clearly show the fish mouth due to foam in the water flow obscuring the fish mouth. This issue could be resolved by reducing the amount of water flowing when a discard chute is used, or modifying catch handling or equipment set-up to ensure that the fish mouth is visible in the video.

The data source pairing process was aimed at minimizing misalignment between the data sets. However, some comparison results may have been affected by errors innate in the comparison method itself rather than in measurement error or misidentification. In many cases, in particular for length data within a specific species or for species identification between similar species, these errors cannot be detected and hence quantified. In cases that include species identification matching pairs of species that are clearly different the alignment errors become more apparent. For example, the Atlantic cod to ocean pout comparisons between both reviewers and observer (likely recorded in different order) or hake, not known to ocean pout comparisons between Reviewer B and observer (likely the reviewer entering the wrong species name by mistake).

5. CONCLUSIONS

The objective of this work was to provide an initial assessment on whether these methodologies should be pursued further. The data collected during these exploratory experiments was sparse and the results presented in this report are preliminary. Additional data collection is needed in order to improve species identification and weight estimation, test the methodologies on a greater number of species and develop operational methods. Nevertheless, the preliminary results show that the use of length-weight relationships is a promising method for estimating discarded weight of regulated species and that the EM video can be used to consistently recognize indentifying characteristics on several species while others require more work. A volumetric methodology using bushel baskets is not appropriate for accurate weight estimation in applications where low volumes need to be estimated and more work is needed for evaluating whether weight estimates using smaller baskets may be adequate for estimating low catch volumes. Overall the results are positive, especially considering that there was limited opportunity to improve the methodologies since the experiments spanned only 14 trips, and we do not see any obvious obstacles to working on resolving the outstanding issues identified through further work.

Further work on evaluating these methodologies should involve two aspects: expanding the experiments and developing operational methods. Expanding the experiments is needed in order to compare observer and reviewer data for additional species and to improve the experimental design based on the results from the exploratory experiments. In particular, future work should target trips where hake species are expected given that this species group was highlighted as difficult to identify in the New England EM pilot 2010 report (Pria *et al.*, 2011) and the exploratory experiments included less than a dozen records.

Collecting the data required to ground truth these methodologies against observer data during fishing trips is difficult because it is dependent on the schedule and type of fishing the participating vessels are pursuing during experimental data collection. It may take a long time to collect the amount of data necessary for rigorous analysis. Alternatively, these methodologies may be tested in a laboratory environment with sample fish.

The second aspect that requires further work would be to use the lessons learned from the exploratory experiments in order to develop an operational methodology, which would have an on-board component (including equipment configuration as well as catch handling) and data analysis components. This aspect would need to take into account specific requirements for each gear type in the fishery (longline, gillnet and trawl).

An operational on-board methodology would continue to require a set-up where fish are presented to a close-up orthogonal camera view one-by-one for identification and measurement to allow the reviewer to measure and identify the discards. However, the specifics of the experimental observer on-board methodology would need to be adjusted so that captains and crew could carry it out within the operational reality of the vessel.

The reviewer methodology would also need to be adjusted towards maximizing operational efficiencies instead of the experiment's focus on collecting data in a way that allowed alignment to the observer data set on an individual fish or basket level. Other aspects of developing operational methods include training of reviewers and standardizing vessel set-ups to reduce variation in EM estimates.

These two aspects, the expansion of comparisons between observer and reviewer data and the development of operational methodologies, could not occur on the same vessel at the same time. The experiment expansion could take place initially or both aspects could occur in parallel, where some experimental data collection takes place strategically during the best data collection opportunities while other vessels take part in the operationalization of promising methodologies.

When weighing the need to expand the comparison between EM and reviewer data, a determination should be made in balancing rigorous scientific validation and operational realities. Although there was a statistically significant difference between reviewer and observer calculated weights, it is important to assess whether, in the event that this methodology was used in an operational program, this difference would constitute an acceptable risk or whether it needs to be reduced and, if so, to what level. Additionally, when considering the risk associated with using these methodologies for providing weight estimates by species from EM data based on comparisons to at-sea observer data, it is important to frame the issue in the context that there would be measurement and data collection errors intrinsic in any data collection method, including EM and human observer data.

6. Acknowledgements

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APPENDIX I – STATISTICAL TESTS LENGTH EXPERIMENT RESULTS

Reviewer A and Observer Estimated Weight Differences- Linear Regression Model

```
lm(formula = Weight Difference ~ Species + tripID)

Residuals:
     Min       1Q    Median       3Q      Max
-1.57599 -0.03146   0.00272  0.04091  1.36163

Coefficients:
                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                   0.018231   0.026422   0.690 0.490344
Species.Atlantic  cod        -0.124483   0.027344  -4.552 5.91e-06 ***
Species.Atlantic halibut     -0.022509   0.123345  -0.182 0.855233
Species.haddock              -0.052480   0.088962  -0.590 0.555370
Species.ocean pout           -0.084951   0.089643  -0.948 0.343515
Species.sand dab flounder     0.006761   0.024529   0.276 0.782872
Species.winter flounder       0.019720   0.033242   0.593 0.553165
Species.witch flounder       -0.028773   0.173028  -0.166 0.867958
Species.yellowtail flounder  -0.012136   0.024387  -0.498 0.618844
tripID.311820.04             -0.020215   0.021377  -0.946 0.344533
tripID.311821.01              0.014264   0.019463   0.733 0.463775
tripID.311822.03             -0.074205   0.020465  -3.626 0.000301 ***
tripID.311823.02             -0.073174   0.020429  -3.582 0.000356 ***
tripID.311827.01             -0.084007   0.028228  -2.976 0.002986 **
tripID.311828.01             -0.170029   0.024515  -6.936 6.96e-12 ***
---
Signif. codes:   0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.1713 on 1076 degrees of freedom
Multiple R-squared: 0.2352, Adjusted R-squared: 0.2253 F-
statistic: 23.64 on 14 and 1076 DF, p-value: < 2.2e-16
```

Reviewer B and Observer Estimated Weight Differences-Linear Regression Model

```
lm(formula = Weight Difference ~ Species + tripID)

Residuals:
     Min       1Q    Median       3Q      Max
-1.22049 -0.03001   0.00663  0.03485  0.51322

Coefficients:
                               Estimate Std. Error t value Pr(>|t|)
(Intercept)                   -0.076962   0.014792  -5.203 2.38e-07 ***
Species.Atlantic cod           0.283879   0.018819  15.085  < 2e-16 ***
Species.Atlantic halibut      -0.026634   0.096931  -0.275   0.7835
Species.haddock                0.020637   0.096873   0.213   0.8313
Species.ocean pout             0.031057   0.051367   0.605   0.5456
Species.sand dab flounder      0.011860   0.013599   0.872   0.3833
Species.winter flounder        0.010175   0.018638   0.546   0.5852
Species.witch flounder         0.013792   0.096931   0.142   0.8869
Species.yellowtail flounder    0.011347   0.013606   0.834   0.4045
tripID.311820.04               0.073080   0.012404   5.891 5.24e-09 ***
tripID.311821.01              -0.046200   0.010561  -4.375 1.34e-05 ***
tripID.311822.03               0.129755   0.011729  11.063  < 2e-16 ***
tripID.311823.02               0.024867   0.011517   2.159   0.0311 *
tripID.311827.01               0.002937   0.015215   0.193   0.8470
tripID.311828.01               0.025216   0.019597   1.287   0.1985
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.09595 on 990 degrees of freedom
Multiple R-squared: 0.4972, Adjusted R-squared: 0.4901 F-
statistic: 69.94 on 14 and 990 DF, p-value: < 2.2e-16
```

APPENDIX II –SPECIES IDENTIFICATION FEATURES USED BY REVIEWERS

Please note that the feature descriptions were not standardized across reviewers. As a result, descriptions between reviewers may overlap in situations when one reviewer described a feature in slightly more or less detail than the other reviewer or used a combination of features as one.

Feature	Reviewer A		Reviewer B	
	Times Used	% Used	Times Used	% Used
American plaice				
Large Mouth	61	100%	75	75%
Right Eyed	61	100%	22	22%
Convex Tail	15	25%	68	68%
Narrow Caudal Peduncle	43	70%		
Slender Body Profile with Round/Spade Shaped Tail	1	2%		
Large Mouth			1	1%
Thick Body			1	1%
Lack of Other Flounder Characteristics			16	16%
Total entries for American plaice	**61**		**100**	
Atlantic cod				
White lateral line	271	97%	268	98%
Three dorsal fins	236	85%	212	78%
Coloration	209	75%	67	25%
Sub-terminal mouth	90	32%	2	1%
Chin barbel	12	4%		
Slightly forked/squared tail	4	1%		
Two anal fins	1	0%		
Large eyes	1	0%		
Total entries for Atlantic cod	**278**		**273**	
Fish, not known				
Slender body	5	71%		
Long and Silver	1	14%		
No identifying characteristic recorded			9	100%
Total entries for fish, not known	**7**		**9**	
Flounder, not known				
Right eyed	62	97%		
Narrow caudal peduncle	33	52%		
Small mouth	15	23%		
Slender body profile and round tail	6	9%		
Slender body profile	4	6%		
Dark dorsal surface	3	5%		
Thick caudal peduncle	2	3%		
Left eyed	1	2%		
Large mouth	1	2%		
Flat body shape			474	97%
Round body shape			1	0%
No identifying characteristic recorded			15	3%
Total entries for flounder, not known	**64**		**490**	

Feature	Reviewer A		Reviewer B	
	Times Used	% Used	Times Used	% Used
Fourspot flounder				
Left eyed	1	100%		
Large Mouth on Slender Body	1	100%		
Spade-shaped caudal fin	1	100%		
Total entries for fourspot flounder	**1**			
Groundfish, not known				
Three dorsal fins	1	100%		
Sub-terminal Mouth	1	100%		
Mottled brown body color	1	100%		
Round body shape			1	100%
Total entries for Groundfish, not known	**1**		**1**	
Hake, not known				
Long second dorsal fin	4	100%	2	100%
Long anal fin	2	50%		
Round caudal fin	2	50%		
Long pelvic fin			2	100%
Total entries for hake, not known	**4**		**2**	
Monkfish				
Large head with huge mouth followed by short tapering body	1	100%	1	100%
Small fleshy pelvic fins posterior to pectoral fins	1	100%	1	100%
Large body to tail ratio			1	100%
Distinctive fins			1	100%
Total entries for monkfish	**1**		**1**	
Ocean pout				
Very elongate body with reduced caudal fin	34	100%	15	43%
Large orange/yellow pectoral fins	32	94%		
Large fleshy mouth	18	53%		
Dorsal fin ends well before tail	6	18%		
Reduced tail	2	6%		
Large pectoral fins	1	3%		
Orange/brown body color	1	3%		
Rounded pectoral fin			19	54%
Continuous anal/caudal fin			28	80%
Continuous dorsal fin			7	20%
Total entries for ocean pout	**34**		**35**	
Sand dab flounder				
Very round body profile	1182	100%	1151	100%
Left eyed	1169	99%	8	1%
Heavy Spotting on Fins	1143	97%	1138	99%
Visible gut cavity	4	0%		
Large mouth			12	1%
Convex tail			2	0%
Total entries for sand dab flounder	**1182**		**1152**	

Feature	Reviewer A		Reviewer B	
	Times Used	% Used	Times Used	% Used
Silver Hake				
Long second dorsal fin	17	100%		
Long anal fin	9	53%		
Round caudal fin	1	6%		
Coloration			17	100%
Large mouth			7	41%
No barbel			1	6%
Total entries for silver hake	**17**		**17**	
Winter flounder				
Right eyed	102	99%	2	8%
Small mouth	70	68%	20	80%
Thick caudal peduncle	103	100%		
White ventral surface (opaque)	32	31%		
Thick body			25	100%
Flat lateral line			1	4%
Convex tail			3	12%
No upturned mouth			1	4%
Total entries for winter flounder	**103**		**25**	
Witch flounder				
Right eyed	2	100%		
Small mouth	2	100%		
Concave pelvic region	1	50%		
Narrow caudal peduncle with round tail	1	50%		
Dark around anal fins			2	67%
Dark spot on pectoral fin			2	67%
Thin body			2	67%
Total entries for witch flounder	**2**		**3**	
Yellowtail flounder				
Right eyed	1242	100%	163	19%
Upturned mouth/snout	1173	94%	866	100%
Dirty yellow ventral surface of caudal peduncle	338	27%	45	5%
Small mouth	1175	94%		
Narrow caudal peduncle	944	76%		
Slender body with round tail	3	0%		
Convex tail			807	93%
Large fleshy lip			18	2%
Total entries for yellowtail flounder	**1242**		**869**	

NEW ENGLAND ELECTRONIC MONITORING PROJECT PHASE III

Contract EA133F-10-SE-0949

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Acronyms

ACE	Annual Catch Entitlement
ACL	Annual Catch Limit
ASM	At-Sea Monitor
CCTV	Closed Circuit TV
CFR	Code of Federal Regulations
DSM	Dockside Monitoring
EFP	Exempted Fishery Permit
EM	Electronic Monitoring
ESA	Endangered Species Act
eVTR	Electronic Vessel Trip Report
FSB	Fisheries Sampling Branch
GARFO	Greater Atlantic Regional Fisheries Office
LUMF	Legal-sized Unmarketable Fish
MMPA	Marine Mammal Protection Act
NE	Northeast
NEFOP	Northeast Fisheries Observer Program
NEFSC	Northeast Fisheries Science Center
NEFMC	New England Fishery Management Council
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
nk	not known
OLE	Office of Law Enforcement
PTNS	Pre-Trip Notification System
VMP	Vessel Monitoring Plan
VMS	Vessel Monitoring System
VTR	Vessel Trip Report

Executive Summary

The goal of the New England Electronic Monitoring (EM) Project was to investigate the potential for using EM within the broader Northeast Multispecies Fishery (NE groundfish fishery) catch monitoring program. EM systems are designed for the automated collection of fisheries data while vessels are at sea. They collect high-frequency sensor data and closed-circuit television (CCTV) imagery during fishing or related activities which are then reviewed post-trip to provide data needed for fisheries management, compliance, and/or science.

Phases I and II of the project were completed and documented in 2010-2013 (Pria et. al., 2011, 2012) and laid the initial groundwork for understanding how EM could best be applied in the monitoring needs of the NE groundfish fishery. These results led the National Oceanic and Atmospheric Administration (NOAA) to endorse two basic EM monitoring approaches: an Audit and a Compliance approach (NOAA 2013b). Phase III focused on refining the overall design of these two approaches, conducting field trials and outlining operational and cost elements of both approaches.

This report summarizes the results of Phase III and represents the culmination of the New England EM Project, funded by the National Marine Fisheries Service (NMFS) and overseen by the Fisheries Sampling Branch (FSB).

Design Approaches

Both approaches are intended to provide:

- Accurate catch accounting (discards and landings) by area for groundfish managed species (i.e., annual catch entitlement (ACE) species, prohibited species and species with trip limits);
- Individual vessel accountability to support shares-based management (within sector ACE);
- Timely data turnaround;
- Verification of compliance with trip landings limits (i.e., Atlantic Halibut).

In addition to these minimum requirements, the approaches attempt to accommodate several desirable, but possibly non-essential monitoring needs related to catch accounting of non-groundfish managed species, protected species captures, fishing effort and compliance with closed areas and possession limits at-sea.

While both approaches meet the essential information needs for management of the NE fishery, they vary in the type and quality of the data products they deliver. Each approach can be enhanced by exploring multiple options, including hybrid designs which blend features of the two main approaches.

The Audit Approach is designed to conform with existing retention regulations and uses a catch estimation audit. It is based on the principle that a random selection of EM data is reviewed to estimate catches and these are compared with the fishing log catch entries for the same subset of hauls (the "audit") to validate industry-reported record of catches. It assumes that if a random subset of fishing logs from within a given frame is proven acceptable then all logs from within that frame are acceptable without requiring review of all imagery. This approach requires fishing log catch entry on a haul-by-haul level. The key element is that the now-validated fishing logs are then accepted as the official and complete record of discards. It presumes development of an audit process and criteria for what will be considered an acceptable level of accuracy in the self-reported data.

Audit Approach advantages include:

- Individual industry accountability for recording discards similar to a census program but with a lower review rate;
- No changes to the existing possession limit regulations or retention of ACE;
- Involvement of the fishermen in the collection of data used for the management of the fishery, to create buy-in to the overall program;
- Estimation of protected species interactions to the level of taxonomical identification possible and at the level of total sector annual catch (as opposed to individual trips for vessels).

Audit Approach implementation challenges include:

- More deck effort involved in processing high-volume catch data (e.g., trawl vessels);
- Modifications to catch handling to allow for EM estimation.

The Compliance Approach requires retention regulations to be modified so that, with some exceptions, all catch is retained including bycatch species and specimens below legal length. A higher speed and therefore less costly review of EM can then be used. The Compliance approach is complemented by the addition of a dockside monitoring (DSM) program. The key element is that the DSM data provide catch estimates of what previously would have been discarded while EM confirms that the catches are retained but does not provide an estimate.

Compliance Approach advantages include:

- Simplified EM imagery review thereby allowing the reviewer to scan imagery at higher speed (than in the Audit Approach) to determine whether discarding occurred during the haul;
- All species (excluding prohibited species) are sorted and weighed at offload and recorded in the dealer or DSM data;

- Reduced reliance on fishing log data for retained catch estimates.

Compliance Approach implementation challenges include:

- The need to change the existing retention regulations and the associated impact on high-risk fish stocks, safety, and offloading operations;
- Requirement to develop a DSM program to compliment the EM program;
- No ability to verify the stock area of origin for the reported landings (only a concern in multi stock area trips, currently about 1% of the trips [NOAA 2013a]).

Field Trials

Since each approach may require significant changes to catch handling, onboard EM configurations, reporting structure and regulations, field trials were conducted to further test the applicability of EM technology in the NE groundfish fishery with particular reference to each approach.

In general, the Audit trial focused on comparing piece counts and weights of discarded groundfish managed species between EM and fishing log at the haul level. The Compliance trial focused on monitoring adherence to retention rules throughout the entire fishing trip and collecting offload data on the additional retained catch (referred herein as "dockside discards").

The EM systems collected a total of 848 hours of EM data from a total of 91 trips and 266 hauls for the Audit trial across three vessels and 65 hours of EM data from a total of 8 trips and 21 hauls for the Compliance trial across two vessels. More trips were initially planned for the Compliance trial but there were time constraints in obtaining an Exempted Fishing Permit (EFP) and quota constraints from the participating vessels.

Data collection success within trips for the Phase III field trials was >99% and complete imagery data was recorded for 93% of hauls, indicating overall good EM system performance. Interviews conducted by FSB staff throughout the three phases of the project showed that the majority of fishers found the equipment to be user-friendly and reliable. Some respondents suggested the need for a trial or probation period at the onset to allow users to become familiar with the systems. Some fishers mentioned the challenge of providing sufficient power and failure of system components, although most of these were resolved through ongoing communication with the project staff.

The data turnaround time in the audit trial was 20 days or less for 89% of the trips, with a minimum of three days. The turnaround in the compliance trial ranged from two to 11 days. The availability of staff for data analysis throughout the project was the single biggest influence in turnaround time. The trials indicate that turnaround times can be improved with sufficient and flexible staffing levels, well-defined timelines and requirements, and incentives for fishers to handle catch in a manner that optimizes review speed.

The difference in review speed between the two approaches was gear specific. The time to review imagery for day-trawl vessels was much lower in the compliance trial (22 minutes for each hour of video reviewed) compared to the audit trial (1 hour and 40 minutes for every hour of video reviewed). In contrast, the gillnet vessel had similar review times for both trials (29 minutes and 30 minutes for every hour of video reviewed for the compliance and audit trails respectively). While these results are not representative of all trawl and gillnet vessels in the NE groundfish fishery, they indicate that the choice of approach may be gear dependent, among other issues.

In the Audit trials, comparisons between EM and fishing log estimates of the discards indicated that captains tended to underestimate piece counts relative to EM. The degree of bias varied with the vessel and species. It is important to note, however, that for hauls where the piece counts of EM and fishing logs aligned well, the weights from both sources also aligned. This demonstrates the importance of accurate piece counts for both data sources when used for weight comparisons.

The differences in estimates could be reduced with feedback and should not be interpreted to mean that self-reporting is not possible. It can be expected that accurate self-reporting will take time to develop and will be assisted with introduction of well-crafted incentives.

The Audit trial demonstrated that some ACE species (White Hake) are indistinguishable from certain non-ACE species (Red Hake) during imagery review. This creates complexity for estimating the weights of groundfish managed species discards. Other problematic species pairings include American Plaice Flounder (ACE)/Fourspot Flounder (non-ACE) and Yellowtail Flounder (ACE)/Winter Flounder (ACE). The report includes suggestions for mitigating these problems.

The Compliance trials indicated that EM was successful in documenting non-allowable discards and compliance with specified retention rules. The Compliance trial demonstrated that adherence to jointly developed catch handling protocols, and a trusted DSM component are essential for success of the program. Furthermore, results demonstrated that for the approach to be successful it must be supported by the crew. For example, during the trial one of the vessels did not follow the defined retention rules out of concern for the fish stocks and conservation. This emphasizes the need for resolution among conflicting objectives during the program design (e.g., more precision or release of live specimens).

The DSM data illustrated that under modified retention rules, the dockside discards ranged from eight to 553 additional pounds landed per trip. However, owing to the small sample sizes in the Compliance trials these results may not be representative. Under modified retention rules, additional retained catch could hamper fishing and/or increase the costs because vessel hold capacity would be reached more quickly resulting in more trips to catch the same amount of catch sold (i.e., fewer hauls and reduced revenue per trip), introduce safety concerns and add time to offloads. Reducing the volume of retained catch could be achieved by allowing discarding of easily identifiable or abundant low value species (e.g., sharks, skates and rays and other large pelagic species).

In the development of an operational program, the compliance approach would need to address concerns for select species (such as those with possession limits or those targeted by other fisheries). In this trial, some species were discarded due to conservation concerns. Ideally, these species would be easy to differentiate from species that must be retained. This would still allow for a relatively high-speed imagery review. Carefully planned catch-handling protocols that include conspicuous discarding of allowable species would also help to facilitate faster review times.

The trials highlighted issues that could be improved in an operational program. These include the importance of feedback and communication between program staff and fishers and, in particular, the importance of proper completion of the fishing logs. Furthermore, because the onboard methodologies and self-reporting create additional workload for fishers, an adequate incentive structure will be key in integrating an EM program into NE groundfish monitoring.

Operational and Cost Considerations

The overarching consideration that influences the design of the operational components of an EM program is conforming to a realistic budget while still satisfying the monitoring needs. Fishery monitoring programs are bounded by financial limitations and we believe this should be explicitly incorporated during program design.

The level of investment in monitoring should relate to fishery value following the logic that the value of the fishery justifies the cost of obtaining the basic data needed to manage it. Recognizing there are a number of issues that will determine the final level of monitoring investment, this sets the approximate scale and thereby frames the discussion to identify potential monitoring approaches. In the absence of a financial ceiling, program design can easily diverge from what can truly be afforded and what is really needed.

The key operational components in an EM program include outreach, field services, and data analysis services. Tailoring these components to the NE fishery will require defining the scope and size of the program and assessing the resources required for implementation. The design of these operational aspects should aim to achieve an optimal balance between data quality, data turnaround and cost. There are several aspects of a fishery that must be considered early in the design. These design considerations inform or drive the design process rather than being design variables themselves. Design considerations include fishery characteristics, management regime and monitoring objectives, amongst others.

An EM program will have distinct strategies to meet the monitoring objectives, which in turn will affect costs of the program. Stakeholders will have to consider multiple factors and make tradeoffs among them. Stakeholder engagement is critical during the monitoring package design process, and should continue during the operational program. Input from stakeholders will shape the design choices. For this reason, stakeholder engagement is in many ways the single biggest factor affecting the design of the program.

Calculating the total cost of an EM program is difficult as it must take a multitude of operational and program delivery factors into account. However, given the basic design considerations and certain operational assumptions, it is possible to calculate an initial estimation of program core costs. These core costs focus on the effort necessary for collecting, retrieving, processing and reporting the EM data for each of the approaches under consideration. This costing exercise indicates that the annual core costs for the NE groundfish fishery (400 vessels, 15,000 trips and 85,000 hauls per year) would be approximately $2.5 million for the Audit Approach and around $1.7 million for the Compliance Approach. This constitutes two to four percent of the fishery landed value (ex-vessel value). It must be noted that it is possible that different approaches would be adopted by different fleets and EM may not be implemented across the entire fishery. This costing exercise is intended to seed discussion on how different approach design options influence relative costs and what kind of program may be possible within financial constraints of the fishery.

While the core costs should represent the majority of the program costs, there will be additional costs for administration and infrastructure such as program management, outreach, data storage, and travel, amongst others. These costs do not scale directly to the core costs and require a more involved design process and thorough consideration of program delivery. Program delivery relates to the framework of how the program will be run, how decisions are made, who pays, and what motivates stakeholders.

To estimate the total costs we recommend stakeholders first calculate the core costs, then define the program delivery elements that affect costs and finally conduct a detailed design process to optimize the program.

While we focus on EM operational components in this report, EM would be only one component of the NE monitoring package in New England. The cost and operation, and possibly changes to the other monitoring components must also be included while designing a monitoring package that includes EM. In the NE groundfish fishery, these include the costs of fishing log support, NEFOP, VMS, ASM, and, potentially, a DSM program.

Conclusion

Both the Audit and the Compliance approaches will require significant additional design work to fully conform to the existing monitoring and regulatory environment and the operational features of the NE groundfish fishery. They also have their different advantages and implementation challenges. However, the Phase III results, summarized in this report, demonstrate that both approaches have the potential to provide a useful and cost-effective solution to help in meeting the information needs of the NE groundfish fishery. This and the preceding reports provide an essential starting point in the evaluation and assessment of the role that EM can play within the NE groundfish fishery.

Introduction

The Northeast Multispecies Fishery (NE groundfish fishery) is a commercial fishery managed by the New England Fishery Management Council (NEFMC). The fishery generates about $70 million in revenue and involves over 400 vessels (NOAA 2013a). The fishery targets groundfish species including Atlantic Cod, Pollock, Haddock, and several flounder species. The fishery is composed of three primary gear types: longline, gillnet, and bottom trawl. The majority of the activity is from trawl and gillnet, with trawl gear representing 65% of all hauls and 41% of trips while gillnet represents 33% of hauls and 54% of trips. In 2012, approximately 400 vessels completed close to 15,000 dedicated groundfish trips with most of the landings occurring between Rhode Island and Massachusetts (Appendix A).

In recent years, the fishery has undergone significant changes to management with emergency actions in 2006 intended to reduce fishing mortality (NOAA, 2007) followed by a move to a Total Allowable Catch (TAC) and "shares-based" management scheme in 2010.

Sectors were created as a way to collectively manage Annual Catch Entitlement (ACE) among vessels. Sectors are a voluntary group of fishers that hold limited access permits and operate under a collective operations plan (Federal Register 2010).

These changes increased the need for a timely monitoring system to hold individual vessels accountable for their catch. The potential costs of an enhanced catch monitoring program and associated data collection activities have led stakeholders to request studies of more cost-effective monitoring.

In response, the Fisheries Sampling Branch (FSB) of the National Oceanic and Atmospheric Administration (NOAA) initiated the New England Electronic Monitoring Project in 2010 to investigate the potential for using Electronic Monitoring (EM) as part of the broader NE groundfish fishery catch monitoring program. The FSB contracted with Archipelago Marine Research Ltd. (Archipelago) to collaborate in this project.

EM systems are designed for the automated collection of fisheries data while vessels are at sea. The systems are used to collect high-frequency sensor data and associated Closed Circuit Television (CCTV) imagery during fishing or related activities. These data are reviewed post-trip to provide data needed for fisheries management, compliance, and/or science.

EM systems are currently deployed in a wide variety of fisheries around the world and have successfully monitored a range of issues including fishing location and time, catch (quantity, condition, and species composition), fishing effort, gear, protected species interactions, and mitigation measures (Lowman et al., 2013).

Phases I and II of the New England EM project were completed in 2010-2013. The priorities of Phase I field studies were to install equipment, conduct outreach, develop data management capacity, explore potential EM data review methods and determine whether the resulting data could provide the same data as the current at-sea monitoring program (Pria et al., 2011). Building on Phase I, Phase II shifted the emphasis to experiments that used EM to estimate catch weights. These experiments focused on species identification, catch weight estimation using length and volumetric measurements and onboard catch handling protocols (Pria et al., 2012). Phase II (and III) also examined operational details of the fishery (number of vessels, ports etc.) as well as identifying the management information needed to integrate an EM monitoring component into the overall NE fishery monitoring package.

A significant outcome of the Phase I and II research was the finding that the use of EM is not a 'plug and play' replacement for at-sea observers or monitors in the NE groundfish fishery. The two methods are very different, each with associated strengths and weaknesses. Whereas observer estimation methods are designed to provide full catch accounting, this task can be difficult with EM for many gear types, in particular trawl. Instead of considering monitoring as full catch accounting, we found it useful to consider monitoring as a gradient of complexity from maximized retention to catch accounting, then adding or modifying other fishery components such as dockside monitoring data, vessel logbook data, management regulations and onboard catch handling methods in order to provide an integrated approach to catch accounting. Based on the fishery characteristics, information needs and other factors, there are different ways to accomplish catch accounting objectives, and we refer to these as "monitoring approaches".

Building on the results and lessons learned in Phases I and II, two basic monitoring approaches, which illustrate different levels of operational complexity, were endorsed by the Northeast Fisheries Science Center (NEFSC) and the Greater Atlantic Fisheries Regional Office (GARFO) for additional EM design development and field trials (NOAA 2013b).

Approach 1 – "Audit" - is designed to be implemented under existing retention regulations and uses a catch estimation-audit approach. The audit approach is based on the principle that a random selection of EM data is reviewed to estimate catches and these are compared (the "audit") with the fishing log catch entries for the same hauls to validate industry-reported record of catches. This approach requires catch entry on a haul-by-haul level. The key element is that the fishing logs are then accepted as the official record of discards.

Approach 2 – "Compliance" - requires retention regulations to be modified so, with a few exceptions, all catch is retained including bycatch species and specimens below legal length. A higher speed review of EM is used to ensure compliance with the increased retention requirements rather than to estimate weight of the discards of quota species. This approach is complemented by the addition of a dockside monitoring (DSM) program. The key element is that the DSM data provide catch estimates of what previously would have been discarded and EM confirms that the catches are retained.

With the two approaches identified, the objectives of Phase III were to:

- Refine the overall design of the two approaches;
- Trial the two approaches in the NE fishery;
- Outline operational and cost elements of both approaches to be considered.

This report summarizes the additional design work, field trials, lessons learned and conclusions of Phase III, which was completed in 2013. Part 1 provides more detail on the two approaches and options within those approaches. Part 2 summarizes field trials of these approaches with the different gear types. Part 3 first outlines key operational and cost considerations for an EM component regardless of the design approach. It then examines how the characteristics of the fishery (number of vessel, ports etc.) affect costs. Part 4 provides a brief summary. Appendices provide further detail on specific issues.

1.0 Part 1: Design Approaches

In this section we provide a more complete development of the concepts behind the two approaches. Whether the conceptual models described in this section, or some combination of the two approaches is applicable will depend on the operational and design considerations discussed in Parts 2 and 3 of the report.

We examine the two approaches relative to their ability to meet the information and management requirements of the fishery with a discussion of the strengths, weaknesses and key decisions points for each approach. While much of the discussion in this section is based on the results and lessons learned in the Phase III trials, which simulated the two approaches in the NE fishery context, this section does not describe the methods carried out during the trials, which are described in Part 2.

This section begins with background on the current NE groundfish monitoring goals, general information requirements and existing data collection components. We follow this with a summary of assumptions that were used to model the integration of EM into the fishery. This is followed by the design of the two approaches. We note the strengths and weaknesses of each approach and identify key decision points that management may need to consider prior to implementation. The selection depends on the fishing behaviour and gear, data requirements and priorities, as well as cost. We note that multiple variations of each approach are possible depending on needs. Furthermore, these approaches are not mutually exclusive and elements of both may be combined in the EM component of an overall monitoring package or even within a sector.

1.1 Background on NE Groundfish Monitoring

Several data collection components are currently used within the NE monitoring package. These components provide information for management, science and enforcement and would likely continue to do so, even with EM integration. They include a Pre-Trip Notification System (PTNS), scientific Northeast Fisheries Observers (NEFOP), At-Sea Monitors (ASM), fishing logs[1], dealer data, electronic vessel monitoring systems (VMS), and a Port Biological Sampling program (see Appendix A for more detail). Furthermore, each sector manager submits a weekly report to the National Marine Fisheries Service (NMFS), which includes information about each fishing trip in the sector, any compliance or reporting issues and the ACE status calculations.

The general conservation and management monitoring need is an estimate of total annual catch of ACE species by stock area, each of which is composed of several statistical areas. According to Amendment 16 (Federal Register 2010),

[1] Referred to in the NE groundfish fishery as Vessel Trip Report (VTR) in their paper form and electronic VTR (eVTR) when filled in and submitted using specialized software.

management of the fishery requires that a monitoring program provide, at a minimum, the total ACE catch, including discards, by gear type, in pounds by stock area. Because stock area borders differ between species, catch data would ideally be available at the statistical area level, allowing for it to be rolled up to stock area as appropriate for each species.

Furthermore, the transition to sector management and the requirement for updating in-season catches on a weekly basis adds new information objectives and complexity to the monitoring program. We elaborate on this point below by examining each of the information requirements for fishery management based on current monitoring programs and regulatory requirements.

1.1.1 Species Management

Species caught by sector vessels in the NE groundfish fishery are managed in a variety of ways and hence subject to different regulations. Of the species managed under the Northeast Multispecies Fisheries Management Plan (NE Multispecies FMP), nine are allocated and managed through ACE and four are not allocated and are subject to possession restrictions (Table 1). For the purposes of this report, these species are collectively referred to as "groundfish managed species".

Table 1: Groundfish managed species categorized by the manner in which they are regulated.

Regulation Type	Common Name	Scientific Name
ACE	Atlantic Cod	*Gadus morhua*
	Haddock	*Melanogrammus aeglefinus*
	Pollock	*Pollachius virens*
	Redfish	*Sebastes* spp
	White Hake	*Urophycis tenuis*
	American Plaice Flounder	*Hippoglossoides platessoides*
	Winter Flounder	*Pseudopleuronectes americanus*
	Witch Flounder	*Glyptocephalus cynoglossus*
	Yellowtail Flounder	*Limanda ferruginea*
Possession Restrictions - Prohibited	Atlantic Wolffish	*Anarhichas lupus*
	Ocean Pout	*Zoarces americanus*
	Windowpane Flounder	*Scophthalmus aquosus*
Possession Restrictions - One per trip	Atlantic Halibut	*Hippoglossus hippoglossus*

In addition to the groundfish managed species, catch can also include non-allocated target species (species that are not assigned an ACE but vessels are allowed to land and sell) and bycatch species (non-allocated species that are not retained). For the purposes of this report these species are collectively referred to as "other species".

The last catch group involves those species considered protected, which include marine mammals, seabirds, turtles, and sturgeon.

1.1.1.1 *ACE Management by Stock Area*

The management of the fishery is based on allocation of ACE of several species, which GARFO manages by stock area, sector, and gear type (NOAA 2009). This creates a minimum information need for an estimate of total catch (retained and discarded) by ACE, stock area, sector, gear, and year. However, for in-season management, the information must be updated weekly.

There are two components to this requirement. One, the total catch by species needs to be estimated and two, the catch needs to be assigned to a specific stock area. The total catch of ACE species is estimated at the trip level from landed catch (retained) and discarded catch. ACE accounting by stock area is determined through at-sea data (could be fishing log, observer, or EM) based on where the vessel fished and, in the case of multiple stock area trips, how much catch was obtained from each stock area.

While vessels are not individually accountable for ACE holdings to GARFO, they are accountable to the sector managers who must track total sector catch for each participating sector vessel on a weekly basis (Federal Register 2012).

1.1.1.2 *Possession Restrictions*

There are two main possession limits that have monitoring implications. The first is for Atlantic Wolffish, Ocean Pout, and Windowpane Flounder, which are currently prohibited for possession and landing and must be discarded at-sea. The second possession limit is for Atlantic Halibut, which has a possession and landing limit of one fish per trip. While captains can land only one Atlantic Halibut per trip, there is no limit on the number of Atlantic Halibut that captains can retain and then later discard (i.e., to land a more valuable Atlantic Halibut).

Sectors do not have ACE for the four species with possession limits but must report catch on their fishing log. Sector managers, in turn, must report total catch of these species on a weekly basis. For this reason, we include total catch of non-ACE groundfish managed species as an essential information requirement.

The possession limit requirement creates the need to validate that vessels do not land certain species beyond their limit. This requirement can be achieved by monitoring landings. Possession limits at sea are complex to verify because every piece would need to be seen captured and released. Verification of possession limits (e.g., Atlantic Halibut) at sea is not part of the current monitoring program and, while desirable information, for the purpose of the following discussion we consider it a non-essential information requirement for an EM program.

1.1.1.3 *Other Species*

Other species caught in the fishery (i.e., non-allocated target and bycatch species) may include a broad range of species. These species are not managed under the NE Multispecies FMP but some are managed under other FMPs (e.g., Spiny Dogfish, skates, and Monkfish).

Currently catch data on other species are collected through dealer reports, NEFOP and the ASM program. While some non-allocated target species have trip limits, there are no retention requirements and they can be discarded at the captains' discretion.

Amendment 16 states that the at-sea monitoring program "will be used to verify area fished and catch (landings and discards), by species and gear type, for the purposes of monitoring sector ACE utilization" (Federal Register 2010, pg 18278). While not explicitly required by Amendment 16, catch estimates for other species are currently collected for the purpose of calculating sector in-season discard estimates. For the purpose of this discussion, catch estimates for other species are treated as non-essential data for the EM program. They are considered in the discussion below, however, to allow for scalability and flexibility of the proposed approaches.

