June 12, 2014

Dr. Don McIsaac  
Executive Director  
Pacific Fishery Management Council  
7700 NE Ambassador Place, Suite 101  
Portland, Oregon 97220-1384  
(Delivered by email)

Dear Dr. McIsaac,


The attached paper summarizes the results from 2004 to 2010 EM program carried out with the US shore-based whiting fishery. While the results were previously reported in the individual annual reports, the purpose of this paper was to compile the results of the seven-year EM program in order to review the operation of the monitoring program and how it evolved over time. The paper was also intended to document the operational aspects to demonstrate that effective EM programs are a lot more than the underlying technology. As well, the intent of the paper was also to summarize what we learned, with the aim of evaluating the merits of the program and providing insights that would assist in other fisheries where EM is being considered.

The EM program evolved over time with operational efficiencies and improvements in technology. EM data collection success across these years exceeded 98% sensor data for all but one year, image data over 95% for five of seven years, and sensor and image data 99% for the last two program years. The EM program provided increased transparency which was a contributing factor to the marked decline in at sea discards over the seven year period. In particular, vessel specific information showed that the majority of the discard problem could be attributed to a small minority of the fleet, and that many vessels could successfully participate in the fishery with little or no discards. In 2005, nearly all vessels discarded, with most discarding 1.5% or more of their catch. Over time, the discard levels declined with increasing numbers of vessels showing very low levels of discard. By 2010, a third of the fleet had no observed discards, and among those vessels with discards, all but three discarded less than 0.6% of their total catch.
The program was co-funded by industry and NMFS, and the 2007-2010 average annual cost was $6.03 per mT, $254 per sea day, or 3.6% of the landed catch value. The EM cost per sea day was about 30% less than the rate for an at-sea observer, yet the latter does not reflect the total cost of the observer program. The cost comparison between EM and observers from an industry perspective would likely center on the portions of the program they would fund, rather than the total program cost. Cost effectiveness of EM as compared to observers comes down to an assessment of the resource risk associated with potentially less granularity of EM data versus more detailed observer data at greater cost. Given that EM was lower in cost and that the incidence of discarding was reduced to a low level, EM is considered to be the most cost-effective monitoring solution for this fishery.

The report summarized a number of lessons learned that would be applicable to the application of EM in any fishery:

- EM based monitoring should not be considered a “plug-and-play” alternative to observer programs as each has their own opportunities and challenges.
- The utility of EM for collecting fisheries data relies on a careful design process that integrates the EM technology, the vessel specifications, and specific on board catch handling and EM system duty of care requirements.
- EM programs are much more than the underlying technology. The majority of cost is with the service components and thus, a structured program design approach is needed.
- Successful use of EM often depends upon integration with other data collection processes and information sources. Data integration opportunities should be considered in the design process.
- Stakeholder engagement is an essential ingredient to EM program success. This should occur at a variety of levels in order to improve the program, optimize operations, and effect change.
- A key risk to EM is the hidden bias that can result from strategic intentional data loss (i.e., turning the system off to avoid recording). While some data loss is to be expected in any monitoring program, effective measures are needed to control, monitor and manage the level of missing data.
- EM technology will change over time and the program design needs to be flexible to include change, where appropriate.
- Effective EM programs require control measures through governance, regulations, incentives or disincentives. Instruments such as an EFP are particularly effective as they can be easily modified during the early stages of program implementation.
- EM programs take time to implement and a multi-year time horizon is needed to establish operations and infrastructure, and offset start up costs. Uncertainty of program tenure will slow the process and reduce cost efficiencies that can be achieved with EM approaches.
The EM program for the shore-based fishery was discontinued in 2010 with the onset of the 100% at-sea monitoring and the IFQ program. I believe this was more the result of an effort to bring the entire west coast groundfish fishery under a single monitoring framework than from a shortcoming of the EM program.

As the potential for EM is being considered by the Pacific Fishery Management Council it is hoped that this paper will aid in these discussions. Please feel free to distribute this report. I would be happy to address any comments or questions at the email address provided below.

Sincerely,

Howard McElderry, M. Sc.,
VP Electronic Monitoring Technologies
howardm@archipelago.ca
The 2004 to 2010 US Shore-based Whiting EM Program: What Did We Learn?