1.1.2 Minimum Fish Sizes

Captains are currently required to retain all legal-sized ACE specimens and discard all sub-legal ACE specimens. ACE deductions, however, include both legal and sub-legal catch (retained and discarded). This regulation requires captains to retain and land any legal-sized unmarketable fish (LUMF) ACE catch. Landed catch can be verified at the offload, whereas data from fishing activity at sea is required to document compliance to size restrictions of discards.

While this regulation is in place, it is not part of the at-sea monitoring program requirements in Amendment 16, so, for the purpose of this discussion, we do not consider fish size as a requirement of the proposed monitoring approaches. We consider size limits only for scalability and flexibility for the approaches.

If size determination at sea were to become a necessary information requirement for individual accountability at the haul level, it would create a need to accurately measure all discarded catch or confirm that discarded catch was sub-legal (i.e., not legal-sized). Verifying individual accountability with respect to discard size composition would raise the cost of EM data review. As noted above, this is one of many examples of where a full design will require intensive discussion on the cost-benefit of specific data/information elements.

1.1.3 Protected Species Captures

Captains are not required to report interactions with seabirds and species protected by the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA) in relation to sector reporting, however, they are obligated to report these under the MMPA and ESA. Both NEFOP and ASM collect these data. It is our understanding that it would be desirable to have information on protected species captures as part of an EM component, but since it is not a primary objective of the monitoring program under Amendment 16 it is treated as non-essential information for the purpose of this discussion.

1.1.4 Closed Areas

There are permanent and rolling closed areas where vessels are not allowed to fish. The U.S. Coast Guard and NOAA Office of Law Enforcement (OLE) monitor closed area fishing and vessels are required to stow gear while transiting through closed areas.

While this regulation is in place and EM data could be used to complement current programs, closed-area-monitoring is not treated as being essential for the proposed approaches. However, we make note of monitoring closed areas because it could be easily added to the EM data outputs with minimal additional costs.

1.1.5 Requirements Summary

Based on the above review, the following are **essential information needs for a monitoring package for the NE groundfish fishery**:

- Estimates of ACE discard weights by statistical area;
- Estimates of ACE retained weights by statistical area;
- Estimates of possession-restricted- prohibited species discard weights by statistical area;
- Evidence of compliance with possession-restricted- one per trip limits (i.e. Atlantic Halibut).

Based on the above review, the following are **not essential information needs for a monitoring package for the NE groundfish fishery**, but would be beneficial:

- Evidence of compliance with:
    - Possession limits at-sea;
    - The requirement to discard sub-legal sized specimens;
    - The restriction on landing minimum fish sizes for groundfish managed species;
- Estimates of other species weights;
- Estimates of protected species captures or encounters;
- Evidence of presence/fishing activity within a closed area.

1.2 Key Assumptions and Considerations for Both Approaches

In order to simplify the explanation of the two approaches we must make a number of assumptions regarding the NE fishery and its context. The following list helps to emphasize that EM will only be effective if integrated within a package of complimentary monitoring components supported by an appropriate regulatory and management framework.

As noted above, while the assumptions were necessary to facilitate the study and test the two approaches effectively, they are not necessarily representative of standards and functional logistics in an operational program. Necessary regulatory changes, the incorporation of supporting monitoring tools, and data requirements are dependent upon the specific objectives of an operational program, which may differ from objectives tested in this study. Additionally, assumptions were based on management needs and did not incorporate a full assessment of biological stock assessment needs.

- Individual trip accountability is required due to the need for sector managers to manage ACE holdings by vessel on a timely basis.
- Sectors may choose ASM and/or EM as their primary monitoring tool (the EM approaches treat the EM program independently from ASM).
- NEFOP and VMS will not be changed and the approaches treat the EM program independently from these data sources.
- An EM program could operate in combination with either electronic or paper-based fishing logs but the use of electronic fishing logs would be more efficient since they offer the advantage of streamlining the data collection process (no additional data entry after submission, use of validation rules to enforce certain elements of data quality and completeness, etc.).
- Fishing log location and catch data can be recorded on a haul basis based on the data requirements of a given approach (at least one of the currently approved eVTR applications in the fishery already supports haul-by-haul reporting).
- Retention regulations may change as required by the choice in approach.
- Compliance agents (i.e., Office of Law Enforcement) may be interested in using monitoring data to ensure that regulations are being met.
- Offload weights by species are the best available data for retained catch and could be acquired from either dealer data or DSM data as required.
- A DSM program would be required to provide third-party verification of landings data by species for catch not accounted for by dealers, depending on the approach.

- The following information does not need to be verified using EM:
  - Discard estimates of other species;
  - Possession limits at sea because this requires all hauls to be reviewed to ensure that the vessel did not exceed possession limits at any time during the trip.
- Vessels using EM would have 100% data collection, meaning that the EM system would be on for 100% of the trips. Sensor data would be reviewed for all trips to validate completeness as well as compliance with closed area regulations and location for all hauls.
- To minimize costs, a portion of the EM imagery data can be used as a verification tool for discard estimates and/or compliance to retention rules.

1.3 Audit Approach – Discard Catch Estimation

1.3.1 Overview

The audit approach conforms the use of EM to existing retention regulations. This approach uses the fishing log as the primary data source for discards and fishing location and relies on using EM to verify haul location and an audit of a random selection of hauls to verify discarded catch data. Because the unit of comparison between fishing log and EM for catch and location is a haul, the approach necessitates fishing log reporting at the haul level.

The model discussed concentrates on obtaining the essential information requirements outlined in section 1.1.5.

In this model, discarded groundfish managed species are verified using the EM data. Total discarded catch of groundfish managed species is then treated as known for each haul and can be summed for the trip, sector, etc. Since haul location is known for each haul, the estimates of discarded groundfish managed species catch can be assigned to the correct statistical area and stock area.

For the purposes of this discussion, we assume that random verification of 10% of the hauls would provide a sufficient deterrent to misreporting and meets the objective of verifying the fishing log data (see section 1.5.1 for more detail). As noted below (see section 1.5.2 “Catch Dumping”), if discarding outside of hauls is a concern, a sample of trips could be randomly selected for complete review for enforcement purposes. As noted in section 1.5.3, piece counting at the offload might also be used to test for dumping.

Retained catch information for allocation of groundfish managed species is obtained at the time of landing. Retained catch is also recorded in the fishing log but is not verified by EM.

Dealer records are used as the primary record of landings data. The landed catch by species total can be prorated to event (and therefore assigned to area) by the relative proportion of each haul's catch in the fishing log retained catch; however, retained catch (unlike discarded catch) by event is not validated by EM (see section 1.5.3 for more detail).

Note that the audit procedure has to be completed in a timely manner in order to confirm and update the quota status of each vessel and requires a review/appeal process that can respond within a reasonable period.

We limit the discussion to discarded groundfish managed species as this appears to provide the most cost-effective approach, assuming that landings data are reliable. We recognize, however, that EM in an audit approach could be used to validate all catch (retained and discarded catch) reported in the fishing log for all species, but this would require more costly review and more complex catch handling protocols, particularly in trawl vessels. Another consideration would be that the resolution of species data would be dependent on the ability to identify species.

1.3.2 Quick Facts

Retention: Status-quo

Haul time and location verification: 100% of hauls

Imagery review: 10% of hauls per week for each vessel pooled across all trips with a minimum of one haul reviewed per week [2]

EM imagery review output: Record discards of groundfish managed species and protected species

Fishing log: 100% (catch and fishing effort at haul level)

1.3.2.1 *Essential Information*

- **Groundfish managed species* discards amounts-** Fishing log- 10% verified by EM
- **Groundfish managed species* discards area-** Fishing log- 100% fishing location verified by EM, 10% catch by area allocation verified by EM
- **Groundfish managed species* retained amounts-** Dealer weights
- **Groundfish managed species* retained area-** Fishing log- 100% fishing location verified by EM, 10% catch by area allocation verified by EM
- **Landing limits-** Confirmed by dealer reports

** Groundfish managed species refers to ACE, prohibited and trip limit species (Table 1).*

[2] See section 3.4.2 under the Primary Data Processing sub header for more details on the operational and cost considerations of reporting periods.

1.3.2.2 *Not Essential Information*

- **Possession limits at sea (i.e., Atlantic Halibut)-** Not verified as part of this approach
- **Discards sub-legal fish sizes**- Verified by EM only if fish measured when discarded (i.e., slower review rate)
- **Landed minimum fish sizes**- Not confirmed as part of this approach
- **Other species retained amounts-** Dealer weights
- **Other species discard amounts-** Fishing log
- **Protected species captures-** Collected on 10% of EM imagery review[3]
- **Closed areas-** Fishing log and 100% verified by EM

1.3.3 Assumptions

The audit approach relies on the following assumptions in addition to those noted above:

- The fishing log can be used as the primary data source for at-sea catch data after a random portion of the data has been verified using EM data;
- For multiple stock area fishing trips, if catch data and event location reported in the fishing log is verified by EM, then the apportioning of discard catch to stock area is also correct (only an issue for multiple stock area trips and not tested during the EM trials);
- Management needs catch amounts to be in pounds but weight estimates can be calculated from other units (e.g. length, volume, pieces, etc.- note that only weight estimates from length and volume were tested as part of the NE EM project as reported in Pria et al., 2012);
- Catch verification may be based on weight or piece count comparisons;
- Groundfish managed species can be differentiated on video from other groundfish and non-groundfish species[4].

1.3.4 Summary of the Audit Approach

The audit approach, which uses EM data to validate a portion of fishing log catch, has several advantages. These include:

- Individual industry accountability for recording discards similar to a program where 100% of the fishing activity is verified but with a lower review rate;

[3] Alternatively, protected species captures could be obtained from fishing log data with 10% verification from EM (i.e., protected species could be included in the audit comparisons).
[4] If groundfish managed species cannot be distinguished, retention regulations for select species may be needed to supplement the approach.

- No changes are needed to the existing possession limit regulation or retention of ACE;
- Fishermen are currently involved in the reporting process through the requirement to report discards on the fishing log. The audit approach further involves fishermen in the data collection process by accepting the validated fishing log data as the official record of discards, thus helping to create buy-in to the overall program (Stanley et al., 2011);
- Estimation of prohibited species interaction, albeit to the level of imagery resolution and at the level of total sector annual catch (as opposed to individual trips for vessels).

The main advantage of the audit approach is that it can be applied under the current regulations with no change to retention rules or landings limits and requires minimal imagery review effort. Conversely, the main challenge for this approach is the effort involved in processing high-volume catch data (e.g., trawl vessels) and modifications to catch handling. We propose minimizing these weaknesses by limiting the catch estimation to only discarded catch and, perhaps, to only discards of managed groundfish species (i.e., those regulated by ACE and possession restrictions) and protected species for trawl. While this limitation would result in less data for other species compared to the ASM program, it would meet the catch monitoring objectives for catch accounting of managed groundfish species by stock area at the individual vessel level.

1.4 Compliance Approach – Full retention of groundfish managed species

1.4.1 Overview

In the compliance approach, the regulations and fishing operations are modified such that captains would be required to retain all catch with few exceptions, including protected species. The intent is to minimize the catch handling requirements for monitoring and reduce the need for catch estimation at-sea by transferring the task of catch accounting to the offload, thereby increasing the speed of EM imagery data review.

This approach uses weights at the time of offload as the primary data source for catch data. It uses the fishing log data as the primary data source for haul location and relies on using EM to verify fishing location and compliance with retention rules. Because the unit of comparison between fishing log and EM for location and compliance is a haul, the approach necessitates fishing log reporting at the haul level.

The model discussed concentrates on obtaining the essential information requirements outlined in section 1.1.5.

In this model all catch of ACE species must be retained so they can be accounted for at the time of offload though dealer and/or DSM data.

In discussions over which species, if any, should be discarded under the compliance approach the following should be considered:

- Protected species should be returned to sea due to conservation concerns;
- Species with conservation concerns and high survivability should be returned to sea;
- Species allowed to be discarded should be easily differentiated from ACE species;
- Large species which would be difficult to retain (such as large pelagics);
- Industry concerns over retention of certain species should be considered.

This discussion is based on the retention exceptions used during the Phase III field trial.

Of the species with possession restrictions, Ocean Pout and Windowpane Flounder were retained and accounted for at the offload. However, Atlantic Halibut, and Atlantic Wolffish were identified by GARFO as species of special conservation concern and high survivability. They also are distinguishable from ACE species and occur in low numbers in the fishery, meaning that discarding them has minimal impact on the overall speed of imagery data review. Since weight estimates of Atlantic Halibut and Atlantic Wolffish are an essential information requirement, discarded weights are provided in the fishing log and verified by EM.

GARFO also identified several large sharks and Barndoor, Smooth, and Thorny Skates as species of concern that should continue to be discarded under a compliance approach. To minimize the impact of these discards on EM imagery review speed and catch handling requirements, all sharks and skates could be allowed to be discarded. This allows the EM data reviewer to simply identify that the item being discarded is a “shark” or “skate” without having to ensure that they can be identified to species. Other large pelagic species (such as tuna) could also be discarded due to the ease of distinguishing them from groundfish managed species and in order to avoid forcing small vessels to retain large catch items.

Additionally captains requested to be able to discard American Lobster due to their high market value for lobster fishers and high survivability. Finally, the state of Massachusetts required discarding of Striped Bass.

Catch of ACE species, the key monitoring requirement, is known at the trip level based on the landings data. Landings data are available through dealers and/or a DSM program. Here we present a model in which dealer data is used for legal sized ACE species catch, and all other kept catch, and DSM data is used for sub-legal ACE species, possession restriction species. While weights of other species landed but not recorded by the dealer are not essential information, they could be collected by DSM if required.

Similar to the audit approach, the landed catch by species total can be prorated to event (and therefore assigned to area) by the relative proportion of each haul's catch in the fishing log retained catch; however, retained catch by event (and therefore the proportion by area) is not validated by EM (see section 1.5.3 for more detail).

EM imagery review provides an account of whether retention rules were followed and, in cases when they are not, it provides as much information as possible with regards to species (or species group) and amounts discarded (e.g., piece counts or visual weight estimates).

There are certain concerns with the additional retention of bycatch in instances where there may be safety or operational concerns (such as large hauls of Spiny Dogfish). In these cases captains may want to discard additional bycatch. The compliance approach could be designed to deal with these situations given that bycatch estimates are not an essential information requirement. These situations could be accommodated as long as the bycatch was discarded in a manner that was conducive to confirming that no ACE species, Ocean Pout or Windowpane Flounder (i.e., the groundfish managed species that must be retained) were discarded. If required, estimates of discarding in the event of a reported safety or operational discarding event could be obtained from the EM imagery data as was done during monitoring on the West coast Whiting fishery from 2004 to 2010 (McElderry 2014).

Similar to the audit approach, it is not necessary to review all hauls. A review rate of 10% of hauls (or the percentage that is considered a sufficient deterrent- see section 1.5.1 "Imagery Review Sample") could be used to document compliance to retention regulations. As noted below (see section 1.5.2 "Catch Dumping"), if discarding outside of hauls is a concern, a sample of trips could be randomly selected for complete review for enforcement purposes.

1.4.2 Quick Facts

- **Retention:** Modified retention regulations- full retention with limited exceptions.
- **Haul time and location verification:** 100% of hauls.

- **Imagery review:** 10% of hauls per week for each vessel pooled across all trips with a minimum of one haul reviewed per week[5].
- **EM imagery review output:** Confirmation of compliance with retention rules, Atlantic Halibut and Atlantic Wolffish discard weights, information on deviation with retention rules (description of discarding), protected species captures (note that the relatively small number of encounters is expected to have little impact on review rate.)
- **Fishing log:** 100% (catch and fishing effort at haul level).

1.4.2.1 *Essential Information*

- **Legal-size ACE retained amounts-** Dealer records
- **ACE sub-legal retained amounts-** DSM weights
- **ACE species, Ocean Pout and Windowpane Flounder retained area*-** Fishing log- 100% fishing location verified by EM, 10% catch by area allocation verified by EM
- **ACE species, Ocean Pout and Windowpane Flounder discard amounts*-** 10% EM confirmation of no discarding (EM estimates if this occurs)
- **ACE species, Ocean Pout and Windowpane Flounder discard area-** 100% fishing location verified by EM, 10% catch by area allocation verified by EM
- **Atlantic Halibut and Atlantic Wolffish discard amounts-** Fishing log-10% verified by EM
- **Atlantic Halibut and Atlantic Wolffish discard area-** 100% fishing location verified by EM, 10% catch by area allocation verified by EM
- **Landing Limits-** Confirmed by dealer reports, and DSM

*As mentioned above, for the purposes of this discussion we assume Ocean Pout and Windowpane Flounder would be retained as per the Phase III trials.

1.4.2.2 *Not Essential Information*

- **Possession limits at sea (i.e., Atlantic Halibut)-** Not verified as part of this approach
- **Discards sub-legal fish sizes-** NA to this approach
- **Landed minimum fish sizes**- Not confirmed as part of this approach
- **Non-allocated target species amounts-** Dealer weights
- **Bycatch species landed catch-** DSM weights (if required)

[5] See section 3.4.2 under the Primary Data Processing sub header for more details on the operational and cost considerations of reporting periods.

- **Other species discarded-** Fishing log- retention rules verified by EM in 10% of hauls
- **Protected species captures-** Collected on 10% of EM imagery review[6]
- **Closed areas-** Fishing log and 100% verified by EM

1.4.3 Assumptions

The compliance approach relies on the following assumptions in addition to those noted above:

- Retention regulations could be changed to require sub-legal ACE species to be retained and landed;
- Retention regulations could be changed to require species with possession restrictions (i.e., prohibited and/or trip limit) to be retained and landed;
- All catch is retained with few exceptions, for example protected species (e.g. turtles, marine mammals, seabirds, and Atlantic Sturgeon), large sharks, easy to identify prohibited species with conservation concerns if retained, and species easily differentiated from groundfish managed species that may create operational challenges with retention.

1.4.4 Summary of the Compliance Approach

This approach, which uses EM data to verify retention compliance and transfers the catch accounting requirement from at-sea to the landing event, has several advantages, mainly that it:

- Simplifies the EM review and allows the reviewer to scan imagery at higher speed (than in the audit approach) to determine whether discarding occurred during the haul;
- Requires that all species (excluding prohibited species) are sorted and weighed at offload and recorded in the dealer data or DSM data;
- Reduced reliance on fishing log for retained catch estimates because dealer and DSM data become the primary catch data sources.

There are two main advantages of the compliance approach. The first is that the speed of EM imagery review for each haul is high compared to the audit approach, specifically for trawl vessels (see section 2.3.4.3). The second advantage is that the catch handling requirements for monitoring are low compared to the audit approach.

The main weaknesses of this approach include the need to change the existing retention regulations. The approach would bring previously unmarketable fish to land which will need to be accommodated. In the BC groundfish HL fishery,

[6] Alternatively, protected species captures could be obtained from fishing log data with 10% verification from EM (i.e., utilize an audit approach to protected species).

industry created new markets after the advent of full retention regulations for rockfishes (*Sebastes* spp.), many of which were previously considered bycatch. The added volume of landings was also negligible. The new retention regulations for the NE groundfish fishery will need to consider what may be appropriate ways for dealing with additional retained catch that is not allowed to be sold under the current regulations. A DSM program, or an alternative way for obtaining total weights of all landed groundfish managed species, will need to be developed.

While the catch handling requirements for monitoring purposes in the compliance approach are low, increased retention could impact catch handling by fishers as the additional retained catch will need to be stored onboard. Also, the increased retention of catch may require changes in fishing activity (e.g., reduction of effort per trip or changes in fishing practices).

1.5 Other Considerations

1.5.1 Imagery Review Sample

For the purposes of this discussion, as mentioned above, we assume that random verification of 10% of the hauls would provide a sufficient deterrent to misreporting and meets the objective of verifying the fishing log data or deterring non-allowable discards. In this section we explain the rationale of 10% based on the experience within the BC groundfish hook-and-line fishery.

In the BC groundfish HL fishery, 10% of the hauls for each trip are reviewed, with a minimum of one haul per trip. This level has been found to be sufficient to meet operational objectives (Stanley et al., 2011). Note that the role of the "10%" is to encourage captains to complete the fishing log correctly and adhere to catch retention rules. As such, the percentage of hauls reviewed is not based on a target coefficient of variation for any catch estimate. The choice of coverage level is a compromise between monitoring cost and the deterrence effect. This is not to say that these data from the 10% review cannot be "re-used" to derive stratified estimates of catch (e.g., total sector catch of a prohibited species – see Stanley et al., 2009), however, the two roles for these data should be kept distinct.

The BC target of 10% emerged during early discussions. In these discussions, the design team (most of whom were industry representatives) chose to be constrained by a hypothetical monitoring budget equal to about 2% of landed revenue. The design team found that while this budget could provide 100% placement of cameras and imagery capture, the funds remaining would cover the review of only about 10% of the imagery. It was obvious that a 10% sampling rate might suffice for providing fleet-wide annual catch estimates using routine expansion methods, but the data would be too sparse to estimate catches at the scale of individual trip or quota share. However, full review of the imagery would result in costs unacceptable to the design team. At this point of the discussion the "audit" concept was conceived. Industry representatives intuited that a 10% review rate would provide a successful deterrent and likened it to the radar "traps" on the highways. The 10% rate was tentatively adopted for subsequent discussions and then final implementation in 2006. In 2012, the sampling rate was revisited while looking for means to reduce costs. However, given the fixed overhead costs (100% camera placement and raw data capture) reducing the variable cost of the imagery review from 10% to 5% resulted in negligible savings. As well, industry representatives suggested that a "once in 20" haul review rate would lose the psychological deterrent effect especially for captains who made fewer trips with fewer hauls. It would also increase the lag time in communicating to new captains that their recording was not of acceptable quality (i.e., it would take more trips to observe an unacceptable recording event). Conversely, since the 10% review rate had proven to be acceptable (Stanley et al., 2009), there was no need to increase costs with a higher review rate. If the fishing log and EM discard and location data match within a defined tolerance ("score") for the randomly selected hauls, then the fishing log is assumed to be correct for all hauls and is used as the official record of the trip for discard weight by species and location by haul. Rules must be in place to define which criteria are used to score the fishing log (i.e., acceptable tolerances), such as percent or absolute differences from the EM record. As well, rules must define the management response that will follow a failing score. Comparisons between fishing log and EM discard quantities could be made on pieces or estimated weight. The latter value might be calculated from individual fish lengths or mean piece weights.

1.5.2 Catch Dumping

In this document, we use "dumping" to refer to catch that is disposed of after initially being retained on board as opposed to "discarding" that occurs during initial capture at the rail or during initial deck sorting. In other words, dumped catch is catch that the EM reviewer (or an observer) and the fishing log would consider to have been retained, but was disposed of subsequently. This would include using fish for bait, consumption on board or high-grading on the way to offloading. If dumping becomes an issue with respect to accurate catch estimation, there is opportunity to address it within a monitoring package that includes EM and other interrelated elements.

For example, within the BC groundfish fishery there is a small-volume live rockfish fishery, which targets Quillback Rockfish (*Sebastes maliger*) for the restaurant trade. In this fishery, a live and medium-sized ("plate"-sized) specimen commands 10 times the value/kg of a dead, small, or large specimen. Therefore there is a strong incentive for the holders of Quillback Rockfish quota (in weight) to dump less desirable pieces on their way to offloading thereby reserving their quota for higher priced specimens. The EM to fisher log piece count audit will obviously not reveal the dumping. Nor can a comparison of the audited fisher log piece count with an offloaded dockside weight reveal dumping because of the real variability in mean size (an issue examined during design). Therefore, the BC design added mandatory piece counts of rockfishes to the dockside validation. The post-trip review comparison demands a close match between dockside piece counts of Quillback Rockfish to the total fisher log piece counts, remembering that the fisher logs are routinely audited with EM. As a result, the combination of EM, fishing log and validated dockside monitoring collectively copes with dumping of Quillback Rockfish. This monitoring strategy is required due to 1) a strong incentive to dump, and 2) the mismatch in measurement units between the EM and dockside, pieces vs. weight.

While piece counting live rockfish during offloading is onerous for the live-rockfish fishery, this solution was less costly than adding cameras to monitor all deck activity until the moment of offloading and the resulting imagery review costs (partial or full). Furthermore, industry representatives on the design team noted that they were sure that they would find ways to discard individual pieces out of camera view.

It is worth noting, however, that the same monitoring rigour with respect to dumping is not currently applied to other groundfish species/sectors in the BC fishery. In this fishery, there are also price differentials between different sizes of Sablefish (*Anoplopoma fimbria*) and North Pacific Spiny Dogfish (*Squalus suckleyi*). However, these sectors land much higher volumes thus piece counting at dockside would incur large dockside costs. This would be particularly problematic for the dogfish fishery, which has chronically low profit margins. Furthermore, the additional handling of frozen Sablefish would lead to breaking of fins and loss of value on higher-end Asian markets. The sector representatives also claimed that high grading was not currently an issue since the price differentials were small and any significant high grading would force more fishing effort to catch the replacement fish.

For these and other reasons, the BC design team (including managers) decided to risk-manage the dumping issue for these sectors and not mandate dockside piece counts until such time as dumping was deemed a problem. Industry is aware of the implicit threat of adding piece counts should it appear that the situation has changed. Note also that egregious levels of dumping would be obvious through a mismatch of total fisher log counts with landed weight through extremely small implicit mean weights. Furthermore, Stanley et al. (2009) provides an example of how the residual data from the 10% imagery review can be used to check for chronic modest dumping on a fleet-wide annual scale when there are dockside piece counts.

1.5.3 Multiple Stock Area Fishing

As noted in the assumptions, we assume that the data recorded during offload is the best available data for estimating total retained catch. Therefore, EM is not used to verify retained catch in either approach. While landings data are the most economical way to determine total retained catch by trip, they cannot verify that the fishing log accurately assigns retained catch to area. In the event that the vessel fished in multiple stock areas, the fishing log can be used to allocate catch among areas, but EM would not be used to validate the allocation. According to GARFO estimates, only about 1% of the trips include multiple stock areas (NOAA 2013a). If required, specific requirements (e.g., accounting of retained catch per haul) could be considered for multiple stock area trips.

1.6 Summary of Part 1

To assess the two approaches, we began by examining the primary monitoring needs of the fishery. These needs determined that the most effective design includes: accurate catch accounting for groundfish managed species (discards and landings), individual vessel accountability to support shares-based management (within sector ACE), timely data turnaround and verification of compliance with landings limits.

Several desirable, but non non-essential monitoring needs relate to tracking possession limits, prohibited species, closed areas, catch accounting of non-groundfish managed species and fishing effort.

The two approaches outlined here are:

Audit Approach– Catch estimation.

Advantages include:

- Individual industry accountability for recording discards similar to a census program but with a lower review rate;
- No changes are needed to the existing possession limit regulations or retention of ACE;
- Involving fishermen in the collection of data used for the management of the fishery, to create buy-in to the overall program;
- Estimation of protected species interactions to the level of taxonomical identification possible and at the level of total sector annual catch (as opposed to individual trips for vessels).

Implementation challenges include:

- More deck effort involved in processing high-volume catch data (e.g., trawl vessels);
- Modifications to catch handling to allow for EM estimation.

Compliance Approach – Full Retention of groundfish managed species.

Advantages include:

- Simplified EM imagery review thereby allowing the reviewer to scan imagery at higher speed (than in the audit approach) to determine whether discarding occurred during the haul;
- Allows that all species (excluding prohibited species) are sorted and weighed at offload and recorded in the dealer or DSM data;
- Reduced reliance on fishing log data for retained catch estimates.

Implementation challenges include:

- The need to change the existing retention regulations and the associated impact on high-risk fish stocks, safety, and offloading operations;
- Requirement to develop a DSM program to compliment the EM program;
- No ability to verify the stock area of origin for the reported landings (only a concern in multi stock area trips).

Both of the approaches we outline meet the essential information needs for management of the NE fishery, although they vary in the type and quality of the data products they deliver.

Each approach has strengths and weaknesses. These can be balanced by exploring multiple variations of each approach, or with a hybrid with elements of both approaches combined in the EM component of an overall monitoring program.

The approaches differ in the way that they would be implemented. Each may require significant changes to the fishery including factors such as catch handling, onboard configuration, reporting structure and regulatory changes. Part 2 looks at a field trial of both approaches to learn more about how they could be applied on active fishing vessels within the fishery with the ultimate goal of developing an operational program.

2.0 Part 2: Field Trials

2.1 Introduction

Field trials were conducted to further test the applicability of EM technology in the NE groundfish fishery under the audit and compliance approaches, consistent with the options outlined by the NEFSC and the GARFO (NOAA 2013b).

The trials simulated and tested the two approaches in an operational setting and allowed the project team to better understand and document the operational requirements for each approach.

The operational components we tested included equipment field support, Vessel Monitoring Plans (VMPs), a fishing log, data processing and reporting, feedback to and from the participants, as well as dockside monitoring in the compliance trial.

2.2 Methods

EM systems were deployed on vessels during normal commercial trips. EM data were collected using different EM configurations and onboard catch handling methodologies. Flexibility was required to effectively work with volunteer participants so, while the trials were based on the approaches outlined in Part 1, their application differed in some respects.

In general, the audit trial focused on comparing discards of groundfish managed species between EM and fishing log at the haul level while the compliance trial focused on monitoring adherence to retention rules throughout the entire fishing trip and collecting offload data on the additional retained catch (referred herein as “dockside discards”).

Specifically, the trials were designed to answer the research questions outlined in Table 2.

Note that the compliance approach discussed in Part 1 does not require comparisons between EM and fishing log catch data to meet the fishery information need but the trial broadened its scope to gain understanding on fishing log reporting under the compliance trial.

Table 2: Phase III field trials research questions.

Research Question	Audit Trial	Compliance Trial
Could the fishers[7] carry out the onboard methodology?	✓	✓
What was the proportion of fishing trips where data collection was complete from the start to the end of the trip?	✓	✓
How did the EM and fishing log haul data compare (haul number, start/end location, start/end time, and statistical area)?	✓	✓
How long did data retrieval services take?	✓	✓
How long did imagery review take?	✓	✓
What was the data turnaround time?	✓	✓
How did the EM and fishing log groundfish managed species discard data compare?	✓	
Did the fishing log provide weight for discarded skates (allowable) and non-allowable discards (e.g. dogfish)?		✓
How long did dockside monitoring take?		✓
How much dockside discards were landed (pounds)?		✓
How can dockside discard catch be disposed of?		✓
How often was catch taken out of view and was the reviewer able to identify the species or species group and provide a piece count or estimated volume?		✓
Were non-allowable discard events detectable and was the reviewer able to identify (to species or species group) and count discarded items?		✓

2.2.1 Vessel Selection

Four vessels were selected from those that had previously participated in the New England EM project. They were selected based on the following criteria:

- Vessels that had a good track record for providing high quality EM data (complete EM data collected for the entire fishing trip and the EM system was powered from port to port);
- Vessels which actively fished in the fishery;
- Vessels that were geographically close to the FSB office (i.e., within a six hour round trip), allowing for operational accessibility and the collection of hard drives after each trip;

[7] "Fisher" is used as a generic term to refer to captains or crew members collectively.

- Vessel captains that were willing to modify catch-handling practices and complete a modified Fishermen's Comment log ("fishing log") designed to match the trial research questions.

The vessels included three day-trawlers and one gillnet vessel. They are referred to as Vessel A, Vessel B, Vessel C, and Vessel D (Table 3). Vessel participation was voluntary, therefore vessels cannot be assumed to fully represent the entire NE groundfish fleet.

2.2.2 Data Collection Period

Data collection took place between May and September 2013 for the audit trial and between August and September 2013 for the compliance trial (Table 3)[8]. The trials included only single stock area trips.

Table 3: Summary of participating vessel and timeline of data collection for the EM project

Vessel	Audit Trial	Compliance Trial	Gear Type
Vessel A	May – September 2013	n/a	Day-Trawl
Vessel B	May – September 2013	n/a	Day-Trawl
Vessel C	May – September 2013	September 2013	Gillnet
Vessel D	n/a	August - September 2013	Day-Trawl

2.2.3 EM System Description

The EM systems used for this project were manufactured by Archipelago in Victoria, BC, Canada and were designed for the automated collection of sensor and image data, which can be used to produce fisheries information. The EM systems consisted of a control center, a user interface (monitor and keyboard), a suite of sensors (including GPS receiver, hydraulic pressure transducer and a drum rotation sensor) and up to four waterproof armored-dome CCTV cameras (Figure 1).

Analog and digital cameras were deployed on vessels. Analog cameras provide imagery data with 0.3 megapixels resolution and limit frame rates, whereas digital cameras can record at frame rates of up to 30 frames per second per camera with up to 1.3 megapixel resolution[9].

[8] The difference in the data collection period between the two approaches was due to a delay in obtaining the Exempted Fishing Permit (EFP). It was necessary to include both fixed and mobile gear vessels in each approach to fully test the models. Phase III only incorporated one fixed gear vessel and therefore that vessel participated in both approaches.

[9] Note that digital cameras are increasingly becoming the standard for EM due to the improved resolution and frame rates and lower costs.

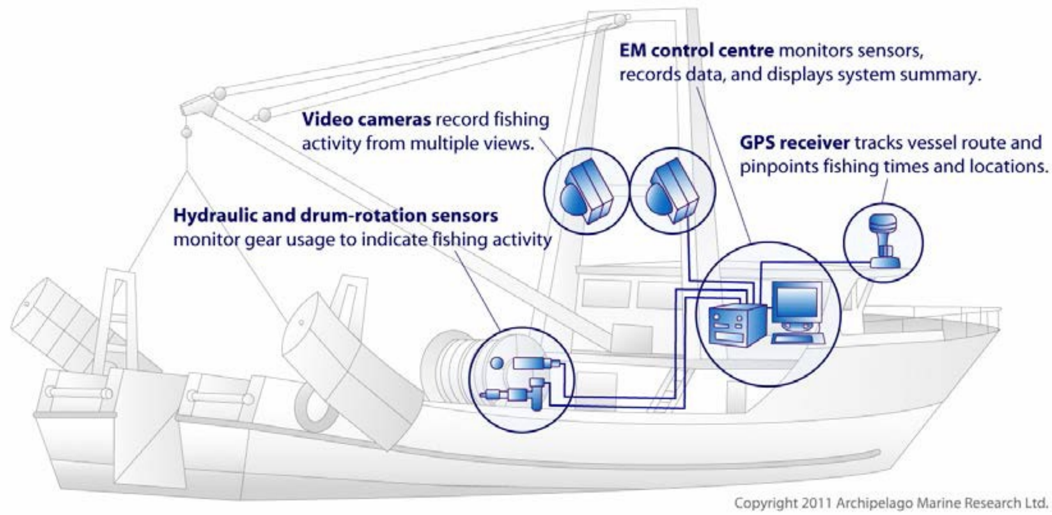

Figure 1: Schematic of the electronic monitoring system used in the trials.

2.2.4 EM Data Collection

We defined the data collection standards for a successfully EM-monitored trip. These standards acted as the recording goals for the participating vessels in each trial (Table 4). When these standards were not met, the captains were provided with feedback.

Table 4: Data collection standards for EM data

Data Collection Standard	Audit Trial	Compliance Trial
The captain completed a fishing log for the trip (as defined in section 2.2.6 "Fishing Logs").	✓	✓
The EM system was on and functioning correctly from dock-to-dock.	✓	✓
Camera views were clean and unobstructed.	✓	✓
Imagery was collected correctly (as defined in section 2.2.4.1 "EM Data Recording Settings") and if cameras were not automatically recording, manual record was used.	✓	✓
Discarding of catch occurred at pre-defined control points within camera view.	✓	✓
Discarded groundfish managed species transited the discard chute or were placed flat on the measurement area immediately before being discarded.	✓	
Catch was discarded one-by-one to allow the imagery reviewers to identify them and to measure groundfish managed species.	✓	
Catch destined for dockside discarding was stowed in a hold (containers could be covered but the container had to remain in camera view).		✓
Catch remained stowed or within camera view throughout the duration of the trip.		✓

Captains were required to keep the EM system operational by supplying sufficient power, running a function test (a series of checks on the different components of the EM system) at the start of each trip, and keeping the camera domes clean. In the event that the system was not functioning or did not pass the function test, fishers were required to notify project staff immediately for assistance.

Fishers were asked to ensure that catch handling procedures complied with the specific requirements of each trial even though these may have required modifications to normal catch handling processes (see section 2.2.4.2).

2.2.4.1 *EM Data Recording Settings*

EM sensor data were recorded continuously while the EM system was on and imagery data were recorded when triggered. The recording trigger differed by trial and gear type.

During the audit trial, imagery recording focused on ensuring all fishing activity was captured. To achieve this, imagery recording on fixed gear vessels was limited to fishing activity (as indicated by the hauler rotation or the hydraulic pressure exceeding a threshold) and continued recording for 10 minutes after the last sensor reading above the threshold[10]. For trawl vessels, given that there was no sensor trigger that could isolate catch processing, recording started at the first trigger and continued until the vessel returned to port.

During the compliance trial, imagery recording focused on ensuring catch handling and catch stowage locations were in view during the entire trip once there was catch onboard. In order to achieve this, imagery started recording once the winch rotated or hydraulic pressure exceeded a threshold level after the vessel left port; imagery recording continued until the vessel returned to the port.

2.2.4.2 *Onboard Methodologies and Camera Configuration*

The combination of catch handling protocols and EM system configurations were based on the essential information outlined in Part 1 (sections 1.3.2.1, audit trial, and 1.4.2.1, compliance trial) and designed to meet the research questions outlined in section 2.2. Each vessel was fitted with a sufficient number of cameras to capture the necessary data given the combination of vessel layout and onboard methodologies. The installation and onboard methodologies differed between the two trials, and are described in detail below.

Audit Trial

Catch handling for the audit trial specified that the fishers were to bring all catch on board prior to any discarding, discard only at pre-determined control points and ensure all discarded groundfish managed species passed one-by one across a

[10] A ten-minute run-on time was chosen for the fixed gear vessels because it was sufficient to record all catch sorting as per Pria et al. (2011,2012).

measurement grid area prior to discarding. These catch handling processes facilitated length measurement in the EM review (see Appendix B for more details on catch handling).

To collect the data necessary for measurement, a digital camera provided a close-up view that was as perpendicular to the measurement area as possible (Figure 2). The EM technician created the length measurement grid on each vessel by marking either the discard chute or measurement surface with nine calibration points (Appendix C). Measurement grids were set on discard chutes for the trawl vessels and on the sorting table by the hauler for the gillnet vessel. The technician re-marked the calibration points as required throughout the trials. Further details on the length measurement tool are included in Appendix C.

To facilitate accounting of groundfish managed species discards, captains were required to sort them out of the conveyer belt so that they would have an opportunity to count them and estimate weight before discarding them through the discard chute.

Figure 2: Camera views from a day-trawl vessel showing all areas of the deck where catch was handled. The checker pen views (top right and left) were used to confirm that all small catch came onto the conveyer belt. The close-up views of the conveyor belt (bottom left) were used for a closer look at catch sorting and support view of what would be coming on to the discard chute. The discard chute view (bottom right) was used for species identification and length measurement. Images used with captain's permission.

Figure 3: Camera views from the gillnet vessel. The sorting table view (top left) was used for a closer look at catch sorting and support view of what would be discarded or moved to the stern checkers. The stern view (top right) was used to confirm that only other species (non-groundfish managed species) were discarded at the stern. The close-up view of the measurement area (bottom left) was used for species identification and length measurement. The roller view (bottom right) was used to confirm discarding of groundfish managed species. Images used with captain's permission.

Compliance Trial

Catch handling for the compliance trial specified that the fishers were to bring all catch on board prior to any discarding and discard only at pre-determined control points and ensure all catch was handled within camera view at all times or stowed in the hold (see Appendix B for more details on catch handling).

Only the following catch were allowed to be discarded (referred to as "allowable discards"):

- Protected species (marine mammals, seabirds, turtles, and sturgeon)
- Atlantic Halibut
- Atlantic Wolffish
- Skates
- Large pelagics
- Striped Bass
- American Lobster
- Debris

All other catch had to be retained. An Exempted Fishing Permit (EFP) was required to carry out the compliance trial portion of the study because it required landing sublegal ACE and two prohibited species (Windowpane Flounder and Ocean Pout). In cases where these species were discarded, they are referred to as "non-allowable discards".

For the compliance trial, camera coverage of the entire catch handling area, catch stowing areas, and control points for allowable discards was critical to the study and ensured the EM system would document compliance with retention requirements. Camera views on Vessel D provided coverage of the entire deck and catch stowage areas (Figure 4). Vessel C was not set up with a deck view because the captain expressed concerns about privacy, since the imagery on the compliance trial was configured to be recording continuously from the first haul (rather than only during fishing activity as in the audit trial) (Figure 5). The lack of a deck view was not ideal since it was likely that some catch would be taken out of camera view, but it was a condition to the vessel's participation on the trial. The captain agreed to handle all groundfish managed species within view to ensure that they could be accounted for.

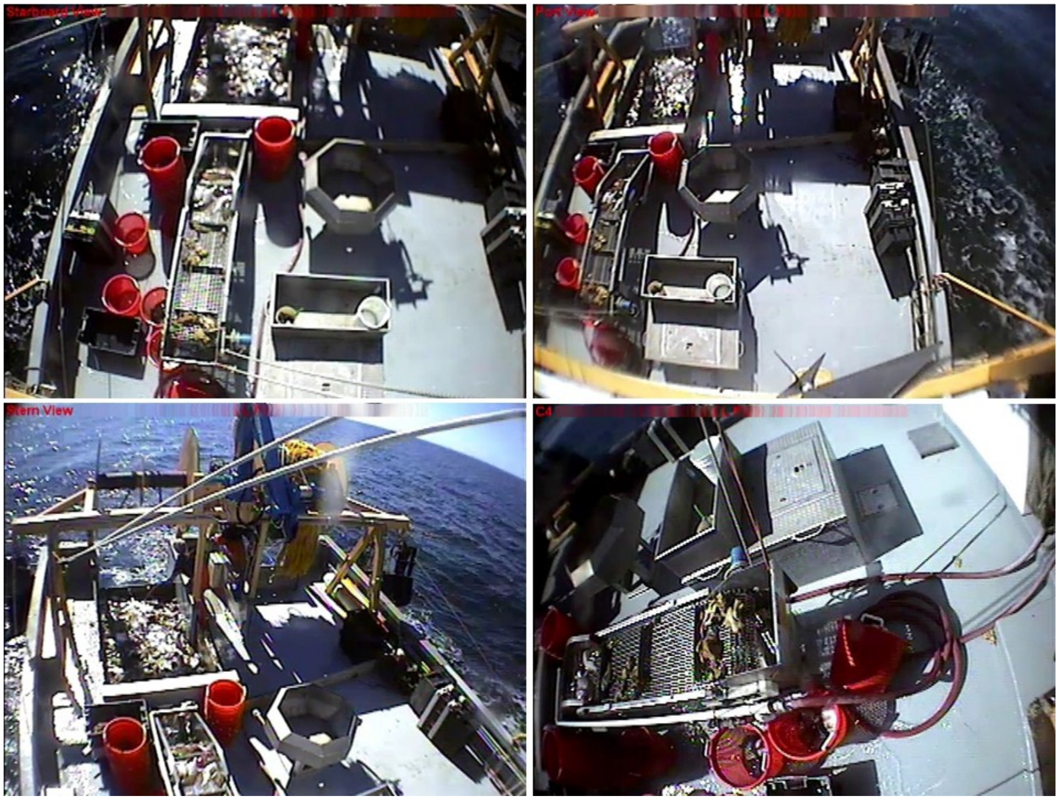

Figure 4: Camera views for the trawl vessel. Starboard wide-angle view (top left), port wide-angle view (top right), stern view (bottom left) and conveyor belt view (bottom right). Large catch items from the "allowable discard" list were discarded at the rails by the stern. Other allowable discards occurred at the port rail. Images used with captain's permission.

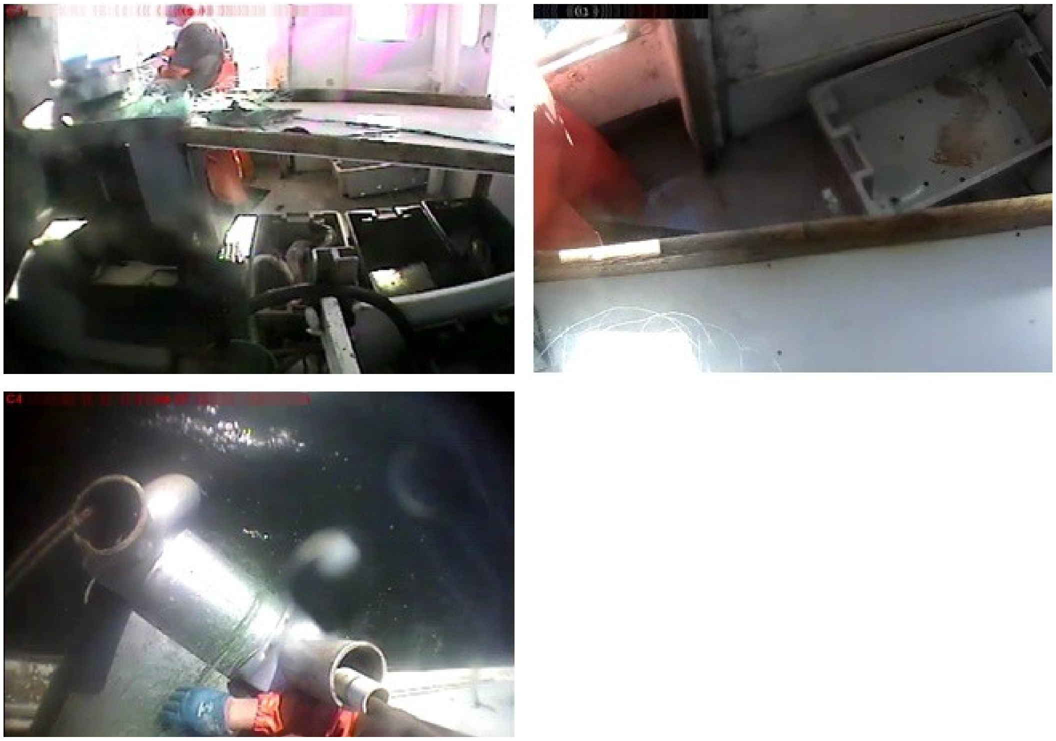

Figure 5: Camera views from the gillnet vessel. Wide-angle view of interior processing table (top left), close up view of processing table (top right) and roller with catch (bottom). Allowable discard species were discarded by the hauler. Images used with captain's permission.

2.2.5 Vessel Monitoring Plans

Vessel Monitoring Plans (VMPs) were developed at the start of the trial for each of the participating vessels. The VMP is a communication tool used to ensure that captains, EM field technicians, EM data reviewers and project coordination staff understood their roles in the simulated operational EM program.

The VMPs outlined vessel-specific catch handling protocols and EM system configurations that were used throughout the project (see Appendix D for an example VMP). Project staff introduced initial catch handling protocols, solicited feedback from captains, and proposed adjustments in catch handling procedures as needed throughout the project. During the first four weeks of the trials, the EM imagery viewers (both FSB and Archipelago staff) provided feedback on the EM system configurations and onboard methodologies. This continued until configurations and methods were considered acceptable and met the data collection requirements of the project.

2.2.6 Fishing Log Data Collection

To capture data from fishers while the vessel was at sea for both trials, we used a modified, paper-based, Fishermen's Comment Log ("fishing log") and defined specific data that the fishers were required to collect (see Appendix E for example fishing logs). Fishers were asked to record general trip and haul information as well as some discard catch data. At the outset of the project, captains were not given specific direction on how to measure weights, however advice was provided as requested throughout both trials.

The audit trial required fishers to document:

- Date and time of the trip start and end;
- Date, time, location, and fishing area (based on the starting point) of each haul;
- The number of pieces and estimated weights of groundfish managed species that were discarded for each haul at the species level.

Under this trial, fishers did not document retained catch or other species discards.

The compliance trial required fishers to document:

- Date and time of the trip start and end;
- Date, time, location, and fishing area (based on the starting point) of each haul;
- For allowable discards: haul number, species, weight estimate;
- For non-allowable discards: haul number, species, piece count and weight estimate[11];
- Occurrence (yes/no) of debris discarding, full or partial codend tripping and a comment when it did occur;
- For discards outside of catch handling for a specific haul[12]: date, time, location, species, volume of discard and a short explanation for the discard when discarding occurred.

Under this trial, fishers did not document retained catch.

The EM technician (audit trial) or FSB staff acting as DSMs (compliance trial) collected the fishing logs with the EM data hard drive after each trip.

2.2.7 Dockside Monitoring Data Collection

As a component of the compliance trial, FSB staff worked as DSMs to document all dockside discards. These discards included any catch that would normally have been discarded but were retained as part of the trial. The DSM weighed all

[11] Some captains expressed concerns over keeping certain non-allowable discards, in particular, live sub-legal sized ACE specimens and large catches of bycatch such as Spiny Dogfish, so the fishing log was modified to record the amounts of these species when discarded.

[12] While discarding would be associated to a specific haul, the fishing log allowed fishers to document discarding at any point during a trip. For example, it was considered possible that a fisher may choose to discard catch, e.g. dogfish, part way through a trip due to safety reasons.

dockside discards using a motion calibrated Marel scale or spring scales. Dockside discards were composed of the following:

- Sublegal ACE species or catch that were smaller than the regulated minimum size but retained for the trial;
- Prohibited species retained for the trial;
- Bycatch that would normally be discarded at-sea (e.g. Sea ravens, Sculpins etc.);
- Legal sized unmarketable fish (LUMF).

Captains were required to notify FSB (via phone or texting communication) prior to landing to coordinate dockside monitoring services. DSMs did not verify landed catch that captains sold and dockside discards were not permitted for sale by the vessel owner/operators. FSB developed several options for disposal of dockside discards, which are described later in the report.

2.2.8 Data Processing and Analysis

2.2.8.1 *Data Turnaround*

EM technicians collected hard drives (referred to as a "data retrieval") of EM data sets after each trip was completed, excluding some of those completed on Friday, Saturday or Sunday due to staff limitations during the audit trial. During the compliance trial, a DSM monitored all offloads and conducted a data retrieval service immediately upon vessel landing.

Following data retrieval, the hard drives were hand delivered to FSB offices to begin the data review and reporting process. Vessel activity, fishing log data and EM data were tracked from the start of a groundfish trip to completion of a trip report (Figure 6). Data turnaround time was calculated as the number of days between the EM data arriving at FSB and the completion of the trip report.

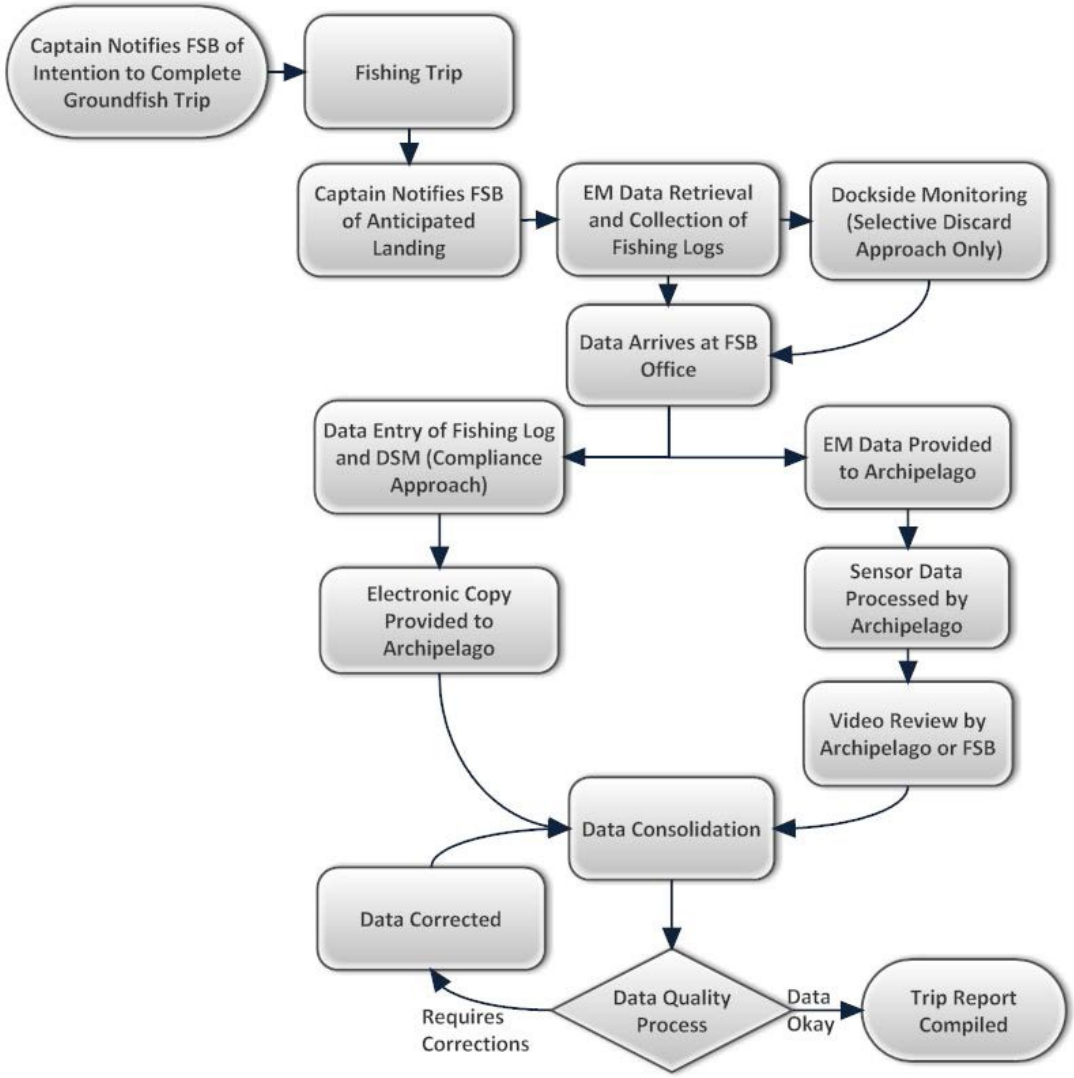

Figure 6: Flow of data and steps involved in collecting, consolidating and reporting the EM, DSM, and fishing log data.

2.2.8.2 *EM Data Processing*

Project staff reviewed the data set using EM Interpret™ Pro software a specialized software package designed to help the reviewer quickly process, evaluate, and report on fishing activity. The EM Interpret™ Pro software integrates imagery, sensor, and GPS records into a single synchronized profile, and presents it along a common timeline (Figure 7), so reviewers can quickly follow cruise tracks, review gear deployment and retrieval times and locations, and verify catch records. Key events, comments and observations were saved as annotations by the reviewer. All information was then stored in a relational database for analysis.

Sensor Data Processing

The first processing step was to use the sensor data to identify trip, haul time and location data and to determine when specific activities occurred (Table 5). Fishing activity start and end were identified by gear activity and vessel speed (Figure 7) using the same methods as in previous studies (Pria et al., 2011 and 2012). The EM reviewer documented the statistical area fished based on the start location of the haul.

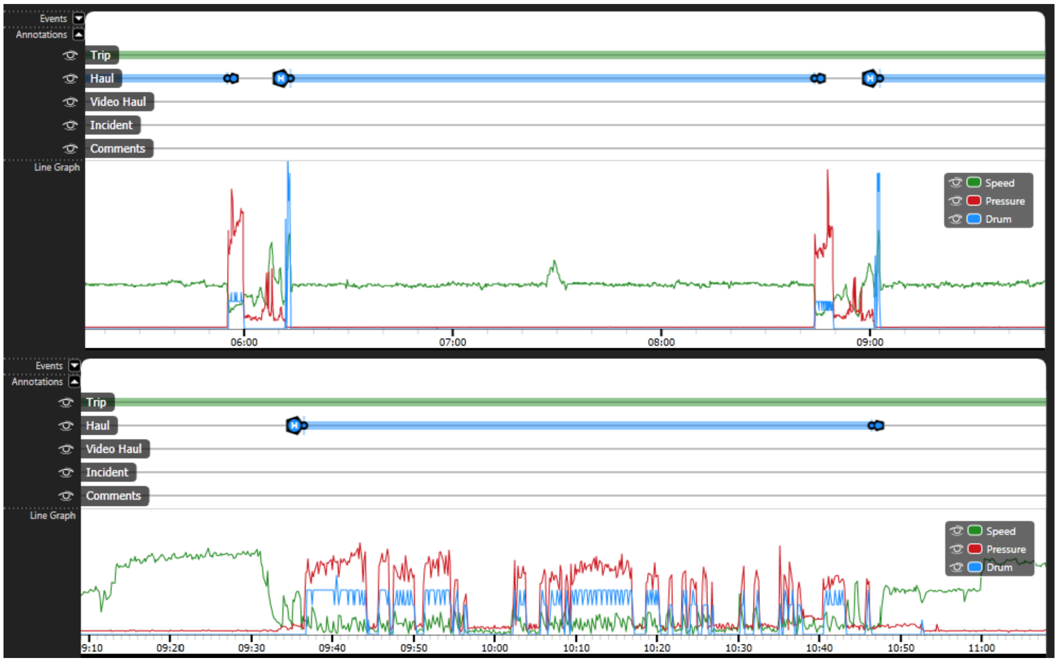

Figure 7: Example of typically haul activity as identified by sensor data (GPS, drum, and hydraulic sensors) for trawl (top) and gillnet (bottom) vessels.

Sensor data were used to determine the total time gaps; these gaps are defined as periods *within* the EM data sets for which data were expected, but not present. For example, sensor data should be present from the departure from port to return to port if the system was on during that time. Any period for which the data were not available is a time gap. Periods prior to the system being switched on, or after the system is switched off are not considered time gaps.

Table 5: Annotated sensor data types per trial.

Data Annotated	Audit Trial	Compliance Trial
Trip start and end date and time	✓	✓
Haul start and end date, time and location	✓	✓
Time gaps	✓	✓

Imagery Data Processing

Only one of the four reviewers, who included Archipelago and FSB staff, processed each data set. All imagery reviewers were trained in Northeast groundfish identification and EM imagery review. Reviewers documented species to the lowest taxonomic group possible (i.e., species) and used species groups (such as flounder, nk) when it was not possible to discern species.

The audit-based imagery was reviewed for each event only and not between events, whereas the compliance trial imagery was reviewed from the start of imagery until the end of the trip.

For the purposes of the trial, all usable imagery was reviewed to maximize data available for comparison and feedback, which is different from how an operational program would operate where only a portion of the data would be reviewed (see Part 1 for more details on the design models of the two trials).

Table 6 summarizes the data entered during EM imagery data processing under each trial.

Table 6: Annotated imagery data per trial.

Data Annotated	Audit Trial	Compliance Trial
Imagery quality	✓	✓
Total review time	✓	✓
Species identification, length measurement of groundfish managed species discards including: • Discarded flounder species that were not possible to identify to the species level (flounder, nk) • Discarded fish species that could not be identified to any species or group level (fish, nk)	✓	
Factors that restricted length measurement (i.e., curled fish, discard en masse, etc.)	✓	
Piece counts and identification for discarded individual catch items		✓
Allowable discards - pieces		✓
Non-allowable discards - pieces		✓
The species and number of any catch items that crew removed from camera view to the extent possible		✓
Date and time of codend tripping		✓
Discarding outside of hauls (i.e., transiting)		✓

While codend tripping, catch removed from camera view, and discarding outside of a specific haul catch handling were technically possible under an audit trial, as noted earlier, the audit trial focused on the comparison between EM and fishing log estimates of groundfish managed species discards and not on monitoring other discarding.

EM reviewers recorded the amount of time required to review each haul (for the audit trial) or trip (for the compliance trial). For the audit trial, review ratio is the time required to review a haul divided by the real catch handling time per haul.

For the compliance trial, the review ratio is the time required to review a trip divided by the total imagery duration per trip.

Length Measurement

The audit trial relied on measuring the length of each discarded catch item. Length estimates were collected using the length measurement tool in the EM Interpret™ Pro package. Length measurements were collected following the methods defined by Wigley et al. (2003) (see Appendix C for more detail). The length observations were converted to weight using combined-sex, length-weight conversion formulas derived from survey data (Wigley et al., 2003).

During processing, the reviewer calibrated the tool at the beginning of each trip and each time the discard chute (trawl) or sorting table (gillnet) appeared to shift in camera view (see Appendix C).

When the EM reviewer could not measure a fish, the fish was assigned the mean weight of all the measured pieces for that species observed for that haul, because a length-weight relationship could not be applied to groups of species. We summarize the frequency of this occurrence in the results along with the reason for each assessment. The EM reviewer documented and categorized the reasons that a fish could not be measured as described below and illustrated in Figure 8:

- *Curled* - fish was curled, therefore reducing the length on the screen;
- *Missing frame* - part of the fish was outside the camera view in the imagery available;
- *Discard en masse* - multiple fish were discarded simultaneously and either the mouth of the fish or the tail of the fish was not visible in the imagery available;
- *Human interference or chute interference* - part of the fish was not visible due to obstruction by the discard chute or crew member;
- *Poor image quality or missing frame* - low image quality caused the edge of the fish to be difficult to discern;
- *Not placed on measurement area* - fish did not pass across the measurement area prior to discard;
- *Outside grid* - the fish was visible in camera view partially or totally outside the calibration points on the measurement area;
- *Damaged*- the fish was damaged in a way that prevented measurement such as missing part of the head or tail;
- *Other* – the fish could not be measured for a reason not listed above.

Figure 8: Examples of imagery wherein fish could not being measured and the associated reason: curled fish (top left), outside of grid (top right), poor image quality due to water spots (bottom left) and discarded en masse (bottom right). Imagery used with captain's permission.

Imagery Quality Assessment

Reviewers assessed the imagery quality when reviewing the data. The imagery was assessed collectively and included all cameras. The imagery quality rating was given for each haul for the audit trial and for each trip for the compliance trial. Categories included:

- High - imagery was very clear and the reviewer had a good view of fishing activities. The focus was good, light levels were high, and all activity was easily seen.
- Medium - imagery was acceptable but there were some minor difficulties assessing discards such as slight blurring or slightly darker conditions.
- Low - imagery was difficult to assess, but fishing activity could still be discerned. For example, imagery was somewhat blurred or lighting was greatly diminished.
- Unusable - imagery was poorly resolved or obstructed such that fishing activity could not be reliably discerned. Imagery was not processed and used in comparisons.

2.2.8.3 *EM to Fishing Log Comparisons*

Archipelago produced a trip report for each completed trip. This report contained a summary of catch comparisons (discarded groundfish managed species for the audit trial and all discarded catch for the compliance trial), haul date, time and location comparisons and feedback to the captain. For the purposes of these trials, we considered the EM data to be the standard and compared the fishing log data against the EM data.

The EM and fishing log data were compared for the event start and end locations (nautical miles) and the event start and end time (minutes). EM fishing location was assumed to be correct (GPS is accurate to within three meters, see Garmin International, 2005, and activity was confirmed from sensor and imagery data). If the EM and fishing log reported the same statistical area for a haul, the area fished was reported as 'correct.' If the EM and fishing log statistical areas were not the same it was reported as 'incorrect.' EM data are used as the benchmark and assumed to be correct for this comparison.

For the purposes of this study, unusable imagery was excluded from the catch comparisons.

For the audit trial, project staff compared the fishing log to EM for the discarded groundfish managed species piece counts and weights recorded per event. The EM versus fishing log piece count and weight comparisons were examined with simple predictive linear regressions and scatter plots in Microsoft Excel, with the EM data considered the independent (i.e., measured without error) variable. These analyses were used to assess bias and precision of the fishing log data compared to EM data (Table 7). These tests were conducted to look for impact of gear, volume of discards, vessel, species groupings and species on the precision and bias of fishing log data.

Table 7: Summary of fishing log to EM catch comparisons tests conducted for the audit trial. Tests were only conducted when there were more than 14 comparisons.

Test	Comparison Level	Catch Format	Species Groups	Reason For Test
1	Total catch by haul	Piece Counts	All species	Assess fishing log estimates at haul level for all species
1	Total catch by haul	Piece Counts	All species	Assess fishing log estimates at haul level for all species
1	Total catch by haul	Weight (lbs)	All species	Assess fishing log estimates at haul level for all species
1	Total catch by haul	Weight (lbs)	All species	Assess fishing log estimates at haul level for all species
2	Catch by species by haul	Piece Counts	Flounder species and other species*	Assess fishing log estimates for species groups
2	Catch by species by haul	Piece Counts	Flounder species and other species*	Assess fishing log estimates for species groups
3	Catch by species by haul	Piece Counts	Individual Species	Asses fishing log estimates for individual species
3	Catch by species by haul	Piece Counts	Individual Species	Asses fishing log estimates for individual species
4	Catch by species by haul	Weight (lbs)	Individual Species	Assess fishing log weight estimates when piece counts match
4	Catch by species per haul	Weight (lbs)	Individual Species	Assess fishing log weight estimates when piece counts match

*Flounder species include: Yellowtail Flounder, Winter Flounder, Witch Flounder, American Plaice Flounder and Windowpane Flounder. Other species include: Atlantic Cod, Ocean Pout and Red/White Hake

For the compliance trial, EM imagery was reviewed to verify compliance with retention rules. The comparison of fishing log versus EM catch data at the haul level was conducted when one or both data sources had a recorded observation for allowable or non-allowable discard categories. The EM reviewer did not report catch weight, therefore comparisons are based on the reported presence or absence of species based on the EM and fishing log data. Data compared are:

- Non-allowable discards (catch that should have been landed during the compliance trial as dockside discards) were compared by event as noted by the EM reviewer and the fishing log (EM and fishing log in pieces);
- Allowable discards at sea of skates were considered a “match” if both the fishing log and EM data had an observation (EM in pieces, fishing log in weight);
- Allowable discards were considered a “match” if both the fishing log and EM data had an observation (EM and fishing log in pieces).

2.2.8.4 *Reviewer Comparisons*

To assess the consistency of reviewer species identification and piece counts, four hauls from the audit trial trips were randomly selected for review by all four imagery reviewers (FSB and Archipelago). Comparisons were carried out twice during the trial. Early in the trial, two hauls were chosen from Vessel A and midway through the trial two hauls were chosen from Vessel B.

Reviewers were instructed to document all observations of groundfish managed discards. For the second set of comparisons, reviewers were asked to also record all flounder species, even the ones identified as non-groundfish managed species.

Data sets generated from each reviewer were then compared against each other to determine consistency in species identification and piece count. Results were presented and discussed amongst the reviewers to improve consistency.

2.2.9 Captain Exit Interviews: Phase I to III

The FSB conducted exit interviews utilizing a structured questionnaire for all participating vessels in all three phases of the study. The purpose of the questionnaire was to solicit feedback on the project and the captain's experience with EM.

The feedback was collected during informal interviews that occurred when a vessel exited the study or when the final study data collection period ended (October 2013). Typically, the interview occurred on the day the equipment was removed from the vessel.

Exit interviews cover the entire study period, and not only Phase III of the project. There were 13 participating vessels throughout all three phases of the study (May 2010 – October 2013) (Table 8).

Table 8: Vessel participation including install and removal dates and the project phases each participated in. Phase I took place from March 2010 to August 2011. Phase II took place from September 2011 to November 2012. Phase III took place from October 2012 to November 2013.

Vessel	Installation Date	Removal Date	Participation (Project Phases)
Vessel 1	4/26/10	10/24/13	I, II
Vessel 2	4/28/10	08/20/13	I, II
Vessel 3	4/23/10	11/06/13	I, II, III
Vessel 4	7/21/10	11/18/13	I, II, III
Vessel 5	7/16/10	12/21/10	I
Vessel 6	7/19/10	01/08/12	I, II
Vessel 7	7/22/10	10/30/13	I, II, III
Vessel 8	10/02/10	11/05/13	I, II, III
Vessel 9	10/04/10	10/11/11	I
Vessel 10	10/06/10	06/17/11	I
Vessel 11	04/21/11	08/01/13	I, II
Vessel 12	06/06/11	11/01/13	I
Vessel 13	06/23/11	10/18/13	I

Timing of feedback was dependent on when the vessel actually participated in the study. Furthermore, the summary presented is not phase-specific, but rather relates to the entire project or the period the vessel participated in the study. For this reason, some of the feedback presented relates to project elements that are not part of the results of Phase III. While the scope of the exit interviews goes beyond the Phase III field trials, we present it here as the feedback collected throughout the project was instrumental in the refinement of project research objectives for each phase and helps provide a better understanding of the EM system.

2.2.9.1 *Format of Questionnaire*

The questionnaire format was chosen because the method was simple to implement and summarize, promoted individual contact, and minimized burden to captains as the process occurred during the equipment removal, when the captain was already present. A set of open-ended questions included topics such as equipment functionality and accessibility, information or questions the participants wanted the project to address, ability of EM to meet monitoring needs, and operational feasibility and preference for EM. These questions were used to allow the captain to formulate his own answer based on his personal experience with EM and the project.

The interview process was implemented verbally in a manner suitable for an open and candid conversation with study participants. All questionnaires were facilitated by one of three FSB staff members, who were affiliated with the EM study and had a working relationship with the study participants.

The summary of answers presented in this report includes aggregated questions and associated answers.

2.3 Results

2.3.1 Operational Performance

2.3.1.1 *Data Collected and Processed*

During the audit trial, the EM systems collected 848 hours of EM sensor data from 91 trips and 266 hauls across all three vessels (Table 9). EM imagery was processed for 245 of the 266 hauls (21 hauls were not processed, see Table 11). During the compliance trial, the EM systems collected 65 hours of sensor data across 8 trips and 21 hauls, of which 20 hauls were processed (Table 9).

Table 9: Summary of total EM sensor data collected by totals hours for trips and hauls and EM sensor data completeness by the time gaps for each of the trials.

Vessel	Total Trips	Trip Duration (hrs)	Total Hauls	Haul Duration (hrs)	Total Hauls Processed	Total Time Gaps	Time Gap Hrs
Audit Trial							
Vessel A	26	233	77	138	71	0	0
Vessel B	40	396	124	176	111	4	0.14
Vessel C	25	219	65	68	63	7	0.35
Total	**91**	**848**	**266**	**382**	**245**	**11**	**0.49**
Compliance Trial							
Vessel C	5	37	12	10.5	11	1	1.2
Vessel D	3	28	9	13.3	9	0	0
Total	**8**	**65**	**21**	**23.8**	**20**	**1**	**1.2**

Data completeness within trips was greater than 99% of the total trip durations (i.e., out of approximately 914 hours that the vessels were at-sea there were 1.7 hours of data missing). There were 11 time gaps that amounted to a total of less than half an hour for the audit trial and only one time gap of 1.2 hours from the compliance trial (Table 9). The 1.2 hour gap on Vessel C was caused by the captain turning the EM system off to avoid interference between it and the vessel's VMS system, which caused problems with VMS reporting. This interference issue was resolved by shielding the EM system and running camera cables through different wire runs from those of the VMS cables.

Fishers were requested to turn the EM system on when leaving port and leave it on until the vessel had returned to port. However, sometimes fishers forgot to turn on the system until they were outside of port or turned it off before arrival to port. Vessel reliability for turning on the EM systems before departure from port varied from 46% of the departures captured for Vessel A to 100% of the departures captured by Vessel C for both trials (Table 10). There was better success with keeping the EM systems on until returning to port, with the number of returns captured ranging from 73% to 100% across all vessels in both trials (Table 10).

Table 10: Vessel compliance with turning on EM systems at the start of the trip summarized by the number of departures and returns captured across all the trips for each of the trials.

Vessel	Total Trips	Total Departures Captured	Percent Departures Captured	Total Returns Captured	Percent Returns Captured
Audit Trial					
Vessel A	26	12	46%	19	73%
Vessel B	40	34	85%	40	100%
Vessel C	25	25	100%	22	88%
Total	**91**	**71**		**81**	
Compliance Trial					
Vessel C	5	4	80%	5	100%
Vessel D	3	3	100%	3	100%
Total	**8**	**7**		**8**	

For the audit trial, of the 245 hauls that were processed, 181 hauls had reported discards from either EM or fishing logs and were included in the EM to fishing log catch piece count comparisons. Only a subset of these (n = 154) had weights from both data sources. For Vessels A, B and C there were 66, 104 and 11 comparable hauls, respectively for the EM to fishing log piece count comparisons. The EM to fishing log weight comparisons (154 hauls) consisted of 65, 82 and 7 comparable hauls from vessels A, B and C, respectively.

2.3.1.2 *Imagery Quality*

Imagery quality was rated as medium or high for 116 of the 245 processed hauls that were assessed for imagery quality. There were 128 hauls rated as low imagery quality out of 245 processed hauls. The imagery from only one haul was rated as unusable across all hauls in the audit trial (Table 11).

Discarding en masse occurred in three hauls, of which two came from Vessel A. Image data was incomplete for 18 hauls, of which 12 came from Vessel B. The incomplete hauls for Vessel B were caused by incorrect set-up of the EM software imagery triggers for this vessel at the start of the program. The six other incomplete hauls were caused by power loss to the EM system or the vessel returning to port before catch processing was complete, which caused the EM system to stop recording (called a "port box trigger").

Table 11: EM imagery data collection and image quality rating by number of events for each of the participating vessels in the audit trial.

Vessel	Total Hauls	Processed Hauls				Not Processed	
		High	Medium	Low	Unusable*	Discarded En Masse	Incomplete Imagery
Vessel A	77	13	15	42	1	2	4
Vessel B	124	41	16	54	0	1	12
Vessel C	65	25	6	32	0	0	2
Total	**266**	**79**	**37**	**128**	**1**	**3**	**18**

*Unusable hauls catch data were not used in the catch comparisons.

Specific reasons for the low or medium image quality during the audit trial included environmental issues such as water spots on the lens (n=72 hauls) and sun glare (n=42 hauls), as well as dirt on the lens (n=29 hauls) and poor camera angles (n=19 hauls).

In the compliance trial, image quality was low or medium for seven of the eight trips and only one trip was rated as having high image quality (Table 12), but all events were usable for review. Reasons for low and medium ratings were poor camera angles (n=3 trips), sun glare (n=1 trip) and dirty lens (n=2 trips).

Table 12: EM imagery data collection and image quality rating by trip for the two participating vessels in the compliance trial.

Vessel	High	Medium	Low	Unusable	Total Trips Processed
Vessel C	0	3	2	0	5
Vessel D	1	1	1	0	3
Total	**1**	**4**	**3**	**0**	**8**

2.3.1.3 *Data Turnaround and Retrievals*

For the audit trial, the turnaround time from the end of the trip to completion of the trip report across all three vessels ranged from 0-10 days for 37% of the trips and 11-20 days for 52% of the trips (Figure 9). The turnaround time was >30 days for only 4% or three trips. For the compliance trial, the turnaround time averaged five days and ranged from two to 11 days.

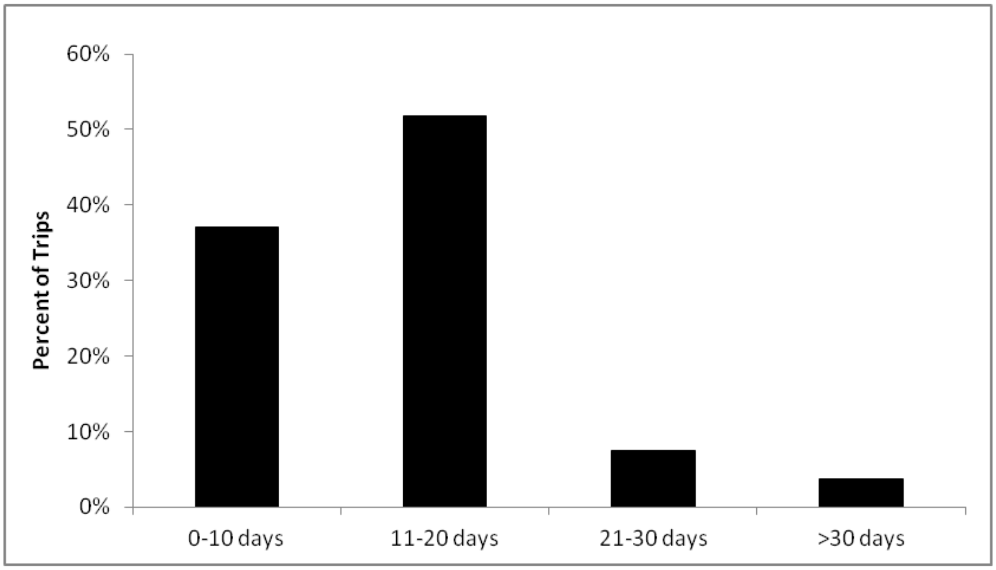

Figure 9: Turnaround time from end of trip to completion of trip report across all three vessels for the audit trial.