June 12, 2014

Prepared by: Howard McElderry, Martina Beck and Jessica Schrader

Archipelago Marine Research Ltd.
525 Head Street
Victoria, BC V9A 5S1 Canada
Telephone: 1.250.383.4535
Fax: 1.250.383.0103
E-mail: amr@archipelago.ca
Internet: www.archipelago.ca
Acknowledgements

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Summary

This paper provides an overview of a seven-year program involving the use of electronic monitoring (EM) on the US shore-based Pacific whiting (*Merluccius productus*) midwater trawl fishery. The paper describes the fishery and the EM program, and how these have changed over this time period. We also examine the operational aspects of the EM program to better inform an assessment of cost effectiveness of this monitoring method.

The whiting fishery is a high volume spring/summer fishery operating off the coasts of Washington, Oregon and northern California, consisting of ~35 vessels making day fishing trips. Total removals are estimated from landed catch and no discards are permitted. Full retention regulations were monitored from 2004 to 2010 using EM, whereby each vessel was equipped with closed circuit television cameras, GPS, winch and hydraulic sensors, operating continuously while the vessel was at sea.

Over the seven-year monitoring program, the fishery ranged from 24 to 180 days duration, 500 to 1,300 vessel sea days, and 40,294 mT to 972,677 mT total catch. EM data collection success across these years exceeded 98% sensor data for all but one year, image data over 95% for five of seven years, and sensor and image data 99% for the last two program years. Early monitoring results yielded a clearer understanding of fishing practices, providing a framework for more practical regulations on permissible levels of ‘operational discarding’. The EM program provided increased transparency which was a contributing factor to the marked decline in at sea discards over the seven year period. In particular, vessel specific information showed that the majority of the discard problem could be attributed to a small minority of the fleet, and that many vessels could successfully participate in the fishery with little or no discards. In 2005, nearly all vessels discarded, with most discarding 1.5% or more of their catch. Over time, the discard levels declined with increasing numbers of vessels showing very low levels of discard. By 2010, a third of the fleet had no observed discards, and among those vessels with discards, all but three discarded less than 0.6% of their total catch.

EM data reviewers estimated discard quantities using volume-density estimation methods. A small study comparing EM estimates with direct weights from a research vessel suggested EM estimates were correlated but highly variable. We believe estimation methods improved over time; however, the 90% decline in discard quantity over the seven-year period reduced discards to a level where the lower precision of the EM estimate became less important.

EM results were compared closely with vessel log data. Estimates of discard quantity were correlated but highly variable and it was not possible to attribute error as both were estimates. Most challenging to estimate were events where
discarding occurs directly from the net without coming aboard. The level of alignment between EM and vessel logs with respect to recorded discard events improved over time and we suggest using EM to audit vessel logs as a possible future program design.

EM data loss was closely monitored, particularly after a 2007 incident involving large discard quantity of widow rockfish. Data loss occurring during catch stowage operations was a particular concern because of the potential opportunity to discard unwanted sensitive species. In 2010, data loss during these critical periods was estimated at 0.5% of the total fishing events for the year. We examined monitored landings data to estimate the potential missed catch from EM data loss and determined the level to be less than 1% of the Annual Catch Limit for all sensitive species except widow rockfish and POP (5% and 3%, respectively). Hence, the data loss occurring in most program years would not pose a resource risk caused by unaccounted for catch but the results underscore the need to ensure that EM data loss is monitored and actively managed.

The program was co-funded by industry and NMFS, and the 2007-2010 average annual cost was $6.03 per mT, $254 per sea day, or 3.6% of the landed catch value. These figures reflect the total cost of the monitoring program, including program planning, field data collection and all the steps required to produce a finished data set. The costs are also reflective of a mature program where startup costs such as data-base development, program design, and infrastructure development have already taken place. EM equipment provision and field service were the largest cost component, over twice the data analysis and reporting component. The uncertain tenure led to higher EM equipment costs as most participants chose to lease rather than purchase.

The EM cost per sea day was about 30% less than the rate for an at-sea observer, yet the latter does not reflect the total cost of the observer program. The cost comparison between EM and observers from an industry perspective would likely center on the portions of the program they would fund, rather than the total program cost. Cost effectiveness of EM as compared to observers comes down to an assessment of the resource risk associated with potentially less granularity of EM data versus more detailed observer data at considerably greater cost. Given that EM was lower in cost and that the incidence of discarding was reduced to a low level, EM was considered a more cost-effective method for this fishery.