During the audit trial, mean time for data retrieval services was 0.87 hours and ranged from 0.25 to 1.25 hours. During the compliance trial, mean time for data retrieval services was 0.43 hours and ranged from 0.25 to 1.00 hour (see Table 29 for DSM processing time).

2.3.2 EM and Fishing Log Area Comparisons

The mean difference between EM and fishing logs for the location of the haul start and end was within 3.36 nm across all three vessels for the audit trial, but as low as 0.36 nm for Vessel A (Table 13). The mean time differences in the haul start and end ranged from approximately 4 to 52 minutes.

For the compliance trial, the mean difference between EM and fishing logs for the location of the haul start and end was within 0.19 nm. Mean time differences between EM and fishing log start and end time ranged from 1 minute (Vessel C) to 13 minutes (Vessel D) (Table 13).

Fishing log data for statistical areas fished was correct (i.e., EM and fishing log matched) for 155 of the 177 comparable hauls across all three vessels from the audit trial (Table 14). The area recorded in the fishing logs did not match EM for 22 hauls across Vessel A and B. When plotting the location information provided by the fishing log, 21 of the 22 incorrect hauls had the start location recorded in the fishing log in the same statistical area as recorded by EM (both EM reviewers and captains were instructed to record the area fished based on the haul start position). Of these, 13 hauls occurred across two statistical areas and the fishing log area corresponded to the area where the haul ended rather than where it started. For the remaining nine hauls, the statistical area recorded in the fishing log did not match the positional data recorded in the fishing log or EM. Only one of the incorrect hauls was due to a difference in the fishing log and EM positional data, with a difference of 1.94 nm for the haul start.

The statistical area fished was not recorded in the fishing log for 16, 38 and 32 hauls for vessels A, B, and C, respectively. This represented 21%, 31% and 49% of the total hauls for vessels A, B, and C, respectively.

Fishing logs area fished for the compliance trial was correct for 13 of the 20 comparable hauls, of which all 9 hauls for Vessel D were correct (Table 14). For Vessel C, the areas fished for 4 of the 11 comparable hauls were correct, but no area was recorded in the fishing log for the remaining 7 hauls.

Table 13: EM to fishing log comparisons for the mean haul start/end positions differences (nm) and mean start/end time difference (minutes) for all hauls that had location or time entered in the fishing log.

		Position Difference (nm)				Time Difference (minutes)			
	Total Hauls	Start		End		Start		End	
Audit Trial		n	Mean Difference	n	Mean Difference	n	Mean Difference	n	Mean Difference
Vessel A	77	73	0.36	74	0.09	74	3.64	73	4.43
Vessel B	124	121	1.21	120	0.54	122	45.43	122	38.91
Vessel C	65	35	1.93	35	3.36	35	8.38	35	51.79
Compliance Trial									
Vessel C	11	10	0.13	11	0.1	11	13.09	11	4.09
Vessel D	9	9	0.08	9	0.19	9	1.33	9	1.22

Table 14: EM to fishing log comparisons by statistical area of fishing activity for both trials. When EM and fishing log were the same the fishing log was considered correct, and when they were different it was considered incorrect.

Vessel	Total Hauls	No Log Area Recorded	Total Comparable Hauls Correct	Total Comparable Hauls Incorrect
Audit Trial				
Vessel A	77	16	49	12
Vessel B	124	41	73	10
Vessel C	65	32	33	0
Total	**266**	**89**	**155**	**22**
Compliance Trial				
Vessel C	11	7	4	0
Vessel D	9	0	9	0
Total	**20**	**7**	**13**	**0**

2.3.3 Audit Approach

2.3.3.1 *EM and Log Catch Comparisons*

Overall, there was consistent catch underestimation by fishing logs in all tests. The slope (*b*) ranged from 0.269 to 0.936 but was always less than 1.0 (Table 15). For example in Test 1-Vessel A, the slope is 0.31, therefore (given the low intercept value) the fishing logs estimates tended to be only 31% of EM estimate of piece counts (Figure 10 and Table 15). Note the points lie consistently below the reference 1:1 line. Not surprisingly the absolute variance tended to increase with the amount of catch in all tests (Figure 10 to Figure 12).

Table 15: Results from fishing log to EM catch comparisons tests across all tests for Vessel A and B for the audit trial. Vessel C was not included because there was insufficient data for comparison (11 comparable hauls with reported discards by EM and fishing log). Tests were only conducted when there were more than 14 comparisons.

Test	Figure	Catch Form	Vessel	Species groups	Number of Comparisons (n)	Slope	Intercept	R^2
1	10	Piece Counts	A	All species	66	0.315	37.05	0.38
			B	All species	104	0.794	-0.41	0.88
	10	Weight	A	All species	65	0.269	10.46	0.36
			B	All species	82	0.797	8.19	0.89
2	11	Piece Counts	A	Flounder species	149	0.454	8.54	0.62
				Other species	53	0	0.55	0
	11	Piece Counts	B	Flounder species	239	0.909	4.03	0.95
				Other species	100	0.497	1.52	0.57
3	12-A	Counts	A	Winter flounder	64	0.502	4.56	0.66
	12-B			Red/White Hake n/a Piece	38	0	n/a	
	12-C			Yellowtail flounder	14	0	n/a	n/a
	12-D			Windowpane Flounder	66	0.381	23.7	0.41
	12-E			Ocean Pout	15	0.894	0.346	0.66
	12-A	Piece Counts	B	Winter flounder	91	0.719	0.512	0.92
	12-B			Red/White Hake	92	0.495	1.73	0.56
	12-C			Yellowtail flounder	40	0.66	0.75	0.9
	12-D			Windowpane Flounder	104	0.936	9.15	0.93
4	13	Weight	A	Windowpane Flounder and Winter Flounder	24	0.495	3.1	0.87
	13		B	Ocean Pout, Windowpane Flounder and Winter Flounder	45	0.778	0.03	0.98

Vessel A results indicated a larger underestimation bias than those for Vessel B for all tests (Table 15). Vessel C did not have enough data for the tests and therefore was not included in the catch comparisons. Tests 2 and 3 indicated that bias and precision improved with broader species groupings as compared to estimating individual species (Figure 11 vs. Figure 12).

Windowpane and Winter Flounder were least biased for Vessel B, but remained poor for Vessel A (Table 15 and Figure 12). For Red/White Hake or Yellowtail Flounder, the slope indicates 0 for Vessel A because there were no associated piece counts recorded in the fishing logs.

It is worth noting that some tests could be expected to have poor results (Test 3 and Figure 12), because captains were only required to record White Hake (some chose to record other species) whereas EM reviewers used the general "Hake, nk" category. The large differences for both day-trawl vessels is likely due to the fact that Red and White Hake could not be distinguished by the EM reviewers so the two species were grouped together while the captains were only required to document White Hake because Red Hake is not a groundfish managed species, although some recorded both species.

In examining the importance of piece counts on weight comparisons (Test 4), the bias and precision improved in cases where piece counts matched within 10% (Table 15 and Figure 13) as when compared to all hauls (Figure 10). While these results are not surprising, they serve as demonstration of the importance of accurate piece counts by both EM and fishing logs when used for weight comparison in an audit trial.

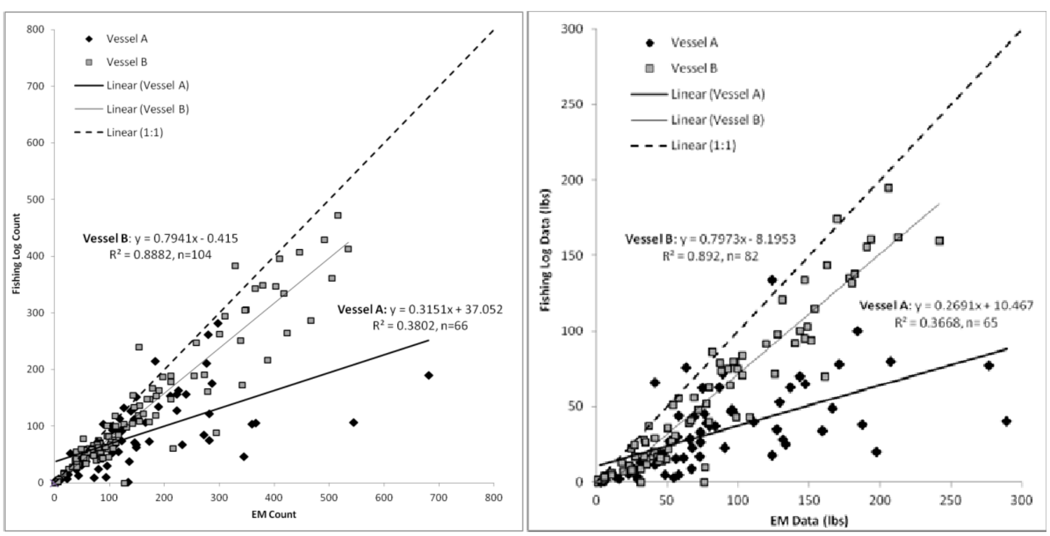

Figure 10: Fishing log to EM total piece count (left) and weight (right) comparisons by haul for the two day-trawl vessels (Vessel A and B) in the audit trial. Sample size represents the number of comparable hauls for EM to fishing log piece counts and weights. The dashed line is the 1:1 line.

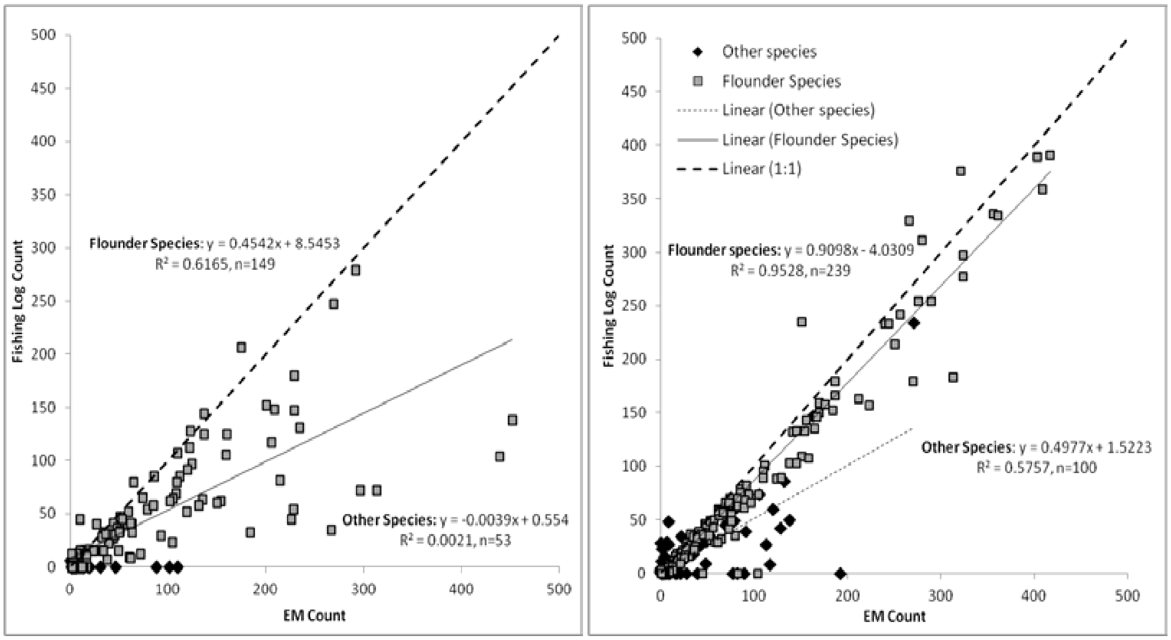

Figure 11: Fishing log to EM piece count comparisons for Vessel A (left) and Vessel B (right) for flounder species and other species. Flounder species includes; Winter Flounder, Yellowtail Flounder, Windowpane Flounder, American Plaice Flounder and Witch Flounder. Other species includes Ocean Pout, Red/White Hake and Atlantic Cod. Trend lines represent linear regression fits for each vessel.

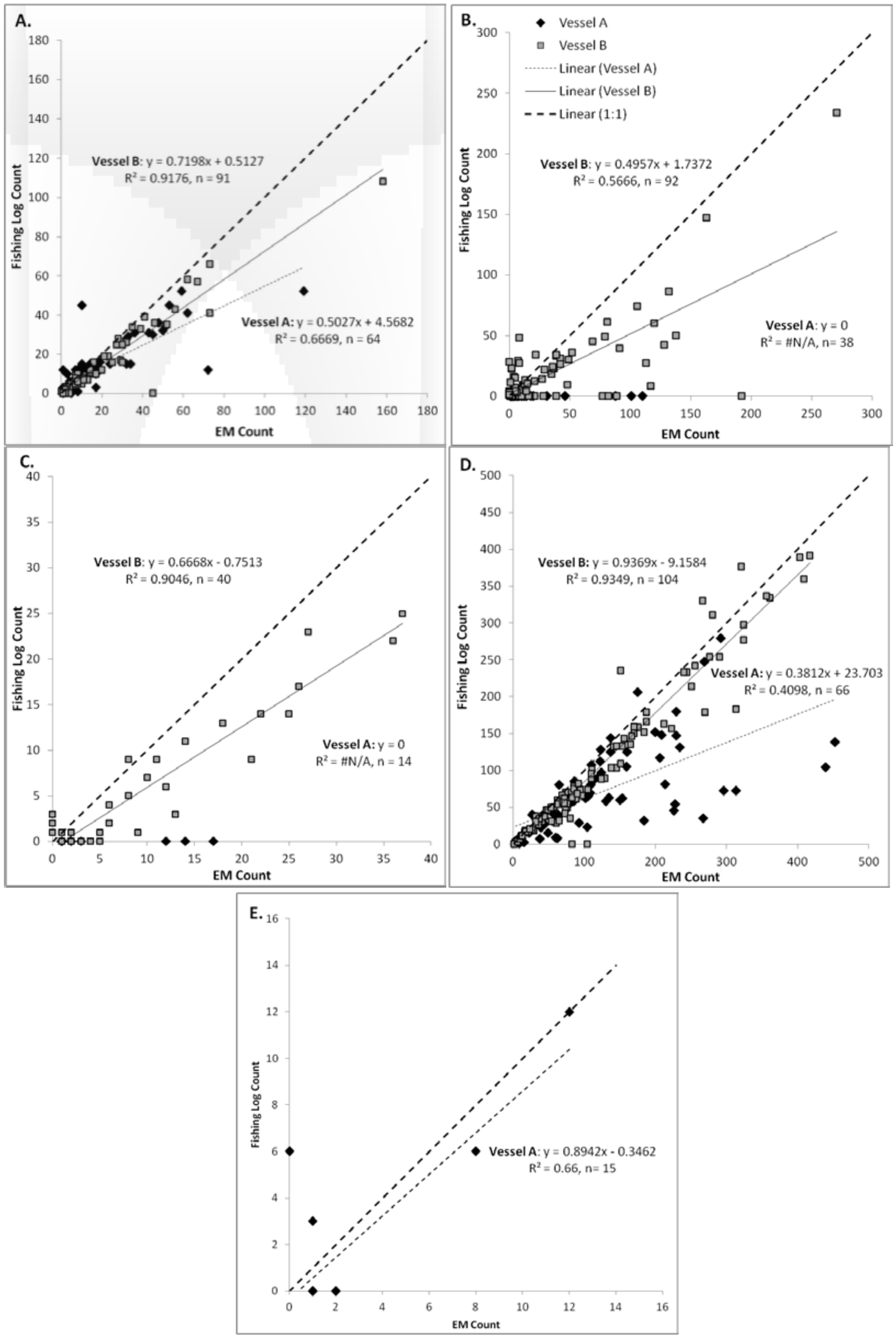

Figure 12: Fishing log to EM piece count comparisons for Vessel A and Vessel B by species for: A. Winter Flounder, B. Red/White Hake, C. Yellowtail Flounder, D. Windowpane Flounder and E. Ocean Pout. Trend lines represent linear regressions for each vessel.

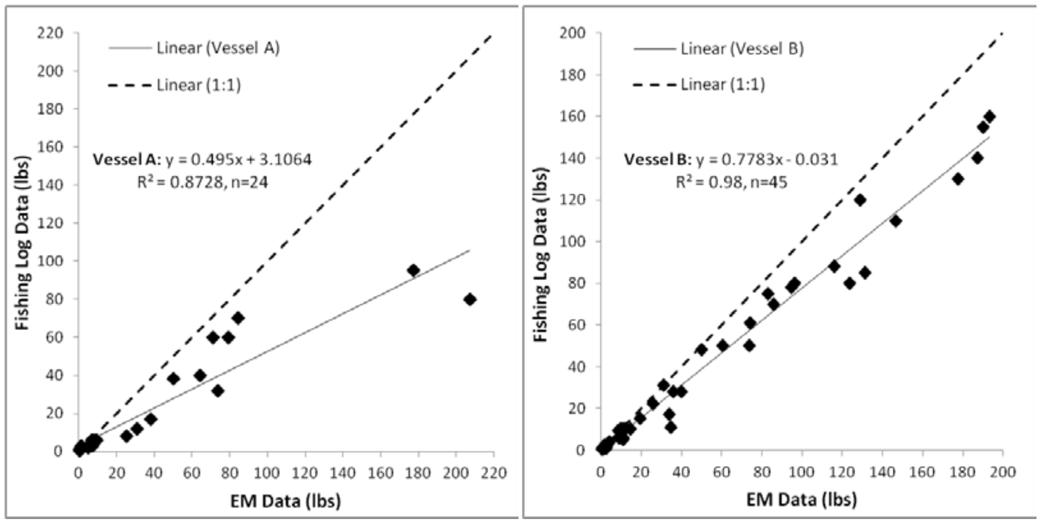

Figure 13: Fishing log to EM weight comparisons for Vessel A and Vessel B for Windowpane Flounder and Winter Flounder for Vessel A and Ocean Pout (Vessel B only). Trend lines represent linear regressions for each vessel, and sample size is the number of comparable hauls within 10% difference by piece count.

The overall results of the comparison between EM and fisher logs piece counts are summarized in Table 16. This provides a clearer picture of the scale of the underestimation bias. The previous figures showed that the bias was present throughout the trials and not the result of a few underestimated large catches.

Table 16: EM and fishing log comparisons of total piece counts and weight estimates (lbs) by species groups for Vessel A, B, and C for species that were observed by at least one method. Difference is EM minus the fishing log count or weight.

Vessel A	Piece Count				Weight (lbs)			
Species	Comparisons	EM	Log	Difference	Comparisons	EM	Log	Difference
American Plaice Flounder	3	3	-	3	1	0	0	0
Ocean Pout	15	36	27	9	3	16	15	1
Red/White Hake	38	566	-	566	-	-	-	-
Windowpane Flounder	66	8,376	4,757	3,619	64	4,861	1,873	2,988
Winter Flounder	64	1,163	877	286	61	699	300	399
Witch Flounder	2	2	-	2	2	2	-	2
Yellowtail Flounder	14	58	-	58	11	28	-	28
Total	**202**	**10,204**	**5,661**	**4,543**	**142**	**5,606**	**2,188**	**3,418**

Vessel B	Piece Count				Weight (lbs)			
Species	Comparisons	EM	Log	Difference	Comparisons	EM	Log	Difference
American Plaice Flounder	4	6	-	6	5	2	0	2
Atlantic Cod	1	1	-	1	-	-	-	-
Ocean Pout	7	7	2	5	3	3	2	1
Red/White Hake	92	2,895	1,595	1,300	-	-	-	-
Windowpane Flounder	104	12,303	10,574	1,729	79	5,710	4,035	1,675
Winter Flounder	91	1,423	1,071	352	72	814	510	304
Yellowtail Flounder	40	351	204	147	20	80	51	30
Total	**339**	**16,986**	**13,446**	**3,540**	**179**	**6,609**	**4,598**	**2,012**

Vessel C	Piece Count				Weight (lbs)			
Species	Comparisons	EM	Log	Difference	Comparisons	EM	Log	Difference
American Plaice Flounder	3	5	6	-1	3	4	6	-2
Atlantic Cod	6	9	9	0	4	18	6	12
Atlantic Halibut	3	5	2	3	-	-	-	-
Atlantic Wolffish	1	-	1	-1	1	-	5	-5
Haddock	1	1	1	0	1	-	5	-5
Yellowtail Flounder	3	1	2	-1	1	-	1	-1
Total	**17**	**21**	**21**	**-**	**10**	**22**	**23**	**-1**

2.3.3.2 *Reviewer Feedback*

Reviewer feedback regarding the onboard methodology compliance during the audit trial identified 58 hauls during which non-control point discards occurred, of which 57 came from Vessels A and B. Reviewers identified 61 and 96 hauls for Vessels A and B respectively, in which groundfish managed species were not fully sorted by the crew. Catch removed from the camera view was noted in only three hauls across Vessel B and C. Vessel C only had one haul identified where non control point discards were observed and one haul where catch was removed from view (Table 17).

Table 17: Summary of feedback from imagery review for use of onboard methodologies for each of the participating vessels in the audit trial.

Vessel	Hauls	Non-Control Point	Not Sorted	Removed From View	No Issues
Vessel A	71	26	61	0	4
Vessel B	111	31	96	2	7
Vessel C	63	1	n/a	1	61
Total	**245**	**58**	**157**	**3**	**72**

Note: The totals do not represent unique hauls because more than one type of feedback may have been provided during a single haul.

Length Measurement

For vessels A, B and C, 57.3%, 79.4%, and 6.1%, respectively, of the discarded groundfish managed species were measured using the length measurement tool during imagery review (Table 18). This amounted to 70.4% of the total discarded groundfish managed species across all three vessels. Vessel C had the highest percent of discarded groundfish managed species that were not measured at 93.9%, however due to the low volume of reported discards for Vessel C this only amounted to 115 pieces. Damaged fish was the most common reason (71.3%) that discarded groundfish managed species could not be measured for Vessel C (Table 18). Discard en masse accounted for 23.5% of the not-measured discarded groundfish managed species for Vessel A. For Vessel B, reduced image quality accounted for 9% of the 20.6% discarded groundfish managed species that were not measured (Table 18).

Table 18: Summary of feedback from imagery review (include high medium and low quality imagery) of the fate (disposition) of discarded catch by percent of total piece counts for each of the participating vessels and processed hauls in the audit trial.

	Vessel A	Vessel B	Vessel C
Measured Total (%)	57.3	79.4	6.1
Not Measured by Category			
Chute Interference	0.7	0.2	0.0
Discard En Masse	23.5	4.8	0.0
Curled	6.8	4.8	0.9
Damaged	0.3	0.4	71.3
Human Interference	0.0	0.0	0.0
Poor Image Quality	8.3	9.0	13.0
Missing Frame	0.1	0.0	0.0
Outside Grid	2.5	0.8	0.9
Other	0.5	0.5	7.8
Not Measured Total (%)	**42.7**	**20.5**	**93.9**

2.3.3.3 *Review Ratio: Audit Approach*

It required 343 hours to review 206 hours of fishing activity across the two day-trawl vessels for a review ratio of 1.66. Whereas the review ratio was only 0.50 (33 hours/67 hours) for the gillnet vessel or about 1/3 that of the two trawl vessels (Table 19). The mean review time of one haul was 1.9 hours for trawl hauls and 0.5 hours for gillnet hauls.

Table 19: Total imagery duration (hours), imagery review time (hours), and imagery review ratios (the total review hours divided by the total duration imagery duration) by vessel and gear type for the audit trial. Note that this table does not include the haul classified as unusable.

	Total Imagery Duration	Imagery Review Time	Review Ratio	Mean Ratio	Standard Dev	Number of Hauls
Day-Trawl						
Vessel A	88.97	157.33	1.77	1.87	0.84	70
Vessel B	116.98	185.25	1.58	1.60	0.57	111
Total Trawl	**205.95**	**342.58**	**1.66**	**1.70**	**0.70**	**181**
Gillnet						
Vessel C	67.11	33.48	0.50	0.51	0.24	63

2.3.3.4 *Reviewer Comparisons*

The first set of comparisons among reviewers was highly variable for piece counts among species and among species groups (Table 20). Haul 1 piece counts of Windowpane Flounder were consistent among reviewers (roughly 84 pieces) whereas the piece counts of flounder, nk were highly variable (from 1 to 41; Table 20).

Table 20: Piece counts by species groups for all four reviewers for Haul 1 and 2 from Vessel A.

Vessel A	Haul 1				Haul 2			
Event 1	**R1**	**R2**	**R3**	**R4**	**R1**	**R2**	**R3**	**R4**
Flounder, American Plaice	1	0	0	0	1	0	0	0
Flounder, Windowpane	81	85	82	86	87	39	75	137
Flounder, Winter	13	8	17	15	6	2	11	8
Flounder, Witch	4	0	0	0	0	0	0	0
Flounder, Yellowtail	0	9	0	0	1	2	0	0
Flounder, nk	14	1	41	2	45	87	83	11
Total Flounder	**113**	**103**	**140**	**103**	**140**	**130**	**169**	**156**
Red/White Hake	0	1	0	1	0	0	0	2
Other	0	0	0	0	2	3	2	2
Total Piece Count	**113**	**104**	**140**	**104**	**142**	**133**	**171**	**160**

The second set of comparisons were less variable among total flounder species (Table 21), with the exception of Reviewer 3, who identified more catch to flounder, nk than the other reviewers. When reviewing Haul 3, the count that Reviewer 1 provided for Hake was roughly half that of other reviewers (Table 21).

Table 21: Piece counts by species groups for all four reviewers for Haul 3 and 4 from Vessel B.

Vessel B	Haul 3				Haul 4			
Event 3	**R1**	**R2**	**R3**	**R4**	**R1**	**R2**	**R3**	**R4**
Flounder, Fourspot	68	78	3	84	83	90	0	94
Flounder, Windowpane	321	317	314	324	314	316	309	318
Flounder, Summer	1	1	0	2	43	46	46	51
Flounder, Winter	62	67	65	71	27	27	28	31
Flounder, nk	21	8	83	0	10	10	88	2
Total Flounder	**473**	**471**	**465**	**481**	**477**	**489**	**471**	**496**
Hake	80	158	197	162	38	49	54	41
Other	1	0	0	0	0	0	0	0
Total Piece Count	**554**	**629**	**662**	**643**	**515**	**538**	**525**	**537**

2.3.4 Compliance Approach

2.3.4.1 *EM Log Catch Comparisons*

The compliance trial comparisons focused on detection of non-allowable discards while at sea (Table 22). EM reviewers did not observe any incidents of codend tripping, or catch discarding outside of specific haul catch handling in any of the trips. EM reported seven non-allowable discard events while at sea for Vessel C, one of which the captain reported in the fishing log. EM review revealed 15 non-allowable discarded catch items across the five monitored trips for Vessel C (Table 22). EM reviewers did not detect any non-allowable catch discarding for Vessel D during the three monitored trips.

Table 22: EM to fishing log comparisons for non-allowable discards for Vessel C for five trips. All non-allowable discards were recorded by piece counts in the fishing log and EM data.

Species	EM Piece Count	Log Piece Count
Monkfish	3	0
Sea Raven	2	0
Dogfish, nk	5	0
Hake, nk	2	0
Lumpfish	1	1
Starfish, Seastar, nk	1	0
Crab, nk	1	0
Total	**15**	**1**

Note: EM did not detect any non-allowable discards by Vessel D.

EM and fishing logs agreed on the presence or absence of a given species for 115 of the 129 comparisons and did not agree for 14 of them across both vessels (Table 23). In most cases, captains were able to track dockside discards using the fishing logs.

Table 23: Catch comparisons of EM and fishing log allowable discards. Comparisons were done for each catch type and haul. EM+/Log – indicates that EM detected the catch but it was not recorded in the log, whereas EM- /log + indicates that EM did not detect the catch, but it was recorded in the fishing log.

Vessel	Trips	Hauls	Catch Type	Number of hauls in agreement		Number of hauls in disagreement	
				Present	Absent	EM +/Log -	EM - /Log +
Vessel C	5	11	Barndoor Skate	3	4	0	4
			Other Skate	10	0	1	0
			Mammals	0	7	4	0
			Atlantic Halibut	0	10	0	1
			Lobster	2	8	1	0
			Large Debris	0	11	0	0
Vessel D	3	9	Barndoor Skate	0	8	1	0
			Other Skate	9	0	0	0
			Mammals	0	9	0	0
			Atlantic Halibut	1	8	0	0
			Lobster	9	0	0	0
			Large Debris	0	8	1	0
			Torpedo Ray	0	8	0	1
Total	**8**	**20**		**34**	**81**	**8**	**6**

2.3.4.2 *Reviewer Feedback*

Reviewer feedback regarding the onboard methodology compliance from imagery review for Vessel C identified two trips with non-control point discards and two trips where the crew removed catch from camera view (Table 24). Vessel D had no events identified as non-compliant with predefined onboard methodologies.

Table 24: Summary of reviewer feedback from imagery review for the use of onboard methodologies by trip for each of the participating vessels.

Vessel	Non Control Point	Not Sorted	Removed From View
Vessel C	2	0	2
Vessel D	0	0	0
Total	**2**	**0**	**2**

EM reviewers documented discarded catch items, discarded damaged catch items and items that were removed from camera view. Vessel C, the gillnet vessel, recorded fewer discards than Vessel D. Vessel C had 164 pieces of catch recorded as removed from camera view, meaning that the EM reviewer could not determine whether the piece was retained or discarded. Only nine damaged discards were observed between the two vessels, all of which occurred on Vessel C (Table 25).

Table 25: Summary of the fate of catch by total piece counts identified during imagery review. Note that only the categories listed below were used and retained catch was not documented by EM.

Vessel	Discarded	Damaged	Removed from Camera View
Vessel C	27	9	164
Vessel D	500	0	0
Total	**527**	**9**	**164**

Monkfish accounted for the largest number of pieces removed from camera view for Vessel C (Table 26). In addition to Monkfish, American Lobster, crab and skate made up the four most common catch items that were removed from view. These catch items were moved out of view due to the lack of an overall deck camera (not included at the captain's request due to privacy concerns). The only groundfish managed species that were removed from view include one Hake, nk (not confirmed to be White Hake), and one Atlantic Cod.

Table 26: Summary of species and species groups identified as removed from view during imagery review for Vessel C. Note, this was not recorded in the fishing logbook.

Species Groups	EM Piece Count Removed from Camera View
Monkfish (Angler, Goosefish)	72
Skate, nk	30
Crab, nk	1
Crab, Cancer, nk	19
Hake, nk	1
Cod, Atlantic	1
Fish, nk	8
Lobster, American	31
Dogfish, Spiny	1
Total	**164**

2.3.4.3 *Review Ratio: Compliance Approach*

Mean review ratios by trip were similar between the two vessels in the compliance trial at 0.48 and 0.36 for gillnet Vessel C and trawl Vessel D, respectively (Table 27). The mean review time of one trip was 2.5 hours for trawl trips and 2.2 hours for gillnet trips.

Table 27: Imagery review duration per trip (hours), imagery review time (hours), and review ratios for each of the vessels for the compliance trial.

Vessel	Imagery Duration by Trip	Imagery Review Time	Review Ratio
Vessel C	7.1	5.0	0.70
	5.3	1.6	0.30
	3.3	2.5	0.76
	3.1	1.3	0.42
	7.0	2.0	0.29
Vessel C Total	**25.8**	**12.4**	**0.48**
Vessel D	6.3	2.3	0.37
	6.3	2.3	0.37
	5.5	2.0	0.36
Vessel D Total	**18.1**	**6.6**	**0.36**

2.3.4.4 *Dockside Monitoring*

Dockside monitors collected offload catch data for all dockside discards during offloads for the eight compliance trial trips (Table 28) (see Appendix F). Vessel C's dockside discards ranged from 8 to 84 lbs per offload and Vessel D's dockside discards ranged from 90 to 553 lbs per offload (Table 28). Vessel C had few discards due to the fact that it was fishing with large mesh gillnet and trial included other fish species (e.g., Fourspot Flounder, Longhorn Sculpin and Sea Raven) and non-fish species (e.g., sponge, rock crab, scallops, starfish).

Table 28: Range of landed dockside discard weights (lbs) by catch type by trip for Vessel C and D.

	Vessel C	Vessel D
Catch Type	**Range (lbs)**	**Range (lbs)**
Trip Limited	0-28	0
Prohibited*	0	3-11
ACE	0-15	22-49
Other fish	7-72	27-116
Non-fish	0-12	8-385
Debris	0	0-5
Total Dockside Discards	**8-84**	**90-553**

* DSM data included Windowpane Flounder. Note that Windowpane Flounder and Ocean Pout, although usually prohibited, were required to be landed for the compliance trial.

The dockside monitor took between 0.2 and 1.2 hours to complete catch processing per trip (Table 29). Vessel C's catch processing times were consistent with a mean time of 0.24 hours. Vessel D's catch processing times were longer with a mean time of 1.07 hours due to higher catch volumes. This translates to 0.3 minutes of DSM sampling per pound of dockside discards for Vessel C and 0.1 minutes per pound of dockside discards for Vessel D, not including travel and waiting time.

Table 29: Summary of travel, wait time and catch processing time (hours) associated with dockside monitoring services. DSM catch processing refers only to dockside discards. Numbers in parentheses represent the standard deviation.

Vessel	Gear Type	Trip Number	DSM Travel Time to Dock	Wait Time for Vessel to Land	DSM Catch Processing Time	Dockside Discards (lbs)
Vessel C	Gillnet	1	5.5	0.5	0.2	76
		2	5	0.5	0.3	84
		3	5.5	0.5	0.2	23
		4	4.5	0.5	0.2	19
		5	3	1	0.3	16
Mean			**4.7 (±1.03)**	**0.6 (±0.22)**	**0.24 (±0.05)**	**43.6 (±33.44)**
Vessel D	Trawl	1	2	0	1	200
		2	2.5	0.25	1.2	317
		3	2.5	0.75	1	1032
Mean			**2.33 (±0.28)**	**0.33 (±0.38)**	**1.07 (±0.11)**	**516.3 (±450.4)**

2.3.5 Captain Exit Interviews

Below is an aggregated summary prepared by FSB of the responses to the exit interviews.

Have you had any issues with the equipment? Do you think it is reliable?

Some participants had issues with the equipment and a few had no issues at all. The participants who had issues noted they improved over time. The range of issues reported included: power issues (vessel needed a new alternator, power surges, vessels with insufficient power to support EM, and alternating current that interrupted power to the control box), the need to repair and switch out control boxes due to malfunctioning systems, camera issues (camera module failure, cameras with static blue screens with no video recording due to internal component malfunctioning), GPS failure, low voltage readings related to power supply issues, software glitches associated with software upgrades or the switching out of control boxes, hydraulic sensor failure, VMS interference, and poor video quality when fishing at night. One participant stated there is a learning curve to the system but overall it was more user-friendly than other electronic reporting technologies. One participant liked that it was easy to run on a daily basis.

Most participants thought the equipment was reliable but a minority did not agree due to problems with the main control box which had to be replaced frequently. One participant noted the equipment is reliable except for minor adjustments and another said there should be a "shakedown" (e.g., adjustment or trial period) period if EM is implemented where the boat is provided time to work out any equipment issues. Another participant suggested a more durable housing unit for the cameras.

What kind of data would you like to see included in the report?

Participants would like to see how other data reporting systems (e.g., eVTR) or gear information (door sensors, etc.) could be incorporated into the system to reduce duplicate reporting. Participants were interested in comparisons of data at both the trip and haul level. In addition, comparisons of the captain's discard estimates (visual or scale) to EM discard weight estimates and if there was noted improvement overtime. Participants were interested in the percent of accuracy in identification of catch to the stock/species level and wanted to know which species were unidentifiable. Participants noted that higher catch volumes resulted in more time and effort for crew to track discards (e.g., catch handling). Participants who experienced radio frequency interference issues with the EM system and Skymate Vessel Monitoring Systems (VMS) were interested in additional information on interference and mitigating measures.

A majority of participants wanted cost estimates (specific to vessel size, gear type, fishery) for an operational program in order to compare program costs between programs (ASM and EM). In addition, identifying data needs and program requirements (for sector managers) was a primary request. Participants were interested in EM program requirements including, level or rate of necessary coverage, percent of video review required, and if there is flexibility to alternate between EM and ASM/NEFOP coverage throughout the year.

Would you recommend EM to other fishermen?

Most participants would recommend EM to other fishermen for groundfish and non-groundfish trips and smaller vessels, but have reservations if EM is more cost effective than an observer. Several participants thought the EM system was excellent, they liked it, adjusted to it well, liked the authentication EM provided, thought EM was a good idea, made more sense than putting a human observer onboard (safety concern associated with humans), and felt that EM was the best monitoring option (with no concerns around the accuracy of the system). Participants felt there was less conflict with EM and had no concerns for the treatment of their property compared to observers. One participant said they would only recommend EM if it was cheaper and produced good data. One fisherman stated that EM was a simple system and it was a matter of engaging the right people to accept and use EM. The participants found EM easier to plan around and more suited to the realities and nature of fishing.

One participant would not recommend EM because the project developed a poor reputation, not on its own merits but in combination with other political and logistical issues taking place in the Northeast simultaneously (quotas, observer coverage etc.). One participant stated that he tried to recommend EM to other fishermen but was told it was too much like "Big Brother." Participants noted the industry would be more receptive to EM if funding of monitoring costs shifted from the government to the industry.

Do you feel EM could sufficiently meet monitoring needs?

All participants felt that EM could sufficiently meet monitoring goals and indicated that some boats may need at least 5 cameras to capture everything. Participants commented that the cameras capture everything and are not biased. One participant thought the cameras could do better than observers in many cases with no gaps in coverage but the technology should keep up with improvements in the field, such as implementation of automated species identification.

If EM is approved, would you use it?

All participants answered yes and one commented that he would use EM only if he did not have to take observers (ASMs) as often. One fisherman said he would use EM even if it was slightly more expensive than observers.

2.4 Discussion

In the audit trial, current retention regulations were left in effect. Captains were asked to record haul details including date and time, location, piece count, and weight of discarded groundfish managed species. EM reviewers created a parallel version of the same information from EM data for comparison. A similar comparison was made in the compliance trial, except additional catch was retained and EM reviewers documented when at-sea discarding occurred but did not estimate the amount discarded, and DSMs sampled dockside discards when the vessel landed. We discuss the results below.

2.4.1 Operational Performance

2.4.1.1 *EM System Performance*

Data collection success within trips for the Phase III field trials was >99% indicating overall good EM system performance. Complete imagery data was collected for 93% of hauls. Incomplete hauls were mostly caused by incorrect set-up of the EM software imagery triggers for this vessel at the start of the program, followed by power loss to the EM system or the vessel returning to port before catch processing was complete, which caused the EM system to stop recording.

In general captains did a good job at keeping the EM systems powered during the entire fishing trip although some forgot to turn on their EM system when they left port or turned it off part way through the transit back to port. In one case, the EM system was powered down to avoid EM interference between the EM system and the Skymate™ VMS on Vessel C, which caused a 1.2 hour time gap.

Interference between the EM system and Skymate™ VMS had been observed on three other vessels during previous phases of the study and, with the exception of one vessel, the issue was addressed successfully by a combination of re-routing EM cables to be away from VMS cables (at least 30 cm apart), repositioning the GPS away from the VMS antenna and/or shielding the EM system. For future work involving EM on vessels using VMS it would be ideal to ensure that EM systems meet radio communication standards compatible with the standards currently in place for bridge equipment deployed in a protected environment. For example, one of the considerations when moving forward with the next generation of the Archipelago EM equipment this year was to secure BS EN 60945 certification, which includes a series of stringent radio interference, temperature, and shake and vibration tests.

During exit interviews, the majority of fishers that participated throughout the three phases of the study found the equipment to be user-friendly and reliable. Some respondents suggested the need for a trial or probation period at the onset to allow users to become familiar with the systems. Some fishers mentioned the challenge of providing sufficient power and failure of system components, although most of these were resolved through ongoing communication with the project staff.

2.4.1.2 *Onboard Methodology*

An important aspect of an EM program is to ensure that captains maintain the systems as planned. In general, fishers followed the onboard methodologies but there was discrepancy among vessels. In one instance, the degree of adherence to defined onboard methodologies varied between the two trials on the same vessel.

The participating trawl vessels all used conveyors for handling and sorting catch. This arrangement may have helped as it confines most of the catch sorting to a single area, but some discarding did occur outside of the defined control points (i.e., during regular operations, some catch sorting still occurs in the checker pen area). Vessels that do not use conveyors were not part of the study, and may have different results due to the differences in catch handling. On either type of vessel, it is reasonable to assume that catch handling would need to be defined in a VMP to ensure it is aligned with EM data processing.

Vessel C, a gillnet vessel, followed the defined onboard methodologies well during the audit trial but less so during the compliance trial. During the compliance trial, imagery recording was continuous until the return to port after the first haul, which led the captain of Vessel C to ask that the camera be moved to protect crew privacy. This resulted in the loss of a view of catch handling. In addition, the captain was concerned with retaining sub-legal catch items from a conservation perspective which led to several instances of non-allowable discarding. Receptiveness to the requirements of any given trial is an important consideration in the development of an operational program. This example also reflects the need for cooperative development of the design.

Overall, vessels documented 78 of 99 trip departures and 89 of 99 trip returns for both trials (Table 10), but results varied among vessels. One vessel captured only 46% of departures while others were able to capture 100% of departures. Missing data resulted from crew powering the EM system on after the vessel had left the dock or off before returning to port was usually due to simply forgetting to switch the system on, and remembering before the first fishing event. The on/off action can be automated with engine sensors that are available at minimal additional cost as part of the EM system, but were not available at the time of the trial.

Providing feedback is extremely important for modifying behaviour and improving compliance with catch handling protocols. The development of onboard methodologies and self-reporting is challenging and it takes time for fishers to develop practices and habits to support the trial. An example of successful communication was when the captain of Vessel B met FSB staff during the audit trial and processed the vessel's data. Subsequently there were marked improvements in compliance with onboard methodologies and piece count comparisons.

Furthermore, communication should not be one-way, but rather a two-way conversation between program staff and captains to help speed up the period of adjustment. For example, in one case the feedback to captains was that they should separate groundfish managed from other species prior to discarding to assist reviewing during the audit trial. However, crew found it difficult to comply with this while completing other fishing duties. Captains reported that some specimens, particularly small Windowpane Flounder, were often covered on the conveyor belt by specimens from other, larger, species (such as skate) and were not detected by the crew. Collaborative work with captains should lead to the development of novel onboard methodologies that improve both review times and fishing log data. While it can be assumed that it will take time for a re-designed new monitoring program to mature, it is difficult to predict the length of that period. However, this period will be dependent on the level of acceptance in the fleet, which in turn is determined by how well the program meets their needs. Additional discussion on program maturity is provided in section 3.2.1.

At the end of the trial, captains indicated that although modifying their catch handling increased processing time they considered it achievable. Given the short timeframe of the trials, underreporting bias of fishing logs should not be interpreted to mean that self-reporting is not possible. It is important to note that accurate self-reporting is difficult and takes time to develop. In the BC HL experiences, self-reporting improved dramatically once captains started receiving feedback in an operational program in a context that provided incentives for accurate recording.

2.4.1.3 *Imagery Quality and Review Time*

Several factors affected the imagery review time including the amount of target catch in a haul, the amount of bycatch, the catch composition and the catch handling practices. For example, in the audit trial, day-trawl vessels typically processed higher volumes of catch during a single haul relative to the gillnet vessel, which resulted in higher review ratios. It is important to note, however, that the participating gillnet vessel (Vessel C) was fishing for monkfish with a larger mesh size than is typically used in the fishery and therefore the volume of catch and species mix is not representative of that fleet.

Crew compliance with onboard methodologies (i.e., use of control points, removing catch from view, discarding en masse, etc.) affected the reviewers' ability to document catch efficiently. Based on feedback from the reviewers, when crew did not comply with the use of control points it was difficult for the reviewer to determine the utilization of catch. Camera views and catch-handling protocols were set up to ensure that all catch was identifiable and visible to EM reviewers. When catch handling protocols were not followed, reviewers required additional time to track fish between camera views.

During the compliance trial, reviewers identified catch removed from camera view to species or species groups and provided a piece count. The ability to identify catch when it is removed from camera view is not sufficient information on its own for accurate accounting of quota. If the crew removes catch from view, some assumptions need to be made regarding the fate of the catch. In an operational program, incentives to encourage catch handling within view of the camera are essential. For example, in the BC groundfish HL fishery, if a fish moves out of camera view, the EM reviewer assumes that the fisher retains it. In this case, if catch is assumed retained, but actually discarded, there will be a discrepancy in the EM, log and dockside comparisons, resulting in increased review (and associated cost) for the fisher.

In an operational program, there are various mechanisms that can be used to decrease review time through improved imagery; these mechanisms include feedback such as was used in these trials and incentives for compliance, which were not used in these voluntary trials. Rules must be defined that dictate consequences for non-compliance with catch handling procedures. These rules can include fees or fines for non-compliance and/or incentives for compliance. For example, in the BC groundfish HL fishery, fishers pay for review time so they have a financial incentive to ensure compliance with catch handling to make reviewing easy and efficient. Additionally, the review times associated with each gear type and trial in combination with the necessary catch handling requirements should be considered in the development of an operational program.

Finally, low image quality increased the review time as it became more difficult to identify and measure the discarded groundfish managed species. Poor camera angles and sun glare were common causes for reduced image quality across all three vessels. Specific requirements can be defined that the captain must follow (e.g. regular camera cleaning) in an operational program, which greatly improve quality of imagery. It is important to recognize that it is not feasible to expect the systems to capture only high quality imagery, given the working environment, but the incentive structures of the program can be designed to help minimize the frequency of poor and unusable imagery and ensure that it does not bias the data set (i.e., occurs randomly and infrequently) and resulting information. Further discussion will be required to define the acceptable tolerance level and associated risk for medium to low quality imagery.

2.4.1.4 *Data Turnaround and Retrievals*

The data turnaround time in the audit trial was 20 days or less for 89% of the trips, with a minimum of three days. The turnaround in the compliance trial ranged from two to 11 days. The difference between the two trials is that at the start of the audit trial, there was a backlog of data due to project staff time being spent on the operational aspects of the trial. In addition, the compliance trial had a much lower volume of data due to the timing of the fishing season and reviewers were available to process data as soon as it was received. Finally, in the audit trial, EM data retrievals did not occur on Friday through Sunday due to staff limitations; however, during the compliance trial data retrievals coincided with DSM work and took place on the day of landing.

The availability of staff for data analysis throughout the project was the single biggest influence in turnaround time. The four imagery reviewers (at both Archipelago and FSB) assigned to the project had competing priorities. During the first eight weeks of the audit trial, it was unrealistic for four imagery reviewers working part time on the project to clear the backlog of data. This demonstrates the importance not only of having sufficient dedicated staff and resources when scaled to a larger operational program, but flexibility in staffing levels to cope with the seasonality of the fisheries.

To put in into perspective, it took about 5.7 hours to review a trawl trip under the audit trial (average of three hauls per trip at 1.9 hour review per haul) and 2.5 hours to review a trawl trip under the compliance trial. In an operational program the effort would scale differently as it did in the trial since only 10% of the hauls (audit trial), or trips (compliance trial), would be processed.

Several other factors, which would not be present in an operational setting, increased the turnaround time in the trials. These include the time zone differences between FSB and Archipelago and the time it took to transfer files between FSB and Archipelago. Both of these could be eliminated in an operational program.

The geographic distance between technical staff home base and port, as well as challenges of coordinating retrievals over weekends also slowed the process. This could be solved in an operational program by integrating calls for EM data retrievals into the existing hail program, as is done in the BC groundfish HL fishery.

The trials indicate that turnaround times can be improved with sufficient and flexible staffing levels, well-defined timelines and requirements, and incentives. The key issue in timely data processing is providing sufficient staff. In BC, Archipelago provides the EM and DSM services for the BC hook-and-line fishery and issues trip reports that incorporate EM, DSM, and fishing log data to fishers within five days of landings to meet regulatory requirements.

Data retrieval time ranged from 15 to 60 minutes for both trials, (excluding travel and DSM). The range was due to a variable amount of EM equipment maintenance during retrieval such as replacing wires or changing camera views. In the BC groundfish HL fishery, the mean data retrieval time is less than 30 minutes if no problems are encountered. However, a data retrieval service also includes an opportunity for two-way discussion with the captain, which can extend the total service event duration.

2.4.2 EM and Fishing Log Area Comparisons

Comparisons showed that mean distance between EM and fishing log start positions was 0.08 to 1.93 nautical miles and the time difference was within 52 minutes for all vessels/trips (Table 13). For comparison, in the BC groundfish HL fishery, the fishing log start time and locations are considered a "pass" or "match" if they fall within 1 nautical mile and 60 minutes of the EM data. In addition, the incentive structure in the BC groundfish HL is designed to encourage accurate reporting by fishers to avoid administrative fees and additional costs.

There were mismatches in the statistical areas recorded for a minority of the events (Table 14). Most of the differences were due to discrepancy in the methods used to define haul area when hauls spanned two statistical areas, and recorded the area where the haul ended rather than where the haul started. Improved alignment of the EM and fishing log fishing area could be achieved through clarification of the standards used to define a haul start, haul end, and fishing area.

2.4.3 Audit Catch Comparisons

The results from the EM and fishing log catch comparisons indicate that fishing logs underreport catch as compared to EM. Furthermore, the bias varied by vessel, species group, and individual species. Vessel B fishing log catch comparisons were consistently less biased, and in some cases more precise, than those for Vessel A, which had a larger underreporting bias for all comparisons. These results indicate that if the captain and crew are motivated to meet the reporting and onboard catch handling requirements are sufficient, it is possible to have reliable data reported by both EM and fishing log. Note that this report assumes that EM estimates are correct based on a previous study (Pria et al., 2012).

Flounder species such as Windowpane and Winter Flounder were well reported by both vessels when compared to Hake species. The discrepancy between EM and fishing logs for Red/White Hake is likely due to the fact that EM reviewers did not differentiate the two species because of the difficulty of identifying them in imagery (many hake were small individuals, less than 30 cm). Therefore, "Red/White Hake Mix" EM piece counts included both groundfish managed and other species, whereas the captains' piece counts only included the groundfish managed species, White Hake.

In an operational program, two possible methods to mitigate the challenge of indistinguishable species are: (1) to categorize similar species as groups (e.g., Hake, sp.) during EM review and apply a conversion as required for in-season management and stock assessment; or (2) to require full retention of similar species for documentation at landing. For example, the crew could retain all Hake species because they do not have a sub-legal discarding requirement. In the BC example, there is full retention of the over 35 rockfish species (*Sebastes* spp.) partially because they are so difficult to distinguish during imagery review.

This discrepancy emphasizes the need for species categories to be the same for EM and fishing logs and used consistently by EM reviewers and captains. One data source can provide a more detailed species breakout if when summed they align with a "total" category across both data source. This alignment is essential.

Similarly, total piece counts among reviewers did not match well when reviewers documented only groundfish managed species (Table 20), but matched well when reviewers documented all catch and used the flounder, nk category as necessary (Table 21). The reviewer catch comparisons demonstrated the importance of consistent reviewer methodologies. It showed that if an unknown (nk) category is used, all species within the broader species group must be documented as well so that piece count comparisons can be made at the species and group level.

EM was generally successful at measuring discarded groundfish managed species, with 70.4% of the specimens measured using the EM Interpret Length-Measurement Tool. There was a large portion of the discarded catch (29.6%) that could not be measured for one of the reasons listed in section 2.3.3.2. We used a mean weight (calculated from the measured specimens for that species for the haul) for these specimens. This may have lead to some bias but its magnitude was not examined.

Captains were not required to use a specific weight estimation method and therefore each vessel used their own methods for estimating the weight of discarded groundfish managed species and often changed these methods within and/or among trips[13]. The methods recorded by captains included actual weights (from an observer or a Marel scale), tally counts (mean weight applied to total piece counts) and visual estimates. Although captains were asked to document in the fishing log the method used for estimating catch, this information was not provided consistently. However, feedback interviews with captains throughout the Phase III trials provided further insight into each of the methods used. All captains' visual estimates were influenced by the species composition of the catch, the relative size of the fish, and the total count recorded by the crew. Additionally, some captains based weight estimates on the volume of fish species per basket. As most captains were using tally counts to influence their weight

[13] Allowing fishers the flexibility to decide how to weight estimation method for their vessel and crew is similar to the BC groundfish HL wherein the fishers are not given a prescribed method of counting pieces (the program does not require they estimate weight) and use the method they see as being most appropriate and accurate.

estimates, it is likely that on day-trawl vessels, where catch was not fully sorted, discard weight was underestimated in fisher logs because some pieces were not counted by the crew.

Discarded weight comparisons closely mirrored the results of piece count comparisons at the haul level, and showed some underreporting bias in fishing logs, with variability among vessels. EM weight estimates were based on standard length measurement conversions and therefore relied on accurate piece counts and associated measurements to provide weights. When only those hauls with piece counts within 10% were included, the bias for Vessel A decreased and was similar for Vessel B (Figure 10 and Figure 13). This result is consistent with other results where Vessel B reporting was generally more accurate than Vessel A reporting.

These results highlight the need for appropriate incentives to encourage accurate reporting by fishers and support the need for a phased-in approach to allow fishers sufficient time to modify handling to improve reporting. Furthermore, this study demonstrates that it is necessary to define an acceptable level of error in an operational program, for example, in the BC groundfish HL, each species or species group has a different acceptable error allowed that all contribute to the overall vessel audit score. The target levels of precision in the BC case were derived from experimental tests of how well an observer could record piece counts relative to EM (assuming EM was known with no error). The design team (including fishers) set tolerance levels of precision to be slightly less precise than what an observer had achieved and what the fishers on the team intuited was reasonable (see Stanley et al., 2011). However, as noted earlier (Section 1.5.2), the overall design in BC is flexible with respect to the bias and precision needs for managing different species.

In summary, EM and fishing log comparisons indicated that vessel and species influence the piece count and weight alignment between data sources. To increase alignment, general species categories should only be used when all species in that group are tracked by both EM and fishing logs. In addition, weight comparisons are dependent on accurate piece counts in EM. These lessons could be applied in an operational program and would improve the overall data comparisons under an audit-based monitoring approach.

2.4.4 Reviewer Comparisons

As mentioned above, the reviewer comparisons indicate that the use of a general species category by the EM reviewer requires that all species within that group are recorded both by the reviewer and in the comparable data source (i.e., fishing logs). Training is also essential for accurate and consistent data review. One reviewer (R3) consistently used the flounder, nk category as the reviewer was not able to effectively identify the species by distinguishing identification characteristics. The other three reviewers were able to identify to the species level and were more consistent among their results. In an operational program, regular tests of reviewer data are necessary to identify when more training is required. For the BC groundfish HL fishery, Archipelago conducts data quality checks monthly and one trip is randomly selected and processed by all reviewers for catch comparisons. This process is essential for ensuring consistent reviewer data quality in an operational program.

2.4.5 Compliance Catch Comparisons

The objective of the compliance approach is to use EM to verify that onboard vessels were abiding by retention rules. This trial demonstrated that EM can be used to determine when discarding of non-allowable discards occurs. Vessel D did not have any discards of non-allowable catch and Vessel C had seven events, with one reported in the fishing log (Table 22). It is not known why the discarding was not recorded, however, the catch was discarded because the captain had concerns about the increased retention rules. From the start of the compliance trial, the captain agreed to participate, but stated that he would discard all groundfish managed species that were still alive, rather than retaining them for dockside discarding.

These results further emphasize the importance of captains completing the fishing log as well as of ongoing outreach while demonstrating that EM can be used to document retention practices at sea. Furthermore, results demonstrate that the approach must be supported by the crew to be successful. In this case, Vessel C did not follow the defined retention rules out of concern for the fish stocks and conservation. More importantly, as noted above, it emphasizes the need to have resolution of conflicting objectives (e.g., more precision or release of live specimens) during the design.

2.4.5.1 *Dockside Monitoring Services*

Retention Weight

The DSM data illustrated that under modified retention rules, the dockside discards, which represented the increased catch compared to normal fishing, ranged from eight to 553 additional pounds landed per trip (Table 28) (Appendix F). One of the participating vessels was fishing with a large mesh gillnet and targeting monkfish, so the dockside discards are not likely representative of the fleet. Furthermore, the participating vessels were small day boats, so the additional catch is not representative of larger multiday vessels with larger catch volumes per trip.

Under modified retention rules, additional retained catch could hamper fishing and/or increase the costs because vessel hold capacity would be reached more quickly resulting in more trips to catch the same amount of catch sold (i.e., fewer hauls and reduced revenue per trip), introduce safety concerns and add time to offloads. In an operational setting, the retention rules would not necessarily be the same as those used here. For example, regulators may not require that debris and non-fish catch be retained and discarded at the dock if it could be shown using EM that the discarded material did not contain fish. As was done in this study, reducing the volume of retained catch could be achieved by allowing discarding of easily identifiable or abundant low value species (e.g., sharks, skates and rays and other large pelagic species). Allowing discards of specific species would increase imagery review and onboard catch handling requirements compared to a no discarding environment. However, the review ratio would remain low if EM reviewers did not need to identify these species or estimate their weight and they are easy to differentiate from groundfish managed species.

In the development of an operational program, the compliance approach would likely have to address concerns for select species (such as those with possession limits or those targeted by other fisheries). In this trial, some species were discarded due to conservation and industry concerns. Ideally, these species would be easy to differentiate from species that must be retained. This would still allow a relatively high-speed imagery review. Carefully planned catch-handling protocols that include conspicuous discarding of allowable species would also help to maintain fast review times.

DSM Operations

Due to limited resources, the study did not have a sufficient number of participant vessels to characterize the impact of the compliance approach on fishing and offloading operations. However, during the EM trials, FSB identified some possible options for disposal of dockside discards. Among others, these options included using the dockside discards for bait or reduction to fish fertilizer and/or animal feed.

The coordination and deployment of dockside monitoring services is an important component of an operational EM compliance program. During the compliance trial, FSB staff members were both the EM technician and DSM. In an operational program, greater resources will be needed to accommodate a larger geographic range and an increased number of participating vessels.

The length of time for a DSM event (not counting travel and waiting) varied between gear types. Vessel C (gillnet) had a mean time of 0.24 hours compared to 1.07 hours for Vessel D (trawl) (excluding EM retrieval time). The time variance is likely related to catch volume and target species because Vessel D landed more catch on average than Vessel C did during the trial (Appendix F) These data represent only a snapshot of each vessel’s fishing effort and activity and therefore are not representative of each vessel’s or fleet’s mean dockside discards catch volume under an operational program.

In addition to travel time, some wait time at the dock was required to allow the vessel to land and offload prior to performing dockside services. If verification and sampling of landed catch becomes a requirement in an EM operational program, more time will be needed to process the catch at the dock to accommodate DSM. To expedite dockside monitoring data services, asking the crew to sort the dockside discards by species would allow the DSM to identify and weigh the catch more efficiently.

2.5 Part 2 Summary

Part 2 presents the technical results from the testing of the audit and compliance approaches completed during Phase III of the Northeast EM project through two trials. The EM systems collected a total of 848 hours of EM sensor data from a total of 91 trips and 266 hauls for the audit trial and 65 hours of EM sensor data from a total of 8 trips and 21 hauls for the compliance trial.

The audit trial demonstrated that captains tended to underestimate catch relative to EM. The degree of bias was specific to vessels and varied by species. However, this could be improved with feedback and the underreporting bias of fishing logs should not be interpreted to mean that self-reporting is not possible. It is important to note that accurate self-reporting is difficult and takes time to develop.

Improving the accuracy of weight estimates alignment between fishing logs and EM may be challenging due to the different estimation methods used (EM used length-weight, and fisher estimation methods were not standardized or prescribed). In the BC groundfish HL, while fishers do not report catch weight, they use any method they see fit for tracking piece counts for the fishing log. It is, however, important to note that for hauls where the piece count aligned well between fishing logs and EM data, the weights from both sources also aligned well (Test 4, Table 15 and Figure 13) This demonstrates the importance of accurate piece counts for both data sources.

The audit trial has demonstrated that some ACE species (White Hake) are indistinguishable from certain non-ACE species (Red Hake) during imagery review. This creates complexity for documenting groundfish managed species discard weight. Other problematic species pairings include American Plaice Flounder (ACE)/Fourspot Flounder (non-ACE) and Yellowtail Flounder (ACE)/Winter Flounder (ACE). The report includes suggestions for mitigating these problems.

The imagery review ratios were much lower for the day-trawl vessel (0.36) in the compliance trial relative to the audit trial (1.66). These results should be considered when moving to an operational program, as it will affect the suitability of one approach over another for specific gear types.

EM was successful in documenting non-allowable discards and compliance with specified retention rules in the compliance trial.

These trials highlighted several issues that could be improved in an operational program. These include the importance of feedback and communication between program staff and fishers. One example is proper completion of the fishing logs to meet the information needs of the audit approach.

The results from both trials suggest that the captain's reporting is an important factor in alignment between fishing log and EM data. Because the onboard methodologies and self-reporting create additional workload for fishers, an adequate incentive structure would be key in integrating an EM program into NE groundfish monitoring.

The compliance trial demonstrated that compliance with agreed-upon catch handling protocols, and a DSM component are essential for success of the program. When fishers did not comply with control points, it was difficult for the imagery reviewer to determine the utilization of catch and therefore compliance with retention rules.

Finally, as it will take time for fishers to develop the necessary methods and habits, collaborative work with fishers may lead to novel onboard methodologies that improve both review times and fishing log data.

The trials completed during Phase III form an essential starting point in the evaluation and assessment of the implementation of EM within the NE groundfish fishery. Part 3 addresses the main operational considerations of implementing a large-scale EM program in the NE groundfish fishery and examines the key decisions that affect costs in a program.

3.0 Part 3: Operational and Cost Considerations

3.1 Introduction

Part 1 and 2 described the high-level design and field trials of two approaches to using EM as part of the monitoring package for the NE groundfish fishery.

If an EM program is rolled out in the NE groundfish fishery, the approach chosen will inform the final design but there are key operational and cost factors that have to be accommodated regardless of which approach is chosen.

Two overarching considerations must shape the design of the operational components of an EM program – a limited budget for monitoring and the need to stay within that budget and still provide all the components of the monitoring package.

Fishery monitoring programs are bounded by financial limitations and we believe this should be explicitly incorporated in the program design process. The level of investment in monitoring should relate to fishery value following the logic that the value of the fishery justifies the cost of obtaining the basic data needed to manage it. For the purpose of program design, we suggest that the monitoring investment be around 5% of the fishery value, or less. Recognizing there are a number of issues that will determine the final level of monitoring investment, this sets the approximate scale and thereby frames the discussion to identify potential monitoring approaches. In the absence of a financial context, monitoring program design can easily diverge from what can truly be afforded and what is really needed. Using this approach, the NE groundfish fishery, valued at around $70 million, would have a total monitoring budget of $4 million or less. The question to consider then is what monitoring approaches and program operations can be successfully used at this level of funding.

A quest for efficiency must drive the design to achieve an optimal balance between data quality, data turnaround and cost. An EM program will not provide the same data currently collected in the ASM program and hence will have distinct strategies to meet the monitoring objectives, which in turn will impact costs of the program.

While in this report we focus on EM operational components, EM will not be the only component in the monitoring package in New England. The cost and operation of the other monitoring components must also be included in designing a monitoring package that includes EM. In the NE groundfish fishery, the total monitoring budget must also consider the cost of fishing log, NEFOP, VMS, ASM, and potentially a dockside monitoring program.

3.2 Operational Considerations

There are several key components in an EM program (Figure 14); tailoring these components to the NE fishery requires defining the scope and size of the program and assessing the resources required for implementation. The following sections describe the key operational considerations and how they relate to the costs of an EM program.

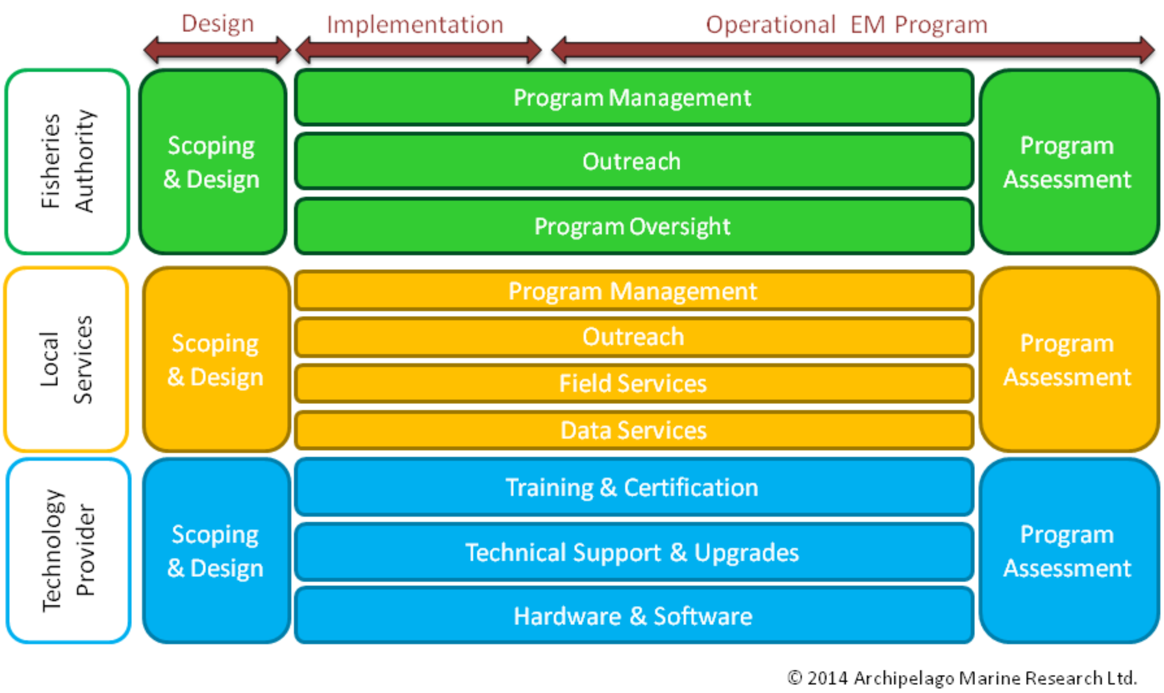

Figure 14: Schematic diagram of an EM program, depicting the main operational component groups, key roles and program deployment timeline

Before describing the operational components, it is important to highlight two points. First, the program deployment occurs in three phases. In the first phase, design, the operational components listed in this report would be assessed and more rigorously defined. The implementation and operational phases follow with some overlap in transition. The implementation phase represents the effort and one-time costs to set-up the infrastructure and processes to support the operational phase. The bulk of the operational components occur in the operational phase with repeating annual costs. The program requires routine assessment on how the objectives are being met and how the operations may be improved (Stanley et al., 2009). Program maturation will take time until it is optimized. This process may take only one or several fishing years. For example, accurate self-reporting is difficult and takes time to develop. While the BC program worked adequately from the outset, probably owing to the clear objectives and substantial industry input to design, it still required two to three years for fishers to become comfortable with the requirements of the program.

The second point is that the operational components are divided among three roles; the fishery authority, local services and the technology provider[14]. There are various service delivery frameworks possible (see section 3.5.2). Each role may be assigned to a different group, or a single group may have more than one role, or more than one group may carry out each role. The number of groups involved and how roles are assigned to them will affect the level of redundancy and coordination needed in the program, which in turn will affect costs.

3.2.1 Program Management

Program management involves the coordination and oversight of all of the parties involved in carrying out the various operational components of the program. Program management will occur at different layers (field services, data analysis services, overall program management). Depending on the service delivery framework, program management will need to be carried out by different groups.

The amount of effort going into program management is related to the overall size and complexity of the program but there is no formula for calculating program management costs. Instead, costs will depend on the perceived requirements to keep the program running. For example a program having relatively lower investment in program management will have less capacity to react to operational issues, which may result in delays or other problems. This may be an acceptable trade-off if the program is generally achieving the monitoring goals.

During implementation, the rate of program maturation will be inversely proportional to the clarity of the objectives as well as to the resources that can be assigned to address issues as they arise. While clear objectives help ensure that the design process addresses the key concerns from stakeholders, unforeseen issues will arise as the program is implemented. For example, in the Phase III field trials the captain's concern about retaining live specimens and privacy on deck noted above are issues that affect the program design, yet these issues were only uncovered during the trials. During the implementation of an EM program there will be many more of these issues. Program management involves resolving these issues as they arise. Hence, project management investment is generally higher during the implementation stage and will decline as the program matures and processes become more standardized and efficient.

3.2.2 Outreach

The involvement of stakeholder groups is extremely important in the success of the EM program (NOAA 2013c and Zollett et al., 2011). In order to effectively

[14] The fishery authority role covers the general oversight of the program. The local services role carries out the work needed to collect, analyze and report on the data while the technology provider is responsible for the at-sea data collection hardware and analysis software used and the support for these.

educate and engage participants, a comprehensive outreach and education program should be in place prior to implementation and should continue during the operational program. Periodic meetings are essential and include:

- Frequent project advisory team meetings to review program operations;
- Outreach meetings with industry groups to gather input and develop solutions to serve the needs of the program and industry; and
- Direct communication meetings with the participating vessels to resolve issues that arise over time.

Communication and engagement during the operational EM program phase accomplish the following goals:

- Provide feedback to agencies and industry on operational aspects of the program, including equipment installations, issues relating to data collection success, port-based services, program responsiveness, data analysis and communications;
- Identify problem areas with program operations and work with industry and agencies to find solutions;
- Examine EM program data to ensure they meet the goals of the program; and
- Conduct periodic analysis of program costs to identify problem areas and inefficiencies.

3.2.3 Field Services

Field services refer to staff and efforts related to installing equipment, maintaining equipment and retrieving data from vessels. They are an essential component of an operational EM program and ensure that equipment functions reliably on vessels.

3.2.3.1 *Equipment Installation*

Successful deployment of EM systems across a part of the fishing fleet will require a large number of people including staff to coordinate the logistics. The amount of time and resources necessary to complete all vessel installations will depend on the number of vessels are involved and the timeframe in which installations need to occur.

Installations typically follow several steps:

- **Pre-Installation Interview** – Prior to installation, technicians and captains discuss an installation schedule, the layout of the vessel, a tentative installation plan, pre-installation requirements and consideration of any issues that may complicate installation process.
- **EM System Installation** – The EM system is set up and connected then tested with the vessel in operation.

- **Vessel Operator Briefing** – Vessel operators will receive a briefing on the system operation, caretaking and procedures to follow when assistance is needed.

There is often a period of adjustment following the installation which includes ensuring that everything is working as expected, providing further support to the fisher on the use and care of the system and fine-tuning camera views and software configuration. Following the installation of EM equipment, we advise scheduling a service after each of the first two trips or until fine-tuning is complete. EM technicians ensure that monitoring objectives are met and any captain or crew questions are addressed quickly by having frequent servicing early in the program.

3.2.3.2 *Vessel Services*

Vessel services can be scheduled through a single or multiple points of contact. A centralized approach with a single point of contact for scheduling services, is recommended in the early stages of a program.

Field staff will be deployed based on the activities of the fleet, the service needs identified and the priority or urgency of those needs, the skill sets required for the service needs, availability of service technician staff, and travel logistics. Port based service is a requirement; however there are a number of approaches that can be used optimizing to balance program cost, timeliness of response, and quality of service. Staffing ports with trained service technicians would be ideal but the investment in maintaining certified technicians may not be justified, particularly in low activity areas where proficiency is difficult to maintain without regular use of skills. In such cases, it may be better to service low activity ports from nearby active ports or from a central program base, although this increases travel costs and reduces the response time. Similarly, certified technicians may not be required for all fleet service activities but this may dilute the available service work, making it more difficult to maintain certified technicians.

Vessel services may originate from a fisher request for support, a request from an EM data reviewer to adjust the configuration on a vessel or the need to retrieve a hard drive from the vessel, also called a data retrieval service.

Data retrieval is the process of collecting data on a hard drive from a specific vessel. Program management must define the frequency and method of data retrieval for the program. In general, while shorter data retrieval intervals create more opportunities to make adjustments and ensure that EM systems are working well, they result in higher costs. Data retrieval intervals also need to accommodate the amount of data being collected because hard drives have finite data capacity.

While repairs or changes to the EM system configuration generally involve a certified EM technician, data retrievals require minimal training and may be performed by people with little or no training including dockside monitors or the fishers themselves. Each of these options has pros and cons:

- Certified service technician
  - Pros- Gives the opportunity to adjust and maintain the system if any problems are encountered.
  - Cons- Requires a targeted visit by a certified EM technician, often requires scheduling with the fisher.
- Dockside monitors (if there is a DSM program)
  - Pros- Reduces costs by creating synergies between programs if travel costs are a concern.
  - Cons- If there is a problem it will not be corrected immediately.
- Fisher
  - Pros- Has the potential to allow for data retrievals at no or little cost to the program.
  - Cons- May result in higher risk of data loss. Could complicate hard drive chain of custody. If there is a problem, it will not be corrected immediately. Fisher needs to devote time to deliver data (takes time away from other responsibilities).

Of course additional synergies may be possible by providing training across programs, such as training dockside monitors as certified technicians.

3.2.3.3 *Equipment Management*

An important service component of the program management is carrying an inventory of replacement parts. Given the specialized nature of these products, this service is essential to ensure continuous operation of equipment deployed on fishing vessels.

This process will depend heavily on the service model, and the service provider may be responsible for spare part replacement inventory.

3.2.4 Data Analysis Services

Data analysis services refer to staff and efforts related to managing hard drives and data, processing EM data, and reporting on EM results and comparisons with other data sources. They are an essential component of an operational EM program and ensure that data are processed and reported in a timely manner.

Data analysis service coordination ensures that hard drives and data sets created by active fishing vessels are properly tracked throughout the operational cycle and that staff are available in connection with primary and secondary data processing program needs (i.e., that staffing levels can meet processing and reporting requirements). Optimizing staffing levels will require consideration of seasonal variation in the fishing activity levels.

Data services may be organized under a centralized model, where all the data is processed and managed in a single location, or decentralized, where processing and management occur at various locations. A centralized model is optimal for ensuring consistency in data processing, in particular during the implementation phase. A decentralized model does not lend itself to easily correct discrepancies in data processing methodologies due to having to interact remotely, as seen in the Phase III reviewer comparisons (see section 2.4.4).

3.2.4.1 *Hard Drive Management and Data Tracking*

Hard drive management requires an inventory management system to track hard dives throughout their use cycle (Figure 15). Key considerations with regards to hard drive management include:

- Ensuring there are enough hard drives to allow for adequate availability of empty hard drives per vessel. This will depend on data storage requirements (see below).
- Gate processes, or prescribed decision points, are used to manage when data are retrieved from the fishery and when hard drives are "scrubbed" (data deleted in a manner that it cannot be recovered) or permanently archived. These gate processes can be triggered on regular intervals (e.g., data is to be retrieved every month or data will be "scrubbed" every two weeks) or triggered by specific conditions (e.g., data is to be retrieved when the hard drive is 80% full or a portion of data will be permanently archived when a certain discarding event occurs).

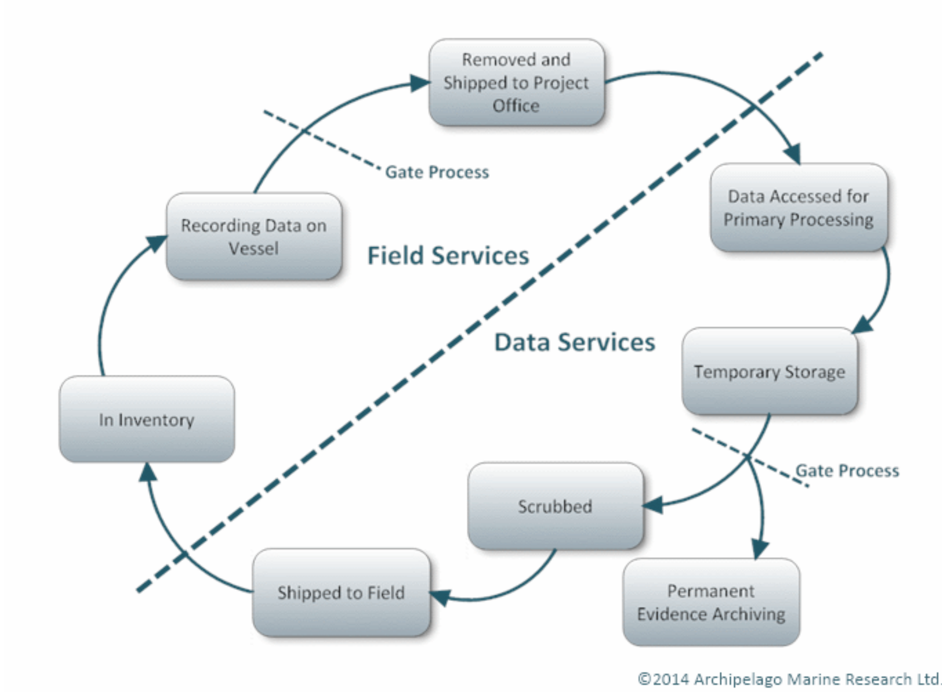

Figure 15: Cycle for hard drive use between field and data services

In addition to hard drive management, data collected by EM systems are tracked throughout the processing cycle (Figure 16). This includes tracking the transit of the hard drive from the vessel to the office, through primary processing, data consolidation and data reporting.

Data tracking involves ensuring that data is meeting the turnaround requirements; the entire cycle shown in Figure 16 must occur within the required turnaround time. Once the turnaround time is defined, the program must ensure that the hard drives are being received in the office and that enough staff is available to process the data in a timely manner.

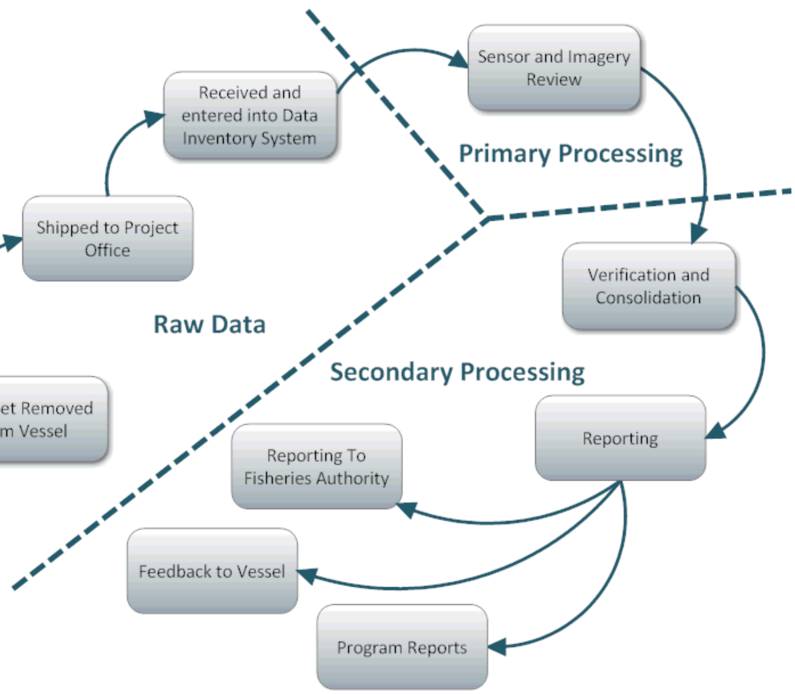

Figure 16: EM data processing cycle between raw data, primary processing and secondary processing

3.2.4.2 *Primary Data Processing*

Primary data processing refers to the processing of EM sensor and imagery output data from its raw form into fisheries data (see section 2.2.8).

3.2.4.3 *Secondary Data Processing*

Secondary data processing converts processed EM data into the information needed by managers, fishers and enforcement.

After primary data processing is complete, the data are summarized and compared with ancillary data (e.g. fishing log, DSM data) as required depending on the approach. A detailed consolidation and reporting plan must include at a minimum:

- Data to be compared;
- Data comparison applicable to the chosen monitoring approach;
- Incentives to correctly report;
- Consequences for misreporting;
- Required data processing turnaround time.

Feedback often results from analysis of a data set in order to improve the quality and effectiveness of the EM deployment on the fishing vessel. Common feedback includes adjustments to system settings, changes to camera positions, data completeness, image quality, or catch handling practices. Feedback may be directed to field services (regarding EM system adjustments) or to the fisher (regarding duty of care or onboard methodologies). A process for filtering and prioritizing feedback, as well as an interface for passing on and tracking feedback between functional service areas (and multiple service providers if applicable) needs to be defined.

Feedback to the vessel needs to be standardized so that all fishers receive feedback in a consistent format. Ideally, critical feedback to the vessel should be tied to an incentive for them to act on the information given and improve data quality. Feedback to the vessel may be included in a report to the vessel (see section "Reporting and Feedback" below).

Reporting and Feedback

Results from EM data processing and consolidation are often delivered in a report to the fisher and/or the fishery authority. Reports can also be used as a feedback mechanism to the fisher to communicate deviations from the VMP, EM data completeness or to raise quality concerns.

A reporting plan must include requirements for format, results content, feedback content, timeline, delivery method and audience. Common report formats include:

- **Trip Report** – Summary of data collected by one vessel during one trip (see Appendix G - Trip Report).
    - Pros – Potential to have more timely results, finer level of detail.
    - Cons – Volume of reports may restrict the number of topics that can be included.
- **Data Set Report** – Summary of the data collected by one vessel over several trips.
    - Pros – Provides vessel specific detail, allows fine level of detail. May allow for a similar level of detail as a trip report but reduces the volume of reports.
    - Cons – May not be as timely and the volume of reports may restrict the number of topics that can be included.
- **Summary Report** – Summary of data collected by many vessels over a period of time.
    - Pros – Ability to provide a wide range of topics about numerous vessels.
    - Cons – Provides a coarser level of detail, less timely.
- **Exception Report** – Summary of a specific activity or behaviour observed during data interpretation.
    - Pros – Low detail report allows very timely reporting, used to supplement other report types.

- Cons – Very limited in scope.

3.2.4.4 *Data Storage*

Data storage requirements will be driven by the regulatory and enforcement requirements.

Short-term storage is required to view the imagery for catch determination. The simplest method is to read the hard drives retrieved from the vessels directly. It is possible to copy the imagery files to another medium (e.g., a centralized server) for viewing, thus creating a duplicate copy of the imagery where only the copy is handled for viewing. This method requires the management of both the hard drives and the copied files.

Long-term storage of sensor data is reasonable given the small storage space requirement of sensor data. Long-term storage of imagery files, however, can be expensive depending on the medium used and the archiving duration. Similarly, storing either the original hard drives or copies of all imagery files requires a significant investment in storage capacity.

A practical solution to balancing imagery storage is to maintain all imagery for a defined period after delivery of each data report to allow for any follow-up, clarification or additional processing that may be required. After that period, the data technicians format hard drives for reuse. Any unique trips or trips where enforcement action is required can be stored indefinitely.

Data storage requires active management to allow technicians to access the data. This process must include a standardized plan for indexing and archiving the data as well as ensuring that access to the data is modernized as technology develops (e.g., updating servers as technology changes).

3.3 Design Considerations

There are several aspects of a fishery that must be considered early in the design. These "design considerations" inform or drive the design process rather than being design variables themselves.

These include:

- **Stakeholders-** Stakeholder engagement is critical during the monitoring package design process. Stakeholders include industry, managers, scientists, enforcement, council, service providers, NGOs and subject matter experts such as IT. Input from all stakeholders will shape the design choices. For this reason, stakeholder engagement is in many ways the single biggest factor affecting the design of the program. The biggest single issue is resolving needs versus costs.
- **Fishery Characteristics-** The program must be optimized to fit within the fishery characteristics. These include how the fishery operates, vessel

characteristics, biological characteristics of target and non-target species, catch composition and the fishery socioeconomics.

- **Management Regime-** The monitoring package ultimately needs to support the fishery management regime and address the key risks in the fishery. Different management regimes and fishery risks require different levels of data quality and turnaround times.
- **Monitoring Objectives-** The monitoring objectives will drive the design process. Stakeholders may have specific objectives to meet their needs. Having objectives clearly laid out will facilitate the design process by being able to weigh the advantages and disadvantages of different options. It is also important to forecast changes in monitoring needs to ensure the initial monitoring package has the built-in adaptability or flexibility to meet changing requirements.
- **Sample-based or Census-based Requirements-** The question of how results from the monitoring program will be enumerated needs to be addressed at the early stages of the program design process. Stakeholders must determine whether the information needs can be achieved under a sample or census approach for each element, possibly even within the EM component. The decision should be based on the management regime and monitoring objectives as well as the fishery characteristics.
- **Fleet Receptiveness to Monitoring-** Given that some design options will require more industry engagement than others, the level of fleet receptiveness to monitoring needs to be assessed and taken into account to guide design. In the case of the NE groundfish fishery, the field trials have shown that there are captains willing and able to substantially modify their catch handling methodologies and provide detailed catch data. However it would be important to understand how representative that attitude is of the fleet in general.
- **Technology Considerations-** The state of current technology will limit what is possible from a technical point of view. Technology is constantly being improved, however, so it is important to build a program based on viable options now and evolve the program as technology becomes available, rather than delay implementation. For example, wireless transmission of data would simplify data retrievals but feasible solutions for manual transfer exist now and can meet program objectives.

3.4 Program Cost

3.4.1 Key Cost Drivers

The cost of any monitoring program depends on the program design, data requirements and specifics of the fishery (Lowman et al., 2013).

The previous sections outline the key operational components and design considerations of an EM program. Each of these has a differing level of impact on the program cost. The two main categories of influences are:

1. External factors – Factors external to the design process, covered in the design considerations, such as number of vessels and landings; and
2. Internal factors – Factors that are internal to the design process and hence within the purview of what can be modified, such as imagery review rate. This is where the design process must balance the trade-offs between costs and benefits of various parts of the program (NOAA 2013c).

There is no simple way to calculate EM program costs. The decisions listed in Table 30 influence the program cost and portion of cost for each component. We present the EM programs for the BC groundfish HL fishery and US shore-based Whiting fishery in a simplistic way to illustrate this point (Table 31). When comparing these programs it is evident that costs can vary between different programs and, moreover, the cost elements can even be distributed differently.

In the BC groundfish HL fishery, data services represent approximately 34% of the EM program costs (Stanley et al., 2011). In this fishery, complex primary and secondary data processing are needed to support the audit approach and program objectives. However, most vessels own their own EM system so equipment costs are low. Field service costs are reduced by balancing the requirement for trip data retrievals with service limited to four main ports with local staff responsible for a relatively small geography. The US shore-based Whiting fishery in the West Coast, however, had relatively high equipment costs due to the high proportion of leased equipment, which resulted from the temporary nature of the monitoring program (it was conducted under an Exempted Fishery Permit). Data services, on the other hand, were a small percentage of total costs in the Whiting fishery due to relatively simple primary and secondary data processing.

Table 30: External and internal costs influences in an EM program.

External Factors	Key Questions
Fishery activity	Number of vessels. Landing patterns. Fishing events. Total sea days.
Port use patterns	Temporal distribution of the fishery. Spatial distribution.
Internal Factors	
Program centralization	Is management of program operations centralized or is replication necessary at various levels and regions?
Cost recovery method	How are costs divided between government and industry as well as within industry? Is the fee structure a percentage of landings or service-based? What are the incentives for care of equipment and for working within the required catch handling protocols?
Service delivery model	Are there multiple service providers or a sole source? Are field and data services provided by single or multiple groups?
Equipment	Are EM systems purchased, leased, pooled/shared?
Fleet coverage	Is program involvement mandatory or optional?
Program lifespan	Is equipment installation permanent or temporary?
Program responsiveness	What are the requirements for: - Review and reporting timelines? - Report frequency? - Field technician availability for equipment maintenance and troubleshooting? - Data reviewer availability?
Data retrieval method	Trained technician vs. DSM vs. fisher retrieval.
Data retrieval frequency	Are retrievals done every trip, weekly, monthly, etc.?
Feedback and outreach	What is the type and frequency of outreach (e.g., reports, meetings, one-on-one feedback, etc.)?
Maturity of data model	How deeply is EM data integrated into the flow of other monitoring data and catch allocation tracking?
Data processing	What is the approach for EM data use (audit vs. compliance approach)? What is the level of detail required during primary data processing? What is the imagery review rate?
Analysis, reporting and archiving requirements	What level of detail is required in the comparisons and reports? What assessment of data quality is necessary? How long, and under what conditions, will data be archived?

Table 31: Simple description of the BC groundfish HL (Stanley et al., 2011) and US shore-based Whiting (McElderry 2014) fishery EM programs. Costs include all aspects of the EM program (including equipment, all field and data service costs, project oversight, outreach, etc.). EM program costs shown are total (i.e., include funding from both industry and government).

Program Characteristics	BC	Whiting
Fishing activity	Year-round.	Seasonal.
Equipment	Majority owned.	Majority leased.
Field services	Hard drives retrieved by an EM technician after every trip (dedicated service schedule) in 4 main ports by regionally based staff (low travel).	Hard drives retrieved by an EM technician opportunistically (efficient service schedule) in 6 main ports with centralized staff deployments (high travel).
Data services	Audit approach. 10% of the hauls imagery processed by third party. Complex primary and secondary processing.	Compliance approach. 100% of the trips' imagery processed by third party. Simple primary and secondary processing.
Number of vessels	202	35
Number of trips	1,323	728
Sea days* **	11,545	1,269
EM program cost per sea day* **	$149*	$208**
EM program cost	$1,725,080*	$412,253**
Supporting monitoring package components** **	Fishing log, notifications, dockside monitoring.	Fishing log.

* 2009/2010 fishing season. Canadian dollars.
** 2010 fishing season. US dollars.
*** "Sea days" are defined as the sum of calendar days when vessels were active.
**** Supporting components are not part of the EM program and hence are not included in EM program costs shown

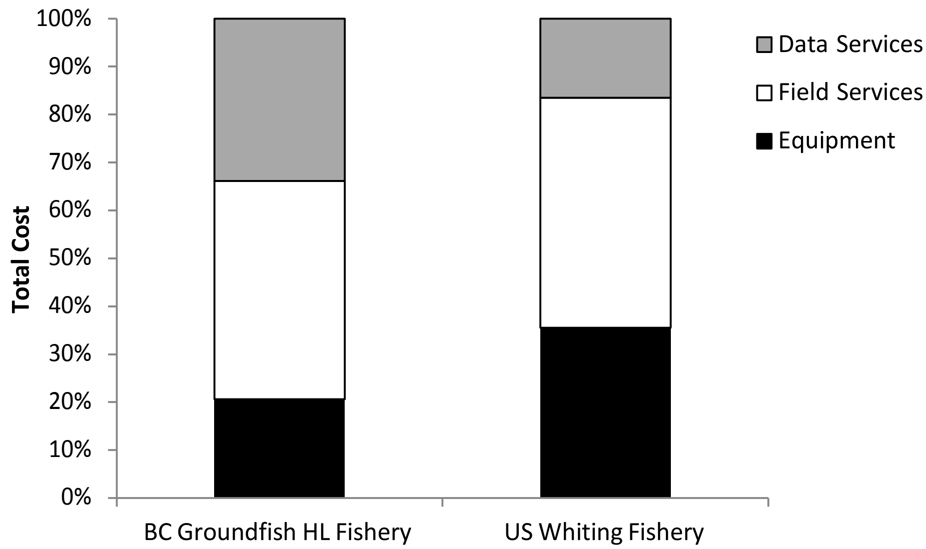

Figure 17: EM program cost breakdown by functional service component for the BC groundfish HL fishery and the US shore-based Whiting fishery.

3.4.2 NE Groundfish Fishery Costing Exercise

Taking the basic design considerations and some operational assumptions it is possible to begin building an indication of EM program costs for each of the approaches under consideration. However, the cost modeling shown below is provided to seed discussion and is not intended as a definitive prediction of the cost of integrating an EM component into the NE groundfish fishery. Its main purpose is to indicate how some of the choices listed above influence relative costs and what kind of program may be possible for less than ~$4 million.

The initial overall cost estimation below focuses on the effort necessary for collecting, retrieving, processing and reporting the EM data, referred to as core costs of the program. It does not include program oversight, outreach, and other overhead costs, which are defined by the program delivery considerations rather than directly from the fishing activity of the fleet.

For the exercise we assume that all vessels participate in the program and that EM is used to monitor all dedicated groundfish trips. For the sake of simplicity we use 400 vessels fishing a total of 15,000 dedicated groundfish trips and 85,000 hauls per year[15]. We assume field and data services staff is billed at $32.63 per hour[16].

[15] The core costs for an EM program in New England will depend on the number of vessels that participate in the program as well as the level of fishing activity for those vessels (i.e., number of fishing trips and hauls). The costing exercise presented in this section could be replicated with a different amount of vessels, trips and hauls to scale EM costs to a portion of the fleet or a specific sector or region.

[16] Based on salary rates for a Biological Technician (GS-0400), Grade 9, Step 10, for Boston-Worcester-Manchester, MA-NH-RI-ME. Data taken from https://www.opm.gov.

Each cost estimate is described below and summarized in Table 32. We estimated that the core costs for an EM program to collect, process and report EM data on a weekly basis for the NE groundfish fishery to be ~$2.5 million for the Audit Approach and ~$1.7 million for the Compliance Approach (Table 32), based on the assumptions and decisions outlined above. This constitutes two to four percent of the fishery landed value (ex-vessel value).

Since the core costs are directly related to the amount of effort, they can be scaled accordingly. For example, annual core costs per vessel on average for weekly data retrievals and reporting would be around $6,300 for the Audit Approach and $4,200 for the Compliance Approach. However, actual core costs for data retrievals, primary processing and reporting per vessel would ultimately depend on the number of trips and hauls taken by each vessel.

Table 32: Core cost estimates of the main EM operational components for the NE groundfish fishery with data retrieval frequencies of one per trip, week, and month based on 400 vessels participating. In all cases we assume 100% of the fishing activity is recorded.

Operational Component	Annual Cost Trip	Annual Cost Weekly	Annual Cost Monthly
Equipment	$960,000	$960,000	$960,000
Installation	$31,325	$31,325	$31,325
Audit Approach			
Data Retrievals	$818,950	$358,820	$132,825
Primary processing	$942,974	$942,974	$942,974
Reporting	$485,861	$212,878	$78,801
Compliance Approach			
Data Retrievals	$744,500	$326,200	$120,750
Primary processing	$200,870	$200,870	$200,870
Reporting	$364,396	$159,659	$59,101
Core Cost Estimates			
Audit Approach	**$3,239,110**	**$2,505,997**	**$2,145,926**
Compliance Approach	**$2,301,091**	**$1,678,054**	**$1,372,046**

Equipment

Equipment and installation costs, amortized across five years (the expected lifespan of the EM systems), result in a cost of ~$960,000 total for all vessels. We assume all vessels would purchase EM systems at $12,000 per system.

Installation

EM system installation takes about 12 person-hours[17]. This onetime cost is amortized across five years for a yearly cost of ~$31,000 total for all vessels.

[17] Install time can vary greatly. It is affected by how involved the vessel owner is in ensuring the vessel is ready for installation as well as in the number of cameras and complexity of camera runs.

Data Retrievals

The frequency of data retrievals affects field services costs (particularly if done by an EM technician). Data retrievals may be scheduled at different time intervals (although in some cases data retrievals are also triggered by the amount of data on the hard drive).

Table 33 shows three alternative scenarios: trip, monthly and weekly data sets. It shows the number of data retrievals that would be expected under each scenario and the amount of data (trips and hauls) that would be retrieved at each service. In the weekly and monthly scenarios, the number of data sets are greatly reduced not only because of the data set interval but because only vessels active during a given month or week would have a service and activity is not constant throughout the year (Appendix A).

A baseline data retrieval cost is calculated for the Compliance Approach. Depending on the interval, data retrieval costs may fluctuate between ~$744,500 (trip basis) to ~$121,000 (monthly basis).

Given that the Audit Approach requires a more complex onboard set-up and increased feedback and communication with the captain, a 10% "premium" is applied to the data retrievals cost to account for some of this additional complexity. This results in data retrieval costs between ~$819,000 (trip basis) to ~$133,000 (monthly basis).

Table 33: Data retrievals under three scenarios: trip, weekly and monthly basis.

	Trip	Weekly	Monthly
Data retrievals	14,890	6,524	2,415
Trips per data retrieval	1.0	2.3	6.2
Hauls per data retrieval	4.0	13.1	35.4

Primary Data Processing

In accordance to the approach baseline presented in Part 1, this exercise assumes that 10% of the hauls will be processed. Given that the majority of the activity in the fishery is trawl, we use trawl data review ratios for each approach. Likewise, we assume catch handling per haul is two hours based on trawl trial results. This equates to primary data processing costs of ~$943,000 for the Audit Approach and ~$201,000 for the Compliance Approach.

When selecting data for the 10% review we suggest that, even if the data set contains less than 10 samples (hauls or trips, depending on the approach), at least one is processed for each data set in order to maintain ongoing feedback with regards to catch accounting or compliance with retention regulations as well as to maintain the psychological deterrent effect of the random review.

Note that a consideration related to the interval in which data will be processed and reported is the number of hauls per data set. Trips in the NE groundfish fishery average about four hauls per trip (Table 33). Sampling a minimum of one haul per trip would result in a 25% sample rate. If a lower level of review will suffice, as we suggest, the program would over-sample for most trips of the fishery at that level. A data set generated on a weekly or monthly basis would allow for a lower sample rate, while still ensuring that each vessel has a minimum of one haul processed for each reporting period.

Furthermore, different strategies can be used in relation with the timeline for reporting and vessel access to fishing. For example, in the BC groundfish HL fishery, vessels are allowed to go out fishing with one outstanding trip data set; but after that they need to prove that they have enough quota to continue fishing, which requires completion of their fishing log audit. This allows vessels to land, have data retrieved and leave for another trip immediately but prevents vessels from fishing without quota. In comparison, when vessels in the US Whiting fishery were being monitored with EM, they could carry out any number of trips in between data set processing since the EM program is verifying compliance and is not tied to vessel quota allocation.

Reporting (Secondary Data Processing)

Usually, data undergoes processing in the same interval as it is retrieved (that is every time a hard drive is retrieved, the data contained in it will undergo primary and secondary processing as a data set).

We assume reports are prepared for each data set. Due to the Audit Approach requiring more complex reporting (detailed comparison with fishing log data) we assume these take one hour to prepare vs. 45 minutes for the Compliance Approach (no multiple data sources).

For the Audit Approach, reporting costs may fluctuate between ~$486,000 (trip basis) to ~$79,000 (monthly basis). For the Compliance Approach, reporting costs are lower at ~$364,000 (trip basis) to ~$59,000 (monthly basis).

Core Costs to Total Costs

While the core costs should represent the majority of the program costs, there are other costs that would still need to be included. The next step would be to narrow down the monitoring approach choice and continue to build on this cost model by adding the rest of the operational components of the program, including those associated with administration and infrastructure.

The costs associated with the administration and infrastructure of the program, such as program management, outreach, data storage, and travel amongst others, do not scale directly to the core costs. They require a more involved design process and thorough consideration of program delivery, as described below. Administrative and infrastructure costs could increase the total cost significantly, therefore program design must focus on finding strategies to minimize those costs.

In summary, the steps we recommend to determine the total costs of an EM program are to first calculate the core costs, then define the program delivery elements that impact costs and finally go through a detailed design process to optimize the program.

3.5 Program Delivery Considerations

Program delivery influences program costs and provides context for some program design choices. Program delivery relates to the framework of how the program will be run, how decisions are made, who pays, and what motivates stakeholders.

Several monitoring programs are currently operating in the NE groundfish fishery (Appendix A – Fishery description) with existing program delivery frameworks. We discuss below how the frameworks will need to address the addition of EM to the monitoring package.

3.5.1 Program Governance

Program governance is the formal oversight and management process to ensure that the mandate of the program is established and upheld as well as to manage and control changes to the program.

In general, the body in charge could be a single agency (government or industry) or a committee that includes different stakeholders. Committees offer a lot of value with regards to developing a common vision and including the needs and knowledge from a diverse group (Zollett et al., 2011)[18]. Committees should have industry, managers, scientific, enforcement and service provider representation and bring additional subject matter experts such as NGOs and IT as needed.

When thinking about governance, the key element is to ensure that there is a clear process for oversight and management. Another consideration is that consistent participation of group members over time increases the efficiency of the governance process because it avoids unnecessary revisiting of previous decisions.

3.5.2 Service Delivery Framework

Very simply, service delivery refers to how the EM monitoring services outlined in Figure 14 are organized. There are a wide variety of options from one to many different entities providing the service. While there are three distinct functional areas that could potentially be carried out by the agency, a local service provider, and a technology provider, this can also be simplified to just one or two groups.

[18] Whether this is a viable option will depend on the legal and social background of the fishery, including the fleet receptiveness to monitoring and the regulatory framework.

In contrast, there might be several providers for each functional area; for example, multiple technology providers offering similar onboard EM systems.

Segregation of functional program areas across multiple entities can lead to challenges to creating a well-integrated, responsive program with minimal program inefficiencies. Multiple entities under separate organizational leadership are more difficult to coordinate than when all the program functions are within a single program umbrella. As well, multiple competing entities may provide incentives for cost reduction, but may also lead to additional costs with redundant infrastructure and unstable tenure. A multiple entities model also requires a far more detailed definition of responsibilities.

The service delivery framework needs to be considered in relation to the characteristics of the fishery (size, activity levels and area), the available skill sets of potential service providers and the existing institutional arrangements with respect to outsourcing fishery monitoring services. There is no single correct service delivery framework but when alternatives exist, it is important to consider the cost implications they may pose.

3.5.3 Cost Recovery Framework

Cost recovery is the method by which the program is funded, including who pays for what and the manner in which costs are charged. The program can either be funded by a single group or through cost sharing between different groups.

With industry-funded programs, the manner in which program services are charged can make a big difference in the total cost of the program. Cost recovery methods that directly align with services provide industry with the opportunity to develop strategies to achieve monitoring at a lower cost. For example, services charged per hour of usage will provide industry with an incentive to minimize total time as compared with services charged as a set rate per pound of quota, per trip, or per vessel. This service-based framework concentrates program costs on those who use the service the most.

Cross subsidies often make sense to balance costs between fishery participants who make a few trips a year versus those who are continuously active. There is some justification for the low user paying a slight premium for the privilege of using a service as needed, while the program is largely funded by the more active participants.

Increased complexity in how services are charged comes with added accounting and invoicing costs. The cost recovery framework needs to be designed in relation to the specific objectives of the program.

Another aspect of the cost recovery framework is with the risks associated with fee recovery. Monitoring program costs will never align with revenues collected from fees and there is a potential to over or under collect revenue. Fee systems based on services (e.g., hourly rates) rather than fishery outputs (e.g., cost per pounds landed) are likely to track more closely to program costs but there are a number of factors that can result in misalignment between fees collected and program costs. Unless there is an agreement to retroactively adjust fees to ensure an alignment with costs, the cost of the program would need to be higher to mitigate the risk of a revenue shortfall.

3.5.4 Regulatory Framework and Incentive Structure

The performance of an EM program relies heavily on the regulatory framework that it operates under to ensure compliance with the program requirements. One way of achieving compliance is through regulations. So long as the regulations are well defined, easily measurable and enforceable, performance objectives of an EM program can be achieved by penalizing non-compliance. The challenge with EM programs is that some key compliance issues (keeping the system powered, clean cameras, etc.) may be difficult to enforce if the violation is deemed slight, yet compliance at this level may be very important. For example, a five-minute data gap may seem insignificant for a three week fishing trip, yet power loss during a high risk capture event could significantly weaken the value of the EM program.

An alternative to program controls through regulation would be to provide administrative incentives. For example, charging higher fees for incomplete data sets relative to data sets with no data gaps and good quality imagery. Vessels with historically high levels of compliance might earn lower review rates (assuming a self-reported audit method) as compared to vessels with poor compliance.

The cooperation and support of the host vessel is almost always needed for effective EM monitoring. Some monitoring approaches are more complex and require greater involvement, but nearly all require some level of involvement to provide value. Ensuring cooperation from host vessels is best if incentivized in some manner, as in a carrot or stick approach.

3.5.5 Enforcement Considerations

The efficacy of regulations is highly dependent on the enforcement capabilities available. It is important to integrate enforcement officials into the EM program so they understand how the program works, the critical risks, the role they can play, as well as provide an opportunity for them to tailor the monitoring to meet their needs or reduce their costs. Enforcement officials need a basic understanding of how the technology works, what data are collected, and the areas in which they can be of assistance. It may take a lot of effort to develop an effective case using EM data, particularly when experience with this type of evidence is limited. There are an increasing number of successful enforcement efforts using EM data, however, so this may largely be a transitional issue.

While enforcement may be an end user of EM data, in many programs they are not the ones who actively review data. Programs benefit from clear guidelines with regards to what type of activities will be targeted for review and reporting for enforcement purposes. For example, reviewers may be asked to document and report on fishing in closed areas or discarding of full retention species for the use of enforcement personnel. These personnel, in turn, may request additional reports or access to more data to pursue their investigations.

3.5.6 Level of Industry Engagement

A successful EM program usually relies on effective engagement with industry. As mentioned, compliance with onboard methods is necessary and often there is a need for ongoing communication to provide feedback and engage industry in developing solutions that balance the operational needs of the vessel and the data collection needs of the EM program. More broadly, engaging industry in vessel or fleet specific performance (e.g., discard practices) can help broaden the understanding of issues in the fishery and identify possible solutions. Demonstrating the utility of monitoring program information helps build support for the program. This inclusivity is the essence of co-management – developing mechanisms for industry to take greater ownership of the issues and challenges.

3.5.7 Monitoring Package Integration

As mentioned before, EM will only be one component of an integrated monitoring package in the NE groundfish fishery that will likely include fishing logs, some observer coverage and dockside monitoring. The value of an integrated monitoring package is to maximize the strengths of each component in a coordinated manner in order to optimize data quality and minimize cost.

A successful monitoring package will have a data model that specifies how EM data is to be linked to data from other monitoring components. This will affect the ability to consolidate and compare data from different sources in an efficient manner and allow for adequate monitoring of sector ACE. These data should also support regular assessment of whether the program is meeting the monitoring objectives.

3.5.8 Data and IT Considerations

3.5.8.1 *Data Model Considerations*

The data model includes a description of all data elements for the program, including data fields, field formats, table structures, relationships and validation rules as well as metadata definitions.

Careful consideration of the data model and related aspects are critical because the ability to effectively manage and report on the data is fundamental to the success of the EM program. The data model needs to incorporate program operations data (service events, data retrieval events, data processing events, reports, etc.) and standard fishery data (vessels, trips, set events, landing events, catch annotation and analysis) with specific outputs from the EM analysis. Furthermore, the data model must address how EM data/information link to other data sources (such as fishing logs, VMS, dealer data, and DSM) and where those additional data reside. The structure of the data model must be documented for the purpose of consistency and communication because it involves all service delivery parties within the program.

Specific data fields (e.g., set start/end) must be clearly defined for the analysis process and data integration. Data fields must define data exchange procedures between service delivery parties and fisheries authorities. From an operational perspective, performance specifications must be defined in terms of timelines and data quality for completed data sets.

The fisheries authority's role includes leading the specifications of the EM data products and the design of the data/information interface for incoming EM data products. The service provider's role includes developing internal data models that include the program operations data.

3.5.8.2 *IT Infrastructure*

The IT infrastructure for an EM program includes the physical systems, as well as the procedures and policies that govern how program information is assimilated, managed and used. The infrastructure supports a variety of processes, including program operations, customer support and management, financial management, quality assurance, and EM data products. Often the architecture is distributed across different physical systems with data housed internally with the program and/or with different agencies (e.g., vessel log and landings data). There may be a requirement for long term data archiving which would necessitate both server storage capacity and administrative systems to manage the archive. The IT infrastructure requirements for an EM program should be considered and built in advance of program implementation but it may take time for all systems to be in place.

3.5.8.3 *Data Ownership and Access*

The nature of EM data (i.e., imagery data and high-resolution cruise track information) generates concerns about its ownership and access that go beyond those that exist with observer and fishing log data.

Details around access to the data, and the requirements around that, will be dictated by the stakeholders (fishery authorities and industry). However, in general, the program design must include clear definition on who can have access to the data, what type of data they can have access to (e.g., raw imagery vs. secondary processing data products), when they can have access to the data (e.g., before or after it has been processed), and the manner in which they can obtain the data.

Unauthorized or inappropriate access to the data can be mitigated by encrypting the data at the time it is created on the vessel and establishing chain of custody procedures. Data protection and chain of custody can be enhanced through a combination of technical (e.g., encryption) and process (e.g., locked cabinets and sign off logs for hard drives) safeguards.

3.6 Part 3 Summary

Part 3 outlines the operational considerations of an EM program, and describes the operational and design considerations that program managers and stakeholders must consider and plan for, regardless of the monitoring approach taken.

Planning of monitoring is bounded by financial limitations, and the fishery value provides a useful frame of reference as this demonstrates that the value of the fishery justifies the cost of obtaining the basic data needed to manage it.

The design process consists of finding an optimal balance between data quality, data turnaround, and cost. Stakeholders will have to consider multiple factors and make tradeoffs among them. A stakeholder outreach and education program should be in place prior to the start of implementation, and continue during the operational program.

Part 3 shows estimates that the core costs for an EM program to collect, process and report EM data on a weekly basis to be around $2.5 million for the Audit Approach and around $1.7 million for the Compliance Approach, based on a series of assumptions. This approximates two to four percent of the fishery landed value. While the core costs should represent the majority of the program costs, there are other costs that would still need to be included, such as those associated to the administration and infrastructure of the program. The steps we recommend to determine the total costs of an EM program are to first calculate the core costs, then define the program delivery elements that impact costs and finally go through a detailed design process to optimize the program.

While this report focuses on EM operational components, the costs of the other monitoring components (i.e., fishing log, NEFOP, VMS, and a DSM) must be included in the monitoring package design process.

The development of an EM program requires careful consideration of the goals, and incentives for participation in the program. Experience in other fisheries, such as the BC groundfish HL fishery, and US shore-based Whiting, has shown that an EM program can meet the information needs, while taking advantage of the flexibility in the operational elements to maintain low costs.

Part 3 has outlined many of the operational and design considerations of developing an EM program, and provided cost estimates as an example of how decisions can affect cost. There are many decisions that remain to be made if an EM program is developed, and we recommend a thorough evaluation, and dedicated planning effort before the program commences.

Overall Summary

Phase III is the culmination of the New England EM Project, funded by NMFS and overseen by the FSB. Phase I and II laid the groundwork for understanding how EM could best be applied to meet the monitoring objectives of the NE groundfish fishery. EM would need to be integrated within an overall monitoring package, which would require changes to the existing monitoring program, in order to be an effective catch monitoring component in New England. As a result, NOAA endorsed two basic monitoring approaches: an Audit approach, and a Compliance approach.

Phase III examined alternative designs for the two basic monitoring approaches endorsed by NOAA, simulated and field-tested the approaches on volunteer vessels, and identified and documented the operational and cost considerations based on the simulating of the approaches, the fishery characteristics, and experience from other EM programs. More detailed summaries of the results and outcomes are provided at the end of parts one to three of this report.

Results in Phase III show that both approaches meet the potential information needs for management of the NE groundfish fishery but each provide different data as well as design, onboard, operational and cost considerations.

In summary, the Audit Approach uses self-reported fishing logs as the official record of the discards of groundfish managed species with EM used to verify the self-reported logs through a random audit process. The audit approach fits within the existing regulations and requires more complex catch handling methods onboard, data processing and feedback mechanisms. The Audit Approach has the additional benefit of engaging captains in the fishery data collection.

In comparison, the Compliance Approach produces actual weights of total groundfish managed species catch at offloading. EM is used to confirm that vessels are complying with increased retention. This approach requires changes to existing retention regulations, a supporting DSM component, and requires relatively simple catch handling methods onboard[19], data processing and feedback mechanisms.

The difference in operational complexity translates to a difference in cost between the approaches. Costs for weekly EM data retrievals and processing data were estimated to be around $2.5 million for the Audit Approach and $1.7 million for the Compliance Approach. However, the Compliance Approach will need to include some form of DSM to account for fish not accounted for by dealers, which should be taken into consideration as part of the monitoring package costs.

[19] Note that while catch handling for the purpose of EM is simple, groundfish managed species will still need to be sorted at some point to be weighed at the dock.

This Phase III report and the other phase reports form an essential starting point in the evaluation and assessment of the implementation of EM within the NE groundfish fishery.

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Appendices

Appendix A: Fishery Background

Fishery Description

In 2012, 404 fishing vessels carried out 14,496 dedicated groundfish trips dedicated groundfish trips in NE (Table A-1). Across all trips there were 85,417 hauls completed in 2012. The fishery is composed of three distinct gear types: longline, gillnet, and bottom trawl. Most of the trips are less than 48 hours (day trips) although most of the hauls occur in multi-day trips (Table A-1).

Table A-1: Summary of gear types and activity levels for the 2012 fishing year (NMFS provided data, 2014).

	Longline		Gillnet		Trawl		Overall	
Sectors	6		10		14		17	
Ports	4		21		30		39	
Vessel Length (ft)	31 to 50 ft		31 to 65 ft		35 to 106 ft			
Total Vessels	**23**		**168**		**227**		**404**	
Number of vessels involved in:								
Day Trips	23		156		142			
Multi-day Trips	7		112		190			
Trips	*Total*	*Percent*	*Total*	*Percent*	*Total*	*Percent*	**Trips**	*Total*
Day Trips	737	97%	6,988	86%	3,468	57%	11,193	75%
Multi-day Trips	24	3%	1,095	14%	2,578	43%	3,697	25%
Total Trips	**761**		**8083**		**6046**		**14,890**	
Hauls	*Total*	*Percent*	*Total*	*Percent*	*Total*	*Percent*	*Total*	*Percent*
Day Trips	1,580	92%	22,534	79%	9,248	17%	33,362	39%
Multi-day trips	146	8%	5,927	21%	45,982	83%	52,055	61%
Total Hauls	**1,726**		**28,461**		**55,230**		**85,417**	
Hauls per trip								
Day Trips	2.1		3.2		2.7		**3.0**	
Multi-day trips	6.1		5.4		17.8		**14.1**	
Overall hauls per trip*	2.2		3.2		5.3		**4.0**	
Catch Handling								
Hours per haul	0.5		1.1		1.2		1.1	
Hours per trip	1.1		3.8		10.8		**6.5**	
Total catch handling hours	**870**		**30,315**		**65,044**		**96,229**	

*Weighted average by proportion of day and multi-day trips.

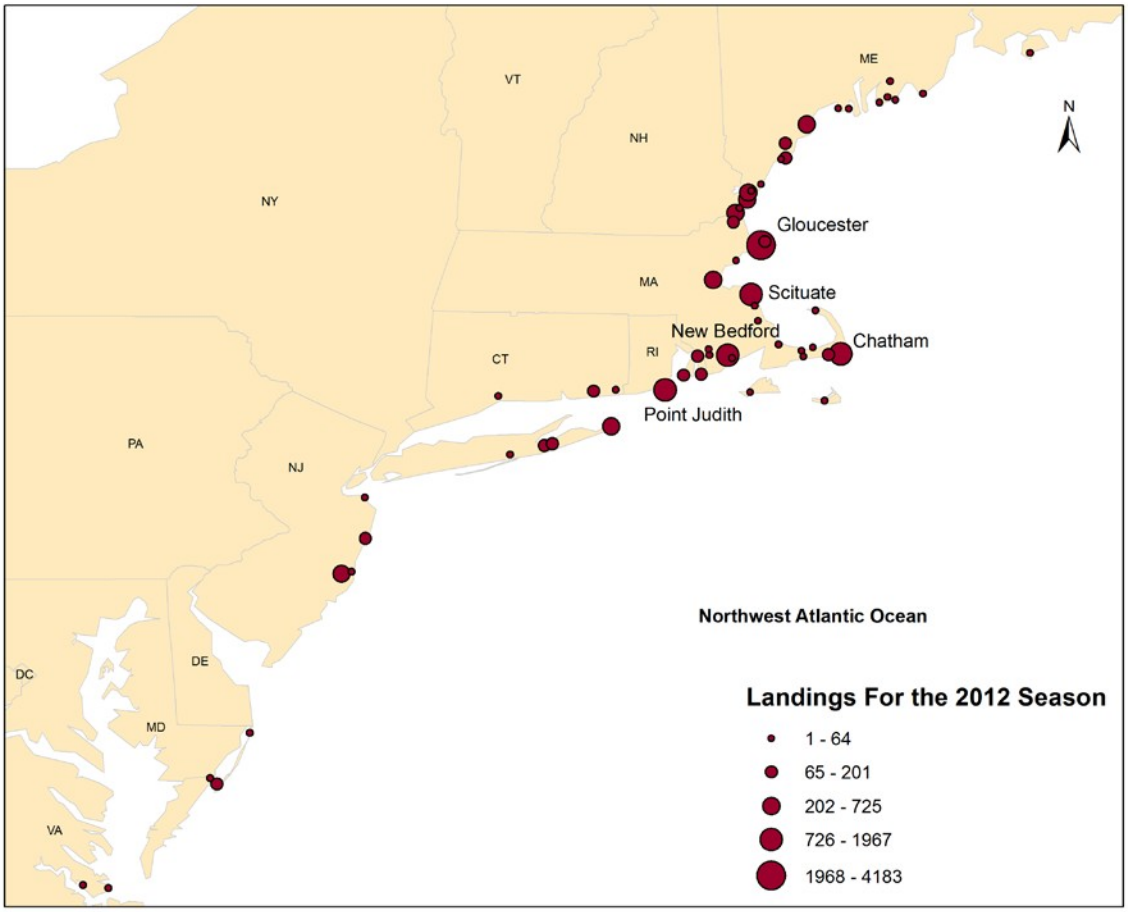


Figure A-1: Spatial distribution of groundfish landing events (count) by port for the 2012 fishing year (NMFS provided data, 2014). Top-five ports, by number of landings, are labeled.

Fishing activity, number of total trips, increases during the summer months and is lowest from January to April. Number of active vessels (i.e. vessels that completed dedicated groundfish trips) also varies throughout the year depending on gear type. The number of active gillnet vessels increases in the summer and is greatly reduced in January to April while the number of active trawl vessels is highest during the winter.

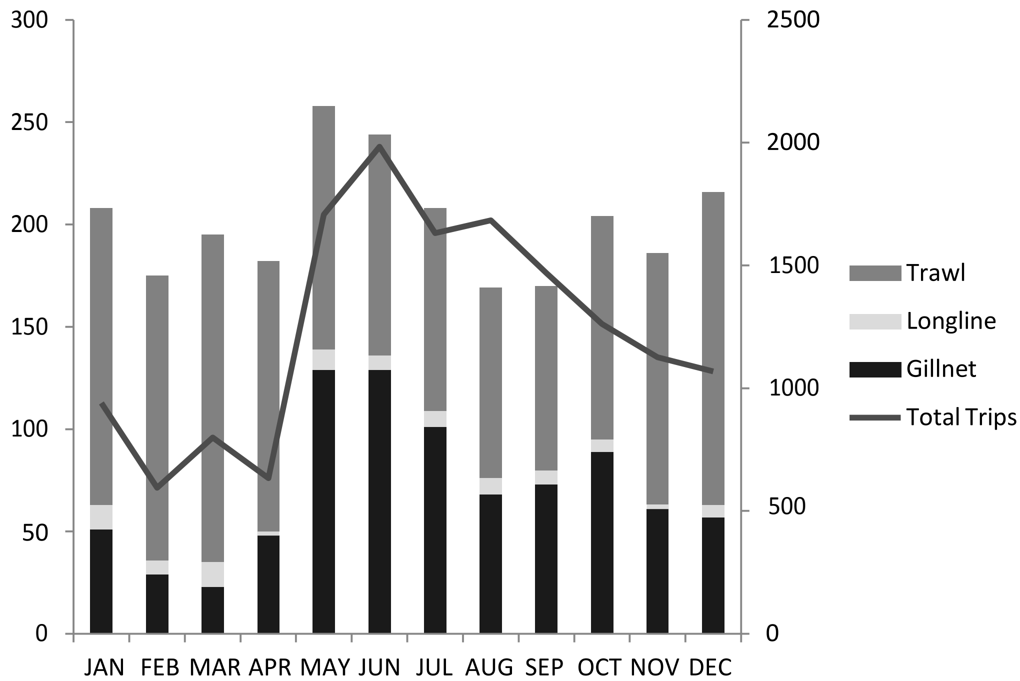


Figure A-2: Fishing activity seasonality. Bars represent number of active vessels by month by gear type. Line represents total number of trips per month (NMFS provided data, 2014).

Existing Monitoring Programs

There are several data collection methods used within the overall monitoring program that provide fishery-dependent data for use in management and enforcement. The existing tactics include a Pre-Trip Notification System (PTNS), Northeast Fisheries Observer Program (NEFOP), at-sea monitors (ASM), trip reports (VTR), dealer reports, electronic vessel monitoring systems (VMS) and a Port Biological Sample program.

Captains must register with the **PTNS** via phone, internet, or email at least 48 hours prior to the start of a groundfish fishing trip. Based on the PTNS, an observer or at-sea monitor may be assigned to the trip.

The **NEFOP** provides scientific observers on a percentage of the fishing trips each year, for example, in fishing year 2013 the coverage level was 8%. The objective is to gather data for scientific and management purposes such as stock assessments, protected species interactions, biological sampling, monitoring experimental fisheries, economics, and gear performance and characteristics. Since the introduction of sector management, NEFOP data is also used for tracking catch of ACE species.

ASMs accompany vessels on a percentage of the fishing trips each year, for example, in fishing year 2013 the coverage level was 14% of groundfish trips. The primary purpose of ASMs is for monitoring catch of quota allocated species.

As such, ASMs collect information on catch composition, and the data contributes to estimates of total discards by sector, gear type, and stock area, which is then used for generating assumed discard rates for trips that are not observed or monitored (ASM factsheet, 2013). Information on trip, gear type, and fishing locations are also collected by ASMs.

A **VTR** is completed by vessel operators for all trips for each area fished and gear type (e.g., if two areas or two gear types are fished, then two VTRs must be submitted). The data recorded on the VTR are catch by species per vessel per trip, but does not include catch by event or area breakdown. VTRs must be submitted by midnight of the first Tuesday following the end of the reporting week. This tool is used to portion the catch by area so that discard rates can be applied to total catch for trips that do not carry an ASM or NEFOP.

Dealer reports (trip ticket/offload data) are completed at the dock for catch that is sold, and report the kept catch by species by vessel per trip. For a single trip, it is possible that a vessel may have multiple dealer reports, and catch can be sold the day after landing.

VMS are deployed on all federally permitted vessels engaged in the multispecies fishery, and are monitored by NOAA's Office of Law Enforcement (OLE) to track vessel location on an hourly basis. The information from VMS is used by OLE for closed area fishing enforcement, but is not used by the NEFSC for science or other management.

The **Port Biological Sampling** program is jointly managed by the NEFSC and the GARFO, and contracted out to a third party. The Port Biological Sampling program collects length and age data from a subsample of all landed catch fished commercially within seven sampling regions. This includes both single and multiple stock species (37 species in total) and sampling takes place in calendar quarters. The program is designed to characterize the landings and to build a catch at age matrix and it is not designed to validate or monitor compliance with management requirements.

Appendix B: Onboard Methodologies

Audit Approach

Trawl Catch Handling

- All catch brought on board and released into the checker pen.
- All catch was run across the conveyor with the exception of large species (such as skate and dogfish) that would not fit on the conveyor belt or were difficult to get onto the conveyor belt; these were picked and sorted prior to processing.
- All discarded groundfish managed species were sorted into baskets by crew as the catch moved over the conveyor belt.
- All other discarded species were released over the chute as normal.
- A measurement control[1] point was established for any discarded groundfish managed species:
    - After the catch sorting was complete, each groundfish managed species was released, one piece at a time, down the discard chute.
- Discard control points were established for any other species discarded:
    - Control Point 1: Large catch items other than the groundfish managed species could be picked from the checker pen and discarded over the rails next to the stern within camera view.
    - Control Point 2: Items were run across the conveyor belt and other species were discarded out a scupper via the discard chute. Groundfish managed species sorted into containers were discarded one by one after catch sorting and discarding of all other species had been completed. All catch handling was to occur within camera view.

Gillnet Catch Handling

- All catch brought on board at the hauler.
- Crew sorted retained catch from the sorting table.
- Other species picked from the net and discarded at one of the two discard control points described below.
- Groundfish managed species placed on the sorting table within the measuring grid for three seconds, and then discarded by the net hauler.

[1] Fish measurements were used to determine weight during EM data analysis, not for minimum length enforcement purposes.

- A measurement control point was established for any discarded groundfish managed species:
  - Discarded groundfish managed species held flat within the measuring grid and within camera view for a minimum of three seconds. Fish were held in the middle section of the body while on the measuring grid so both the head and tail of the fish could be seen.
- Control points were established for all discarded catch items (see Appendix F for example diagrams):
  - Control Point 1**:** Groundfish managed species discarded at the starboard side net hauler within camera view. Other species also discarded at this location.
  - Control Point 2: Other species discarded at the picking station rail (starboard side aft of the hauler) within camera view.
- Catch handling methods specified for the crew member located at the stern was to pass all groundfish managed and other species discard to the captain for release.

Compliance Approach

Trawl Catch Handling

- All catch brought on board was released into either the starboard checker pen (if starboard net is used) or the port checker pen (if port net is used).
- All catch was run across the conveyor with the exception of larger species (skates, dogfish, large Atlantic Halibut, striped bass, Atlantic Wolfish) that would not fit on conveyor belt or were difficult to get onto the conveyor belt; these were picked and discarded at the control points listed below.
  - All dockside discards that could fit on the conveyor were collected in baskets/totes/vats at the end of the conveyor and then dumped into the starboard side vat for storage.
  - Skates were hand-picked from the conveyor and were discarded at a control point. The captain weighed some skates (approximately 30) prior to discard to help estimate the weight of overall discards. All skate were discarded piece by piece.
  - Smaller Atlantic Halibut (<24”) that could come onto the conveyor were held up for the camera and then were discarded one by one at a control point.

- Retained catch to be landed and sold (i.e. commercially landed catch) was picked and sorted into baskets and totes.
- All dockside discards were stored in the starboard side vats and separated by haul. The captain may have separated species when possible.
- Control points were established for any allowable discarding events (see Appendix D for example diagrams):
  - Control Point 1: Allowable discards could be picked from the port checker pen and discarded over the port rails next to the stern (not down the net ramp).
  - Control Point 2: Allowable discards could be picked from the starboard checker pen and discarded over the starboard rails next to the stern (not down the net ramp).
  - Control Point 3: Skates would be discarded by the basket on the starboard rail next to the conveyor.
- During fishing, the crew processed and dressed fish putting the viscera into totes. Tote contents were discarded over either the port or starboard rail and were not counted as discard events.
- All catch was stowed or within camera view for the duration of the trip to ensure discard compliance.

Gillnet Catch Handling

- Fish came on board at the starboard side net hauler; all catch remained in camera view once brought on board until the vessel had returned to port.
- Crew sorted kept catch from both sides of the sorting table and fish were sorted into fish boxes on the starboard side, aft of the crew, and on the port side.
- Crew sorted dockside discards from both sides of the sorting table and fish were stored in totes on the starboard side, behind where the captain works.
- If non-allowable discards (particularly dogfish) were to occur, for safety reasons, the crew was to discard immediately at one of the control points with no attempt to store the catch on board.
- Any allowable discards, with the exception of skates, were discarded at the starboard side net hauler either before they were brought onboard or after they were picked from the net. Skates were discarded at any of the control points by the crew member.

- Control points were established for any allowable discarding events (see Appendix D for example diagrams):
  - Control Point 1: Allowable discards could be discarded at the starboard side net hauler by the captain; non-allowable discarding was expected (particularly dogfish) and could occur at this location.
  - Control Point 2: Skates could be discarded on the starboard side of the vessel, aft of the captain, by the crew member; non-allowable discarding was expected (particularly dogfish) and could occur at this location.
  - Control Point 3: Skates could be discarded on the port side of the vessel by crew members; non-allowable discarding was expected (particularly dogfish) and could occur at this location.
- During fishing, the crew processed and dressed fish and may have put the viscera into totes. These totes were to be discarded over either the port or starboard rail and were not counted as discard events.

All catch was stowed or within camera view for the duration of the trip.

Appendix C: Length-Weight Measurements

Length-Weight Conversions

Table A-2: Measurement types (fork or total length) for groundfish managed species

Species	Fork Length	Total Length
Atlantic Halibut	✓	
Pollock	✓	
Atlantic Cod	✓	
Haddock	✓	
Ocean Pout		✓
Redfish, nk		✓
Atlantic Wolfish		✓
Winter Flounder		✓
Yellowtail Flounder		✓
Witch Flounder		✓
American Plaice Flounder		✓
Windowpane Flounder		✓
White Hake		✓
Flounder, nk		✓

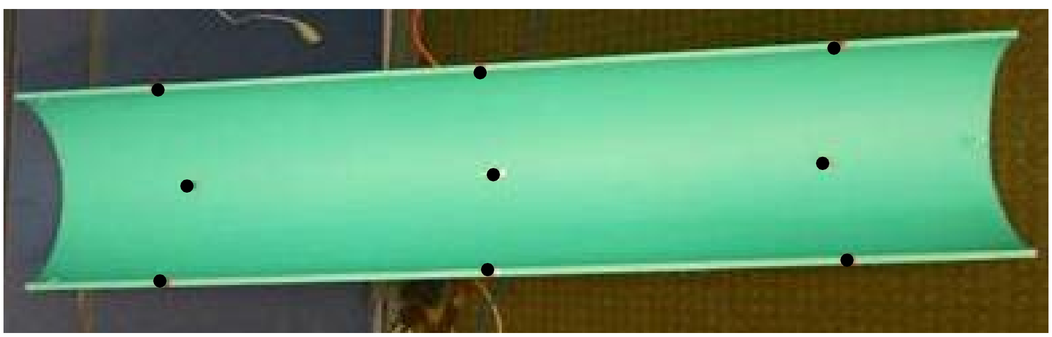


Figure A-3: Example of a discard chute with nine calibration marks (emphasized with black dots).

Table A-3: Length-weight survey data used by month for each species of groundfish managed species

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Atlantic Cod	W	W	W	S	S	S	S	S	S	A	A	A
Haddock	W/S	W/S	W/S	W/S	W/S	W/S	W/S	W/S	W/S	A	A	A
Pollock	W/S	W/S	W/S	W/S	W/S	W/S	W/S	W/S	W/S	A	A	A
Redfish, nk (Ocean Perch)	S/A	S/A	S/A	S/A	S/A	S/A	S/A	S/A	S/A	S/A	S/A	S/A
White Hake	W	W	W	S	S	S	S	S	S	A	A	A
American Plaice Flounder	W/A	W/A	W/A	S	S	S	S	S	S	W/A	W/A	W/A
Winter Flounder (Blackback)	W	W	W	S	S	S	S	S	S	A	A	A
Witch Flounder (Grey Sole)	W/S	W/S	W/S	W/S	W/S	W/S	W/S	W/S	W/S	A	A	A
Yellowtail Flounder	W	W	W	S	S	S	S	S	S	A	A	A
Atlantic Halibut	A	A	A	S	S	S	S	S	S	A	A	A
Atlantic Wolffish	S/A	S/A	S/A	S/A	S/A	S/A	S/A	S/A	S/A	S/A	S/A	S/A
Ocean Pout	W/A	W/A	W/A	S	S	S	S	S	S	W/A	W/A	W/A
Windowpane Flounder	W	W	W	S	S	S	S	S	S	A	A	A

W=Winter, S=Spring, A=Autumn

Length Estimation Tool - Accuracy

This section outlines a number of the tests performed by Archipelago Marine Research Ltd. R&D to document the accuracy of the length measurement tool, summarizes the results, and recommends best practices for working with the EM Interpret™ Length Measurement tool. The suitability of the tool should be evaluated for each individual program before use.

Using the Length Measurement Tool

While viewing video footage in the EM Interpret™ software, the reviewer can use the Length Measurement tool to estimate the length of individual catch items. When the viewer clicks on the start and end point of a catch item, the tool calculates the length of that catch item based on the "known" measurements between calibration marks (placed beforehand on the chute or measuring board and visible to the viewer). EM Interpret uses these calibration marks to compensate for lens distortion and correct for the *keystone effect*[2].

Sources of Error

A number of factors can impact accuracy and influence the suitability of the tool. These factors can be grouped into three main categories: physical deployment, objects being measured, and reviewer methodology (Table A-4).

Table A-4: Sources of error with using the length measurement tool.

Category	Sub-Category
Physical Deployment	• Shape of the chute • Angle of the chute with respect to the camera • Camera type • Lens type • Distance of camera from fish
Objects Being Measured	• Lighting (shadows) • Catch item behavior (i.e. curling of fish) • Catch handling procedures (i.e. discards en masse)
Reviewer Methodology	• Consistent manner for selecting measuring points • Tool calibration • Consistent approach for dealing with non-ideal imagery

Testing Materials and Methods

Archipelago tested whether the angle of the chute (with respect to the camera), the type of camera, or the type of camera lens effect the accuracy of the data outputs. Other potential sources of error, such as lighting and reviewer methodology, were held constant between trials (Table A-4).

[2] The keystone effect occurs when attempting to project an image onto a surface at an angle, as with a projector not quite centered onto the screen; image dimensions are distorted, making it appear as a trapezoid or keystone.

Camera and Chute Setup

Archipelago currently uses two types of cameras: analog and digital (IP). Testing was performed on both types, using two different focal lengths for each camera (wide and narrow). The lengths available for the IP camera were 3.6 mm and 6.0mm, and for the analog 3.2 mm and 6.0 mm. (The 3.6 mm and 3.2 mm lens' are considered comparable for the sake of a wide lens in relation to the narrower 6.0mm lens.)

During the tests, the cameras were permanently mounted between 1.5 and 2.5 meters (5 to 8 ft.) from the centre of the chute. The variation in camera height was due to the setup of the chute which was angled at: 0, 12.5, 22.5, and 40 degrees.

The purpose of these setups was to capture the effects of resolution and distortion from the camera setup and chute angle on the accuracy of the length measurement tool. The distortion may be increased depending on the location of the fish measurement on an angled chute. For this reason, the fish measurement position was also tested at the top, middle and bottom of the chute. Not all combinations of chute angle, camera type, and camera lens were completed leaving an unbalanced design. However, 9 replicates of 33 different test combinations were made for a total of 297 measurements.

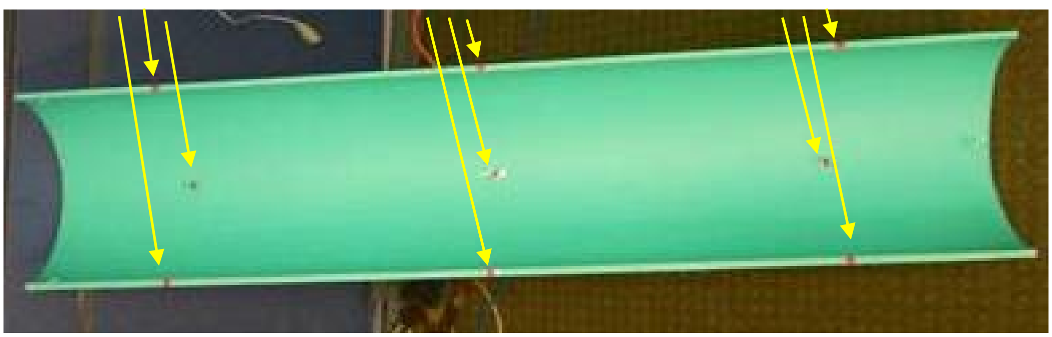


Figure A-4: Components of a vessel chute.

Simulated Fish

Actual fish were not an option for testing purposes, therefore test "fish" in the range of 25 to 43 cm length, were fabricated from 3 mm (1/8") thick wooden material. There are inherent disadvantages to using simulated fish, in that they do not necessarily traverse along a chute in the same fashion as a real fish. The rigidity of the simulated fish was observed to vary the plane of traversal along the chute, and thus project a tilted or skewed image. The accuracy of measurement during viewing was negatively affected by this planar effect.

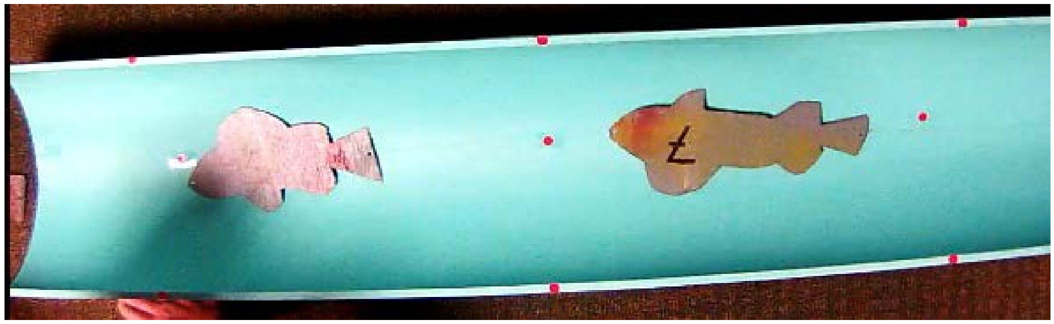


Figure A-5: Simulated fish used for testing the chute configuration.

Analytical methods

The purpose of the different camera, lens and chute angle combinations was to test the overall robustness of the length measurement tool to varying camera and chute setups. For this reason, absolute error was considered for more detailed analysis and not the direction of the error (i.e., over versus under-estimation). Error was the difference between the true length of the fish and the measured length from the video analysis. Both percent accuracy and error were analyzed using a linear regression with a cube-root power transformation for normality. Both models had the same significant effects for all factors including interactions between angle and lens type as well as angle and fish position on the chute. The angle of the chute was considered a continuous variable while all others were treated as factors.

Results

On average, the fish were overestimated by 0.32 cm (se = 0.03). Using an IP camera with a 6.0 mm lens provided the most accuracy. For a level (0 degree) chute there was no impact by the position of the fish on error; as the angle increased, using the middle or the top significantly reduced the absolute measurement error. A wide angle lens (3.2 mm or 3.6 mm) had a larger impact on error than the 6.0 mm lens, although this effect was reduced when the chute was set at higher angles. Under the best set-up conditions (IP camera, 6.0 mm lens, top of chute, and level chute) approximately 0.11 cm (se = 0.05) of error is expected and a percentage error of 0.4% (se = 0.5). Under the worst conditions (analog camera, 3.2 mm lens, bottom of the chute, and 40 degree angle) we expect approximately 1.7 cm (se = 0.11) of error and a percentage error of 5.3% (se = 1.0).

Calibration Consistency

From the results above, we used best practices to determine the most reliable method to analyze catch video. The best practice was used to test how sensitive the measurement tool was to calibration. Using a single frame of a fish, the measurement tool was recalibrated 30 times and a measurement was taken. The result was a standard deviation of 0.04 cm from the average. This result indicates that very little error in measurement can be attributed to how the tool is calibrated.

Conclusion

Archipelago R&D testing confirmed that IP cameras produced much higher-quality video, and lenses with a longer focal length provided less distortion. The best results (i.e. within 0.5% of actual size) were obtained when:

- Using an IP camera with a 6.0 mm lens.
- The camera was level with the measurement surface (0 degrees).
- Objects were measured near the top or middle of the calibration area.

Best Practices and Recommendations

When deploying an EM system on a fishing vessel, it is best practice to use a digital camera with a 6.0 mm lens. The angle of the measurement area with relation to the camera should be as close to zero as possible. If the chute is angled, methodologies for reviewers should recommend measuring each catch item as it passes through the upper portion of the measurement area.

Considering the number of variables that will impact the accuracy of the results, we recommended that the camera set up on each vessel be evaluated for accuracy, using the following procedure:

1. Take three objects of known length (frozen fish, fish cut-outs, etc.) that represent the length of the target species.
2. While recording video with the EM system, have each object slowly transit the calibration points.
3. Review the imagery data, measuring each item three times (Upper, Centre, and Lower calibration marks) and record the values.
4. Compare the recorded values with known length against the standards of acceptable error developed for the project. If the measurements fall within the standards, the camera set up is adequate. If they fall outside of the standards the camera set up needs to be reassessed.

Length Estimate Configuration Checks

This section outlines the procedures used to check the effect the set up of the length measurement area has on the accuracy of the tool as well as the individual results for each vessel. As each vessel set up is unique, so are the physical factors that affect the accuracy of the length measurement tool.

Length Measurement Tool Background

The length measurement tool is a component of the EM Interpret™ software developed by Archipelago Marine Research Ltd. As described in the Application Note *Length Measurement: Accuracy Testing*, the length measurement tool uses a series of reference points that have been visually marked on either the discard chute or measuring board to enable the viewer to estimate the length of a fish as it passes across the camera view and within the nine reference points. Further information on the reference points can be found in the *Discard Chute Standards* document developed by Archipelago Marine Research Ltd.

Objectives

Although all EM cameras are set up in accordance with generic configuration guidelines, some vessel configurations may necessitate some unique variations. The goal of checking the length measurement set up on vessels participating in the Phase III Audit Approach was to determine whether the lengths of known objects fell into acceptable ranges when measured using the length measurement tool.

Methodology

Simulated Fish

Three fish were fabricated using foam and glue. The fish measured 20 cm, 25.5 cm and 30 cm in length (from the tip of the mouth to the fork in the tail) and approximately 0.6 cm wide (at the tip of the mouth and the fork in the tail). These lengths were chosen as throughout this phase of the project, 90% of measured discarded ACE species fell into the 20 to 35 cm range.

Each fish was color-coded so that the length measurements from the video could be aligned with the actual lengths. Double-sided tape was adhered to the back of each fish so that the fish would remain stationary during testing.

Video Clips

Video was triggered to record using the manual record function of the EM system. A foam fish was first placed between points P7 and P8 of the length measurement area; and then placed between points P8 and P9; and finally placed with the centre of the fish lying over P8 (Figure A-6). The fish was left in place for three seconds at each point.

This procedure was repeated with the two remaining fish. After all fish had been placed on the measurement area the sensor and video data were collected from the EM system.

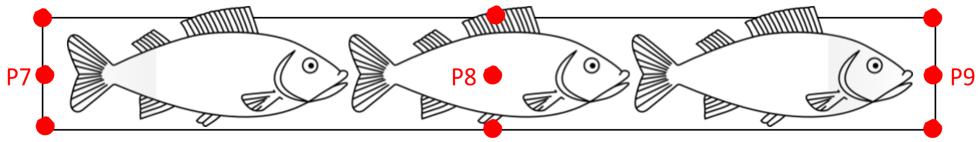


Figure A-6: Diagram of fish measurement area showing the measurement placements for each fish.

Data Processing

Using EM Interpret Pro, catch annotations with length estimation were created for each fish at each point of the grid. The placement of the fish was recorded in the annotation comments.

Results

Table A-5: Accuracy of length measurement based on the position of the fish on the grid for small, medium and large sized fish for Vessel C.

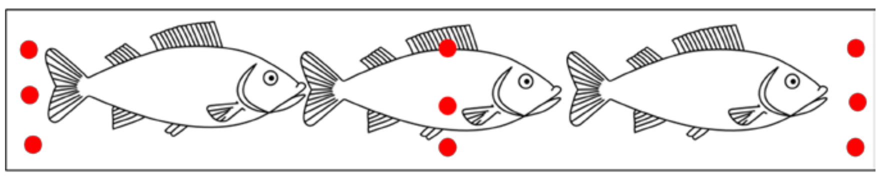
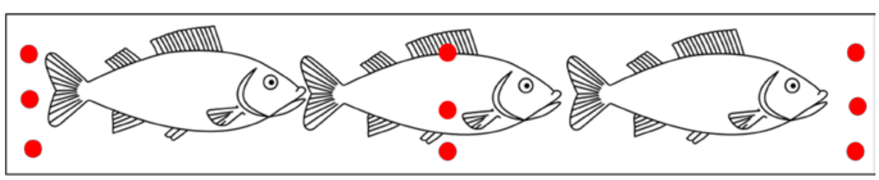
Fish Placement			
35 cm	-2.0%	0.3%	0.6%
25 cm	1.5%	0.6%	2.0%
20 cm	-1.5%	-0.6%	1.4%

Table A-6: Accuracy of length measurement based on the position of the fish on the grid for small, medium and large sized fish for Vessel B.

Fish Placement			
35 cm	3.8%	-0.7%	-2.8%
25 cm	6.8%	2.5%	-0.7%
20 cm	5.0%	1.8%	-1.0%

The vessel configuration for Vessel C enabled a viewer using EM Interpret™ Pro to generate length estimations that range between -2.0% and 2.0%. The difference in actual length ranged from -0.696 cm to 0.490 cm.

The vessel configuration for Vessel B enables a viewer using EM Interpret™ Pro to generate length estimates that range between -2.8% and 6.8%. The difference in actual length ranged from -0.995 to 1.329 cm.

Appendix D: Vessel Monitoring Plan Example

Introduction

The VMP outlines vessel specific catch handling protocols and EM system configurations being used throughout the project. The combination of EM system configurations and catch handling protocols are designed to meet the Project Objectives described in the Project Plan and the Fisher Letter.

The VMP is a communication tool used to ensure that captains, EM field technicians, EM data reviewers and project coordination staff know what their roles are for a successful implementation. Each group has a role to play in ensuring the data collected by the EM system meets the project objectives and will need to provide feedback.

Project Coordination Staff:

- Ensure that the catch handling and EM system configuration requirements are optimal for accomplishing the data collection goals.
- Responsible for addressing feedback from captains, EM field technicians and EM data reviewers in the catch handling and EM system configuration requirements.

Captains:

- Ensure the catch handling requirements are met on each monitored trip.
- Advise the EM Field Technician if the EM system configuration or catch handling described in the VMP will change due to changes in fishing behavior or changed on a recent trip due to rare events (for example gear issues or safety concerns).

EM Field Technicians:

- Ensure that the EM system configuration meet the requirements.
- Work with the captain on optimal configuration-catch handling combinations to meet the project objectives.

EM Data Reviewers:

- Understand the catch handling protocols and EM system configuration to better interpret the EM data.
- Provide feedback to the project coordination staff on whether the catch handling and/or EM system configuration described in the VMP is not being followed or whether the VMP is being followed but it is not resulting in high quality data for meeting the project objectives.

General EM Procedures

EM System operation

EM system performance will be monitored for every trip to maximize EM data collection.

The EM system has been designed to operate with minimum effort by the captain. To ensure successful capture of EM data, the captain should:

- Turn the EM system on when vessel unties or lifts anchor, and
- Leave the EM system on the entire trip until the vessel has tied up in port or set anchor.

These steps will maximize data completeness and quality for the entire trip. For any fish handling activity occurring outside the normal recording of the EM system, captains are requested to use the manual record button on the system screen.

EM System Configuration

EM system components are to be installed on the vessel in a manner that meets the monitoring objectives, is both efficient for the technician and captain, and allows for normal fishing operations with a minimum of interference. Realizing the monitoring objective must be met, the first priority is to configure the EM system to achieve this objective and then complement the process by modifying catch handling protocol as a second priority.

Catch Handling

Catch handling should complement the EM system configuration (sensors and cameras) in achieving the monitoring objective. While every effort is to place and orient deck views with established catch handling procedures, some effort on behalf of the fishermen involved will be required. In this case the main issues are around discarding events.

Observer Conduct

Observers are to familiarize themselves with the EMS Observer Protocols sheet issued to each vessel which is also attached as Appendix B. Complying with discard locations and methods is essential to proper EM data collection. These modifications will ensure that data used as part of the pilot study are high quality. Following these protocols will also contribute to accurate estimates of species important to each vessel's Annual Catch Entitlement (ACE) and sector ACE.

Please note that these protocols are subject to change as EM analysis dictates. All observer protocols are developed by FSB staff. If you have any questions regarding protocol please call either Kelly Neville, (contact information), or Glenn Chamberlain, (contact information).

General Vessel Information

Vessel Name	Example
Gear Type(s)	
Home Port	Scituate
Captain	
Sector	
Vessel Length	
Hull Number	

Home Port – Port Box

Figure A-7: Scituate home port with port box.

Monitoring objective

<table>
<tr><th>Trip Type: EM Experiment Trip, Phase III</th><th>Date Implemented: MM/DD/YYYY</th></tr>
<tr><td colspan="2">Rationale:
Collect information on the EM system performance.
Use EM video to verify catch compliance; verify kept catch is stored in hold and dockside discards are stored on deck in large vats.
Use EM video to verify allowable discards such as large pelagics, marine mammals, sea turtles, sea birds, sturgeon, American Lobster, Atlantic Halibut, Atlantic Wolfish, Striped Bass, skates, Summer Flounder, and large debris at accepted discard control points.
Use a fishermen’s comment log to record fishing event details for EM reviewer alignment of time and location of fishing, and any allowable or non allowable events captured.</td></tr>
</table>

EM System Configuration

Compliance Approach

Software Setup

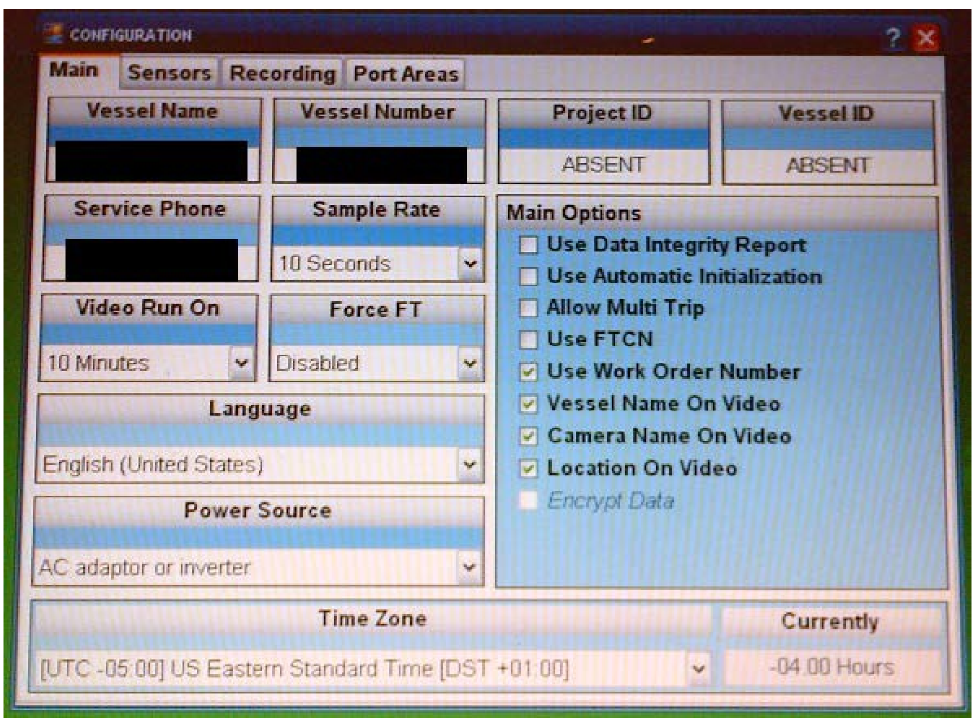


Figure A-8: Screen capture for EM control station.

EM Components Location

Control Center

- In the wheelhouse.
- Controls all the sensors and cameras and stores all the EM data.

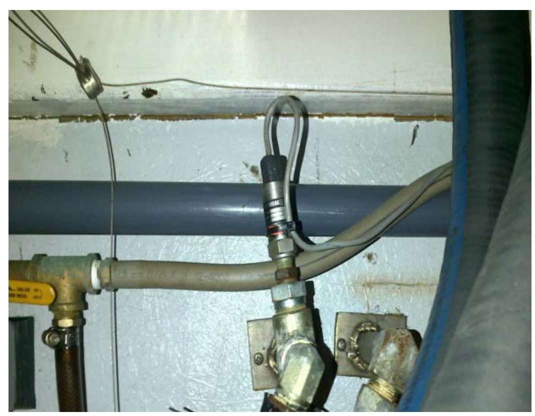
User Interface

- In the wheelhouse.
- Allows the captain and the EM technician to interact with the Control Center to ensure the system is performing well, enter comments, etc.

GPS

- On wheelhouse gantry upper crossbar.
- Provides location, time, and speed information.

Hydraulic Pressure Sensor



- On conveyor belt high pressure line in the engine room.
- Detects hydraulic activity on conveyor belt to signal fishing activity.

Drum Rotation Sensor  • Clamped on to starboard winch • Detects winch rotation to signal fishing activity.	
Camera 1 – Starboard View Location • On wheelhouse gantry upper crossbar. • Aimed towards starboard rail, conveyor and checker pen.	**View and objectives** • Verify all catch is retained. • Dockside discards are stored in starboard side vats. • Kept catch is stored in the fish hold. • Also verify if allowable discarding taking place at starboard side rails.
Camera 2 – Port Location • On wheelhouse gantry upper crossbar. • Aimed towards port rail, center deck and stern area.	**View and objectives** • Verify all catch is retained. • Dockside discards are stored in starboard side vats. • Kept catch is stored in the fish hold. • Also verify if allowable discarding taking place at port rails.
Camera 3 – Stern View Location • On wheelhouse gantry, starboard post. • Stern view of port and starboard ramps and rails as well as checker pen view.	**View and objectives** • Verify all catch is retained except allowable discards (large pelagics, marine mammals, sea turtles, sea birds, skates, Atlantic Wolfish, Striped Bass, American Lobster, Atlantic Halibut, sturgeon, and non-living debris).
Camera 4 – Scale view • Located under wheelhouse overhang, starboard side. • View of foredeck under the overhang where skipper will be weighing baskets.	**View and objectives** • Ensure all catch stays in camera view, particularly when observers are on board and when the captain takes baskets to the scale for measurement. • View for verifying summer flounder identification if discarding occurs in camera 1.

Catch Handling Protocols

EM Experiment trips, Phase III

Details of the catch handling protocols were laid out in this section. These are included in the Materials and Methods section of this report. An example of the diagram outlining control points is provided on the next page.

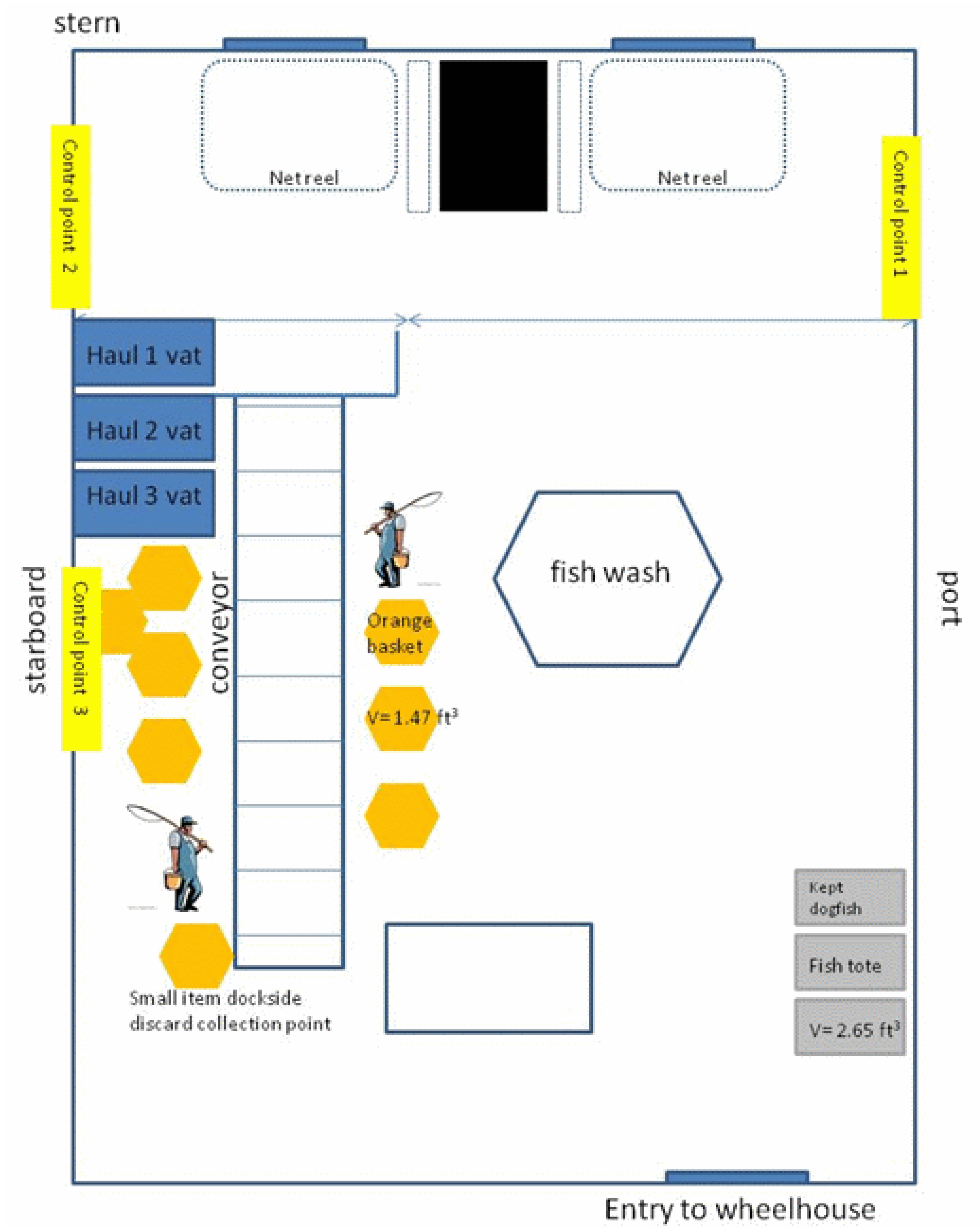


Figure A-9: Example Diagram showing locations of control points.

Notes

This section includes notes and describes changes made to the VMP throughout the project.

MM/DD/YYYY

- New system components and catch handling section added to accommodate for full retention strategy as part of EM experiments trips in Phase III of project. Removal of other sections as they do not pertain to this phase of the project.

EM System Configurations by Date

MM/DD/YYYY to MM/DD/YYYY – Configuration- Non-Observed Groundfish Trips

MM/DD/YYYY to MM/DD/YYYY – Configuration- Observed Groundfish Trips

MM/DD/YYYY – Modified Configuration- 100% Full Retention Catch Monitoring

Vessel Layout

This section contains pictures of the vessel. No pictures have been included in the example to protect the privacy of project participants.

Observer Sampling Protocols

05/13

Captain and Crew On Deck Reference Guide—EM Phase III

Electronic Monitoring

Participant responsibilities– Groundfish ONLY trips

Day before (preferred) or day of a fishing trip

1. Notify FSB of planned groundfish trip; ***call Niki Rossi*** at 508-495-2128 (office) or 781-789-6111 (cell).
2. Call 1-888-284-4904 to notify your EFP trip as per EFP reporting instructions sheet.
3. Text or call Niki when you are ready to steam back to port (hail end trip).
4. Call Archipelago if you experience any issues with your EM system 1-888-383-4535.

Catch handling

1. All catch brought on board and released into checker pen(s).
2. All dockside discards will be collected in baskets at end of conveyor and put in starboard side vat by haul.
3. Allowable discards will be discarded over starboard (or port as needed) checker rail and starboard conveyor rail.
4. Kept catch stowed in baskets and totes in fish hold.
5. Kept dogfish will be stored on deck in totes.

Control Points

1. Control point 1: allowable discards may be picked from the port checker pen and discarded over the port rails next to the stern.
2. Control point 2: allowable discards may be picked from the starboard checker pen and discarded over the starboard rails next to the stern.
3. Control point 3: starboard side along the conveyor

EM system shut down requirements

1. Keep EM system on for a minimum of 10 minutes after automatic or manual recording has ended.

Observer responsibilities– Groundfish ONLY trips

1. ***Do NOT discard any catch***– vessel has an approved exempted fisheries permit that allows them to retain all catch.
2. Discard chute will *NOT* be in use; discards will be collected in baskets at the end of the conveyor
3. Work with discards collected in baskets, and when you are finished working up the catch, put catch items in the large vats on either the starboard or port sides of the vessel
4. Even though all fish are kept for the purposes of the EM study, use the disposition code that would normally apply to a species (ex. If a fish would have been discarded because it was sublegal, or prohibited)

skates may be discarded

Allowable Discards

Marine mammals	Sea birds	Sea turtles	American lobster	Large pelagics
Sturgeon	Skates	Striped bass	Atlantic halibut	Atlantic wolffish

Contacts

Nichole Rossi - 508-495-2128 (office) or 781-789-6111 (cell)
Kelly Neville - 508-495-2151
Glenn Chamberlain - 508-495-2153
Mark Hager - 508-269-8138

Specific Requirements - Compliance Approach

Dockside Monitoring

Define data needs

- Obtain weights on all dockside discards with a focus on allocated species weights

Table A-7: Species involved in the compliance approach.

Groundfish Managed Species	Annual Catch Entitlement (ACE) Species	Prohibited Species
Atlantic Cod	Atlantic Cod	Atlantic Wolffish
Pollock	Pollock	Ocean Pout
Haddock	Haddock	Windowpane Flounder (sand dab)
Redfish	Redfish	
Winter Flounder	Winter Flounder	
Witch Flounder	Witch Flounder	
American Plaice Flounder	American Plaice Flounder	
Yellowtail Flounder	Yellowtail Flounder	
Atlantic Halibut	Atlantic Halibut	
White Hake	White Hake	
Atlantic Wolffish		
Ocean Pout		
Windowpane Flounder (sand dab)		

Procedures and Forms

- Captains will need to sort kept from dockside discards (sort discards by haul if using for a monitored trip[3]).
- Dockside monitors will use the dockside monitor weigh-out report (originally created and used by DSM program).
- Dockside monitors will obtain actual weights for all dockside discard species using Marel scales (monitors will not work with landed catch).
- It will be assumed that any dockside discard ACE species was sublegal, else, it should have been landed and sold.
  - The exception is if the dockside discard ACE species is obviously a poor quality fish (i.e. missing head, missing guts etc.).
- Fish at the dock will be measured in the fish house (if there is one present).
- Fish may be measured on the boat then dumped back out at sea in some cases.
- Dockside monitors will retrieve EM data and fishermen logs.

[3] Vessel D was permitted by GARFO to use DSM data from trips under the compliance trial as 'monitored trips' under sector management requirements (i.e. as ASM data).

Appendix E: Fishermen Comment Logs

Instructions –Audit Approach (Figure A-10):

- Record time and location (coordinates and statistical area) of the start of all hauls (gillnet) or tows (trawl)
- Document all discarding of groundfish managed species
  - Record haul number
  - Record all groundfish managed species piece counts for all hauls
  - Record all discarded allocated (ACE) total estimated weight (in lbs) by species for all hauls
  - Record weight estimation method used
  - Record damaged discarded allocated (ACE) species counts
- Record time and location of the end of all hauls (gillnet) or tows (trawl)

Instructions –Compliance Approach (Figure A-11):

- Record time and location of the start of all hauls (gillnet) or tows (trawl)
- Document all allowable discarding activity
  - Record haul number
  - Provide an estimated weight for discarded skate at the species group
  - Record all species discarded (identified to the lowest taxonomic level possible)
- Document all non-allowable discarding activity
  - Record haul number (if applicable), time and location
  - Provide an estimated weight of the discard by species
  - Record the rationale behind the discard
- Document any codend tripping
  - Record species and weight estimate
  - Record rationale for discard

VESSEL NAME	Example
DATE LAND (mm/yy)	/
PAGE #	OF
EVENT DATE (mm/dd/yy)	/ /

FISHERMEN'S COMMENT LOG
NMFS FISHERIES OBSERVER PROGRAM
05/01/13

Record a count and weight for allocated (ACE) species listed below after each haul where any of these species are discarded. If any groundfish discards are damaged to the point where they can't be identified to the species level (i.e. bones or rack), record a count and estimated weight in the space provided. If you have additional comments, please record them on the back of the log.

VESSEL NAME	HULL NUMBER	COMMENTS CONTINUED ON BACK? NO 0 ____ YES 1 ____	STAT AREA FISHED

HAUL NUMBER	HAUL START DATE	HAUL START TIME (24 hours)	HAUL START LAT	HAUL START LONG	HAUL END DATE	HAUL END TIME (24 hours)	HAUL END LAT	HAUL END LONG

SPECIES	COUNT	WEIGHT (LBS)	ESTIMATION METHOD (VISUAL, ACTUAL, TALLY, OTHER)	SPECIES	COUNT	WEIGHT (LBS)	ESTIMATION METHOD (VISUAL, ACTUAL, TALLY, OTHER)	COMMENTS
WHITE HAKE				WINTER FLOUNDER (BLACKBACK)				
POLLOCK				YELLOWTAIL FLOUNDER				
ATLANTI C COD				WITCH FLOUNDER				
HADDOCK				AM. PLAICE FLOUNDER (DAB)				
OCEAN POUT				SAND DAB FLOUNDER (WINDOWPANE)				
REDFISH				ATLANTIC HALIBUT				
ATLANTIC WOLFFISH								

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Figure A-10: Fishing Log (modified Fishermen's Comment Log) designed specifically for the audit approach.

FISHERMEN'S COMMENT LOG
NMFS FISHERIES OBSERVER PROGRAM
05/01/13

VESSEL NAME	
DATE LAND (mm/yy)	/
PAGE #	OF
EVENT DATE (mm/dd/yy)	/ /

Record a count and weight for allocated (ACE) species listed below after each haul where any of these species are discarded. If any groundfish discards are damaged to the point where they can't be identified to the species level (i.e. bones or rack), record a count and estimated weight in the space provided. If you have additional comments, please record them on the back of the log.

VESSEL NAME	HULL NUMBER	COMMENTS CONTINUED ON BACK? NO 0 ____ YES 1 ____	STAT AREA FISHED

HAUL NUMBER	HAUL START DATE	HAUL START (24 HR)	HAUL START LAT	HAUL START LONG	HAUL END DATE	HAUL END (24 HR)	HAUL END LAT	HAUL END LONG
		:				:		

SPECIES	COUNT	WEIGHT (LBS)	COMMENTS	SPECIES	COUNT	WEIGHT (LBS)	COMMENTS
SKATES				BARNDOOR SKATE			
ATLANTIC WOLFFISH				SUMMER FLOUNDER			
STRIPED BASS				MAMMALS, SEA BIRDS, SEA TURTLES	COMMENTS		
AMERICAN LOBSTER				CODEND TRIPPING	PARTIAL	LARGE DEBRIS	YES
ATLANTIC HALIBUT					FULL		NO
STURGEON				COMMENTS		COMMENTS	
SHARKS (OTHER THAN DOGFISH), TUNAS, BILLFISHES, AND RAYS							

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Figure A-11: Fishing Log (modified Fishermen's Comment Log) designed specifically for the compliance approach.

Appendix F: Dockside Monitoring Results

Below is a summary of all of the dockside discards that were recorded by the dockside monitors during the compliance approach field trials.

Table A-8: Total dockside discards (LUMF, undersized ACE fish, prohibited species, and bycatch) data by species and weight collected by Dockside Monitors.

	VESSEL C (lbs)					VESSEL D (lbs)		
Species	**Trip 1**	**Trip 2**	**Trip 3**	**Trip 4**	**Trip 5**	**Trip 1**	**Trip 2**	**Trip 3**
Alewife	0	0	0	0	0	0	0	0.5
American Plaice Flounder	0	0	0	0	0	12.4	5.1	18
Atlantic Cod	0	0	0	0	0	0	0	1.8
Atlantic Halibut	0	0	0	0	28	0	0	0
Barndoor Skate	0	15	0	3	8	0	0	0
Debris, nk	0	3	0	0	0	5.2	11.9	28
Fish, nk	0	3	0.6	0	6	0	0	0
Fishing gear debris	0	0	0	0	0	5	0	0
Fourspot Flounder	0	0	0	0	0	6.7	7.6	18.4
Haddock	0	0	0	0	0	0	0.8	0
Jonah Crab	0.6	21	4	6	8	2.9	7.2	3.8
Longhorn Sculpin	0	0	0	0	0	0.1	0.2	67.1
Lumpfish	0	0	0	1	0	0	0	0
Monkfish	0	15	0	0	6	15.9	15.4	0.8
Octopus, nk	0	0	0	0	0	0.4	0.2	0
Red Hake	0	0	0	0	0	0.2	1.9	4.6
Rock Crab	1	9	0	0.9	0	2.6	3.1	15.9
Sea Raven	0	0	0	0	0	0	2.2	16
Sea Scallop	0	0	0	0	0	0	0	0.1
Seastar Starfish, nk	0.4	0	0	0	0	0	0.5	0
Shell, nk	0	0	0	0	1	0	0.1	2.1
Shortfin Squid	0	0	0	0	0	0	0.4	0
Silver Hake	0	0	0	0	0	0.8	0.5	2.4
Skate, nk	0	0	0	0	0	0	0	2
Spiny Dogfish	0	18	18	9	26	0	18.9	0
Sponge, nk	0	0	0	0	0	0	0	339.3
Thorny Skate	2	0	0	0	0	0	0	0
Windowpane Flounder	0	0	0	0	0	10.9	9	3.1
Winter Flounder	0	0	0	0	0	17.6	8.7	5.3
Winter Skate	4	0	0	0	0	0	0	0
Witch Flounder	0	0	0	0	0	0.4	0	0
Yellowtail Flounder	0	0	0	0	0	8.6	7.4	23.8
Total	**8**	**84**	**22.6**	**19.9**	**83**	**89.7**	**101.1**	**553**

Appendix G: Trip Report Example

Below are two examples of trip reports that use mock-up data to demonstrate the information that was provided to captains during the trial.

Audit Approach

Vessel:	Example Vessel
Departure Date:	September 21, 2013
EM Trip Number:	111111.01

Feedback

Overall

- Feedback from the imagery viewer indicates that the camera dome above the measurement area requires cleaning. Please try to periodically wipe domes, particularly after catch processing. Clean camera domes facilitate imagery review and can reduce processing time.

Data Completeness

- The EM system was not powered on until the vessel was already outside of port.

Onboard Methodology

- Not all of the discarded allocated (ACE) species were measured. As described in the onboard methodology please place each discarded allocated (ACE) species catch item in the EM measuring grid for three second prior to discard.

Species Comparisons

- The Captain Comment Log had no pieces recorded for Ocean Pout; however, the EM imagery did record some Ocean Pout.

Location and Date/Time Comparisons

- The Captain Comment Log has Area 611 recorded for event 2 but the positional information of the EM data indicates the event start was in Area 539.

Species Comparisons

Flounder, Sand Dab (Windowpane)					
		Captain Comment Log	EM Data	Absolute Difference	Percentage Difference
Event 1	Pieces	83	395	312	79%
	Weight (lbs)	32	252.5	220.5	87%
Event 2	Pieces	36	50	14	28%
	Weight (lbs)	12	32.6	20.6	63%

Flounder, Winter (Blackback)					
		Captain Comment Log	EM Data	Absolute Difference	Percentage Difference
Event 1	Pieces	3	17	14	
	Weight (lbs)	0.5	8.6	8.1	
Event 2	Pieces	15	34	19	56%
	Weight (lbs)	3	20.7	17.7	86%

Ocean Pout					
		Captain Comment Log	EM Data	Absolute Difference	Percentage Difference
Event 1	Pieces		2	2	

Flounder Total (includes Flounder, nk)					
		Captain Comment Log	EM Data	Absolute Difference	Percentage Difference
Event 1	Pieces	86	417	331	79%
Event 2	Pieces	51	90	39	43%

Calculations

$EM\ Weight = \sum(Measured\ Est.\ Weight) + (Unmeasured\ Pieces\ x\ Avg.\ Weight\ Per\ Measured\ Piece\ for\ Haul)$

Notes

Unknown Species entries included:

- Haul 1: 5 flounder, nk
- Haul 2: 6 flounder, nk

Location and Date/Time Comparisons

	Location - Start				
	Captain Comment Log		EM Data		Difference (nm)
Event 1	42° 16.03	72° 13.45	42° 16.01	72° 13.80	0.03
Event 2	42° 08.71	72° 07.62	42° 08.68	72° 07.95	0.02

	Location - End				
	Captain Comment Log		EM Data		Difference (nm)
Event 1	42° 09.45	72° 51.01	42° 09.44	72° 51.00	0.01
Event 2	42° 04.62	72° 56.26	42° 04.62	72° 56.28	0.02

	Date/Time - Start		
	Captain Comment Log	EM Data	Difference (min)
Event 1	09/21/2013 9:27	09/21/2013 9:28	1
Event 2	09/21/2013 11:05	09/21/2013 11:05	0

	Date/Time – End		
	Captain Comment Log	EM Data	Difference (min)
Event 1	09/21/2013 10:17	09/21/2013 10:17	0
Event 2	09/21/2013 11:59	09/21/2013 12:00	1

	Area Fished		
	Captain Comment Log	EM Data	Result
Event 1	611	611	Match
Event 2	611	539	No Match

Compliance Approach

Vessel: Example Vessel

Departure Date: September 21, 2013

EM Trip Number: 111112.01

Feedback

Onboard Methodology

- Great Job!

Allowable Discards

- The Captain Comment Log had no pieces recorded for Atlantic halibut; however, the EM imagery did record one piece of released Atlantic halibut during haul 1.
- The Captain Comment Log had no large debris recorded; however, the EM imagery data did record some large debris.

Non-Allowable Discards

- One lumpfish was observed to have been discarded during this trip.

Location and Date/Time Comparisons

- All location and date/ time information was accurately recorded.

Allowable Discards

2A. Skate Comparison

Skate, other					
	Captain Comment Log	EM Data	Result	Estimated Weight (Log)	Piece Count (EM)
Event 1	Y	Y	Match	122	82
Event 2	Y	Y	Match	45	35

2B. Species Comparisons

Atlantic Halibut					
		Captain Comment Log	EM Data	Absolute Difference	Percentage Difference
Event 1	Pieces	0	1	1	n/a

American Lobster					
		Captain Comment Log	EM Data	Absolute Difference	Percentage Difference
Event 1	Pieces	1	0	1	n/a
Event 2	Pieces	3	4	1	n/a

2C. Large Debris

Large Debris			
	Captain Comment Log	EM Data	Result
Event 1	No	Yes	No Match
Event 2	No	No	Match

Notes

Viewer indicated that one large segment of chain or rope was discarded off the stern.

Non-Allowable Discards

Notes

There were no non-allowable discards observed on this trip.

Unknown Species entries included:

- Haul 1: 2 invertebrates, nk

Location and Date/Time Comparisons

Location - Start					
	Captain Comment Log		EM Data		Difference (nmi)
Event 1	42° 17.80	71° 25.80	42° 17.96	71° 25.93	0.12
Event 2	42° 17.30	71° 22.50	42° 17.42	71° 22.50	0.02

Location - End					
	Captain Comment Log		EM Data		Difference (nmi)
Event 1	42° 10.00	71° 16.00	42° 09.83	71° 15.83	0.20
Event 2	42° 09.20	71° 15.60	42° 09.02	71° 15.54	0.18

Date/Time - Start			
	Captain Comment Log	EM Data	Difference (min)
Event 1	09/21/2013 10:10	09/21/2013 10:10	0
Event 2	09/21/2013 12:50	09/21/2013 12:50	0

Date/Time – End			
	Captain Comment Log	EM Data	Difference (min)
Event 1	09/21/2013 11:30	09/21/2013 11:29	1
Event 2	09/21/2013 13:15	09/21/2013 13:15	0

Area Fished			
	Captain Comment Log	EM Data	Result
Event 1	516	516	Match
Event 2	516	516	Match

ELECTRONIC MONITORING VIDEO IMAGES

Electronic Monitoring (EM) video screen shots are a good tool to illustrate examples of EM performance and utility. Screen shots from EM video are incorporated into numerous outreach and educational resources, including: NEFOP and ASM trainings, EM study participant outreach meetings, EM reviewer/captain feedback mechanism, EM reviewer audit processes, species identification support, informational meetings with the Agency and the fishing industry, vessel monitoring plans (VMPs), observer on-deck reference guides, and for general educational presentations and outreach.

The following EM video screen shots provide examples of strengths and challenges associated with video imagery.

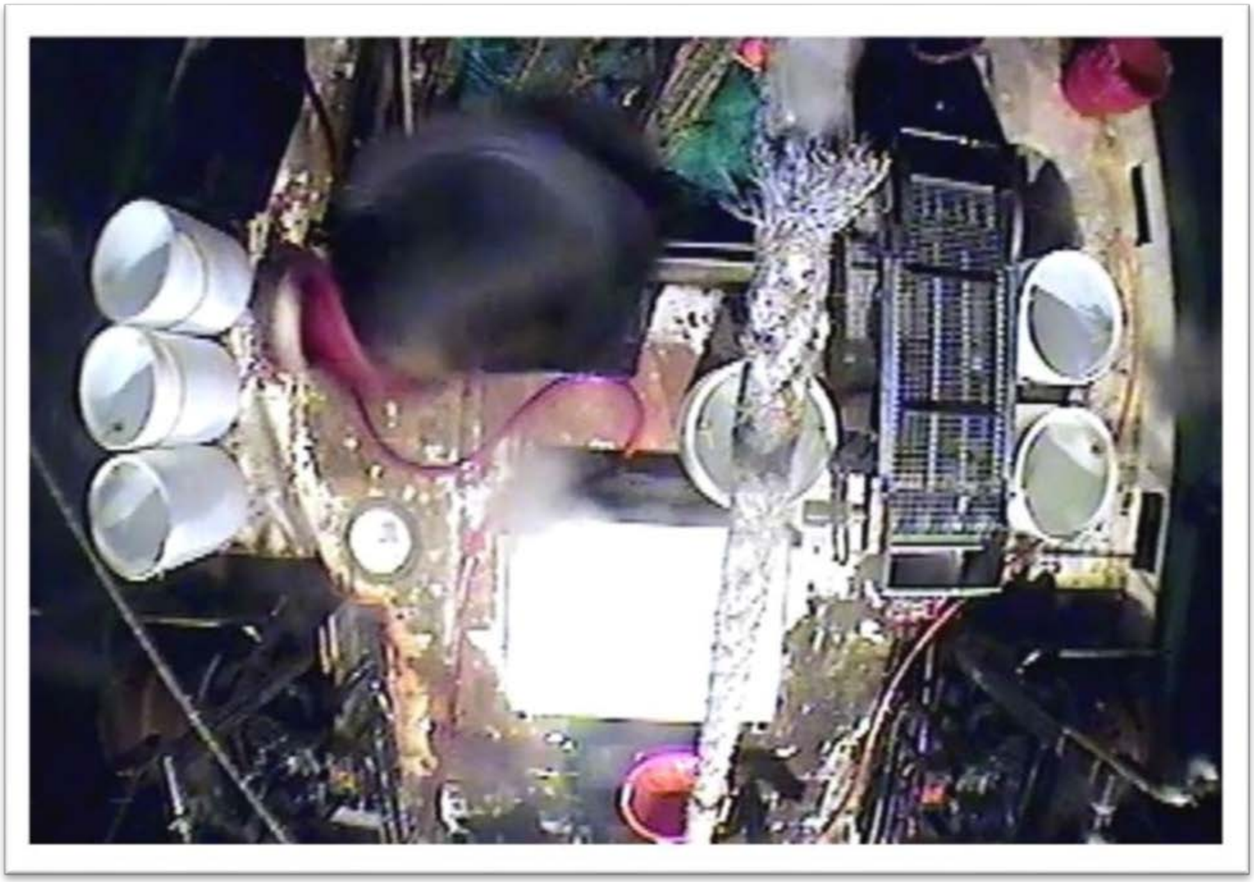

Figure 1: Poor image quality: water droplets on camera lens. Water droplets can appear in the camera view from weather or if the camera is splashed while the crew washes down the deck with the deck hose. Water droplets hinder the ability to identify catch and can impair viewing.

Figure 2

Figure 3

Figure 4

Figures 2 and 3: Poor image quality: glare. Glare is unfortunately unavoidable in most cases. There are sun shields that can be placed on the camera dome to help alleviate some glare but they are not 100% preventative. Glare can also cause shadows on the deck which impair the reviewer's ability to see catch items and activity on deck. **Figure 4:** Poor image quality: low light. Many vessels fish during the early hours of morning before the sun rises. The EM system requires adequate lighting to properly capture video footage. Deck lights are necessary and must be placed strategically to acquire the best footage possible. Imagery captured during night events will not be as optimal as during day events.

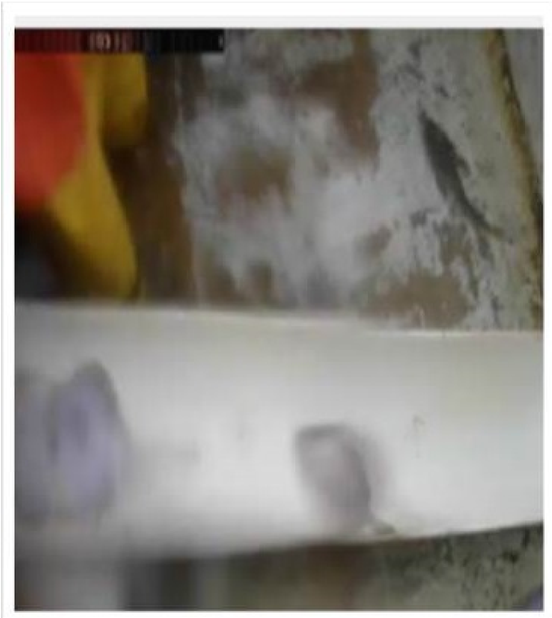

Figure 5

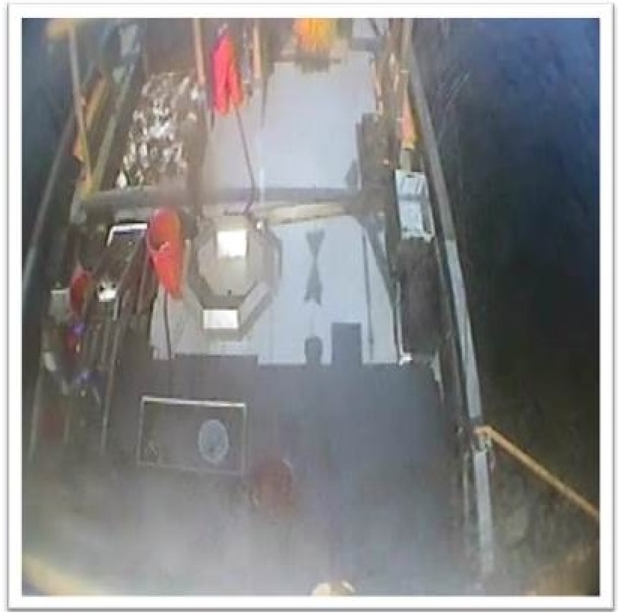

Figure 6

Figure 7

Figure 8

Figure 5 and 6: Poor image quality: dried salt spray. Typically, salt water is used to wash down the deck and cameras. Dried salt from washing or natural salt build-up from being exposed to the elements results in blurred imagery which can impede viewing. Crew members should be required to maintain camera views and rinse with fresh water as a preventative measure. **Figures 7 and 8:** Length measurement issues: examples of curling. Discard chutes are used to identify and measure fish (one by one). When fish do not lay flat or becomes curled, the accuracy of the measurement is degraded. Discard chute measurements are calibrated and fish must lay flat and fall within specified points in order to achieve an accurate measurement. The length of the fish could be used to estimate fish weight for quota monitoring.

Figure 9

Figure 10

Figure 11

Figures 9, 10, and 11: Length measurement and species identification issues: examples of clumping. In order to acquire an accurate measurement on the discard chute, fish must travel down it one by one. Sometimes too many fish go down at once causing clumping. An adequate flow of water must be present which will aid in the single file flow of fish. Clumping impairs the ability to properly identify, count, or distinguish among fish.

Figure 12

Figure 13

Figure 14

Figures 12, 13 and 14: Length measurement issues: fish outside of measuring grid. Figure 12 is an image of the measurement grid. Each fish must fall within the defined measurement grid points in order to be properly measured. EM software is calibrated to the grid points and fish measured outside the grid will not be accurate measurements. Fish length is used to estimate weight so it is imperative to have accurate measurements.

Figure 15

Figure 16

Figure 15: Species Identification Difficulties: small fish. Small fish are a challenge to identify through video footage because identifying characteristics are very hard or impossible to see. This individual for instance, is a member of the hake family but it is impossible to tell if it is a red, white, silver or spotted hake. When managing quota for a specific species such as white hake, decisions must be made as to how to handle ambiguous species that cannot be identified to species in a standardized way that will be effective for management purposes. **Figure 16:** Species Identification Difficulties: similar species. Some species are very difficult to identify without the ability to physically examine the individual for specific identifying characteristics. Below are four different species of skate all of which are very difficult to distinguish through EM. These high quality photos are from the Northeast Fisheries Observer Program (not collected from an EM system) and were taken as part of the Observer Program's Species Verification Program.

Figure 17

Figure 19

Figure 18

Figures 17: The crew member is blocking the view of the discard chute. **Figure 18:** The observer is blocking the view of the checker pen. **Figure 19:** The observer is blocking the view of the discard chute.

It is often asked why EM and observers cannot work in tandem. In order for EM to work on a vessel the crew must make significant changes to their catch handling protocols to facilitate effective video data capture and review. Similarly, at-sea observers also need to modify catch handling to both work with the EM system and crew. Each data collection method (crew, observer, EM) has different goals and methods by which data is collected. Trips with all three data collection resources can be very complicated and often require strategic and organized sampling to be effective.

Figure 20 and 21

Figure 22 and 23

Figures 20 and 21: Analog versus Digital Camera Views. Image quality and clarity increases significantly with a digital camera. Top image is an analog camera and bottom is a digital camera. Programs requiring fine detail viewing (species identification, length estimation, etc.) are best suited for digital cameras.

Figures 22 and 23: Analog versus Digital Camera Views. Top image is an analog camera and the bottom is digital. Digital cameras require more storage space due to the file size; however, if hard drives are exchanged regularly (daily or weekly) storage should not be an issue.

Figure 24

Figure 25

Figure 24: Good Deck View Pictures (bottom otter trawl). These four images are clear and are not obstructed. The viewere can see exactly where and how the catch is being handled. Discards on the discard chute are visible, lying flat, and traveling down the chute un-clumped and one by one (lower right corner).

Figure 25: Good Deck View Pictures (bottom otter trawl). In these images, the captain is sorting species that require a weight for quota allocation. The fish are clear on the discard chute, un-clumped, and traveling down one by one within the measurement grid (lower right corner).

Figure 26

Figure 26: Good Deck View Pictures (bottom otter trawl). Camera views are clear and unobstructed which allows the viewer to see all catch and catch handling. Dried salt spray can be seen clouding the left portion of the screen in the upper right image. It is important to have overlapping views when an EM system is on a vessel so that if one camera view is impaired, other cameras can compensate.

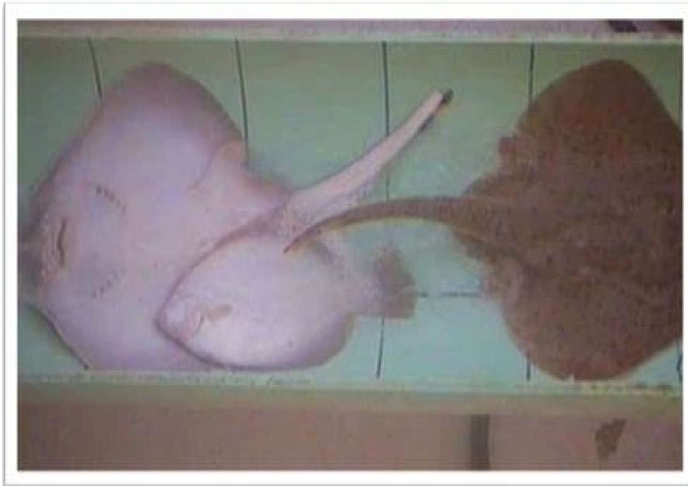

Figure 27

Figure 28

Figure 29

Figures 27, 28, and 29: Species Identification Pictures. These screen shots of flounder are good examples of clear images where identifying characteristics are visible. The top image shows a thick bodied flounder with a small mouth and thick caudal peduncle indicating a winter flounder. The image to the right shows a right eyed flounder with a small mouth and protruding snout indicating a yellowtail flounder. The bottom image demonstrates a dinner-plate shaped flounder with spots indicating a windowpane flounder.

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