Although the EM program likely drove the significant improvement in the full retention compliance and the quality of catch data, it was discontinued in 2011 when the groundfish trawl fleet implemented a catch share quota system with 100% observer coverage, funded by NMFS.
1.0 Introduction

The non-tribal commercial Pacific whiting (also known as Pacific hake) (*Merluccius productus*) fishery is a seasonally intense spring/summer fishery that operates off the coasts of Washington, Oregon and northern California. This fishery consists of an at-sea processor fleet and a shore-based fleet. The shore-based fleet consists of approximately 30 vessels that make day fishing trips and deliver their catch to six ports. During the fishery, most of the vessels operate out of three Oregon ports: Charleston (Coos Bay), Newport and Astoria. The remaining four to six vessels deliver their catch to Westport (WA), Eureka, (CA) and Crescent City, (CA). The dates for the shore-based hake season coincide with the movement of hake along the coast: an early season in northern California, a main season fishery, usually opening mid-June off the Oregon and Washington coasts, and a late season fishery starting in the fall in the same areas.

At-sea information for the shore-based whiting fishery is important because of several factors unique to this fishery. During the fishery, vessels transit for several hours from the fishing grounds to deliver their catch to shore-based processing plants. Unsorted catch must be rapidly transferred from the net to refrigerated seawater holds to retard a parasitic degradation process common to this whiting population (Alderstein and Francis 1991). The immediate transfer of catch to preserve product freshness makes it impractical to sort the catch at sea. Therefore, by-catch monitoring takes place at dockside when the unsorted catch is delivered to the processing plants. In support of this shore-based method of catch monitoring all fishing vessels participating in the fishery are required to maximize retention of catch. At sea monitoring has been a requirement since 2004 to ensure compliance with maximized retention.

Traditionally, trained fisheries observers are used to provide onboard monitoring of fishing vessels. This past approach may not be practical or cost effective in certain circumstances, particularly when the scientific data collection needs are low. A variety of studies have shown that some types of monitoring can be more effectively carried out using electronic monitoring (EM) technologies (MRAG 2004, Ames et al. 2005, Sommerville 2004, McElderry 2008, Stanley et al. 2009, Stanley et al. 2011). In 2002, a pilot study was carried out with a single shore-based whiting fishing vessel (McElderry et al. 2002), and on the basis of these successful results, EM-based at-sea monitoring was extended to the entire shore-based component of the fishery from 2004 to 2010. The EM program for this fishery was established under an annual exempted fishing permit (EFP), which was renewed each year until 2011 when the fishery transitioned to an IFQ program, and 100% monitoring by at-sea observers became compulsory.

The transition from EM to observers in the shore-based whiting fishery in 2011 came about more as a desire to establish a consistent monitoring program for the entire groundfish fishery rather than any documented shortcomings with the EM program. Prior to 2011, the EM program for the shore-based whiting fishery was mostly industry funded (about 70%), whereas the 2011 observer program was
mostly funded by the National Marine Fisheries Service (NMFS). The federal funding of at-sea monitoring was planned as a transition measure with monitoring costs being increasingly borne by the fishing industry over time. With monitoring costs rising for industry, there is increased interest in exploring a technology-based monitoring alternative, which could be more cost effective. While an EM program was carried out over a seven-year period prior to 2011 when it was replaced with human observers there has been no formal assessment of the EM program and its efficacy in addressing the monitoring requirements for this fishery.

The EM program for the shore-based whiting fishery was carried out under an annual contract by Archipelago Marine Research Ltd. (Archipelago) with NMFS. The program was delivered in a generally consistent fashion across all program years, beginning as a program under the science branch, then transitioning to a compliance program in 2007. Over the seven years, the program evolved with improved technology and minor changes to methodology. The results from each program year were summarized in technical reports for NMFS, as referenced in Table 1-1.

The purpose of this paper is to compile the results of the seven-year EM program in order to review the operation of the monitoring program and how it evolved over time, as well as, to describe how the fishery changed over this period as a result of the monitoring program. We also examine the operational aspects of the EM program to better inform an assessment of the cost effectiveness of this monitoring method.

### Table 1-1. Citations for annual technical reports for 2004 to 2010 shore-based whiting EM program.

<table>
<thead>
<tr>
<th>Program Year</th>
<th>Report Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002 (Pilot)</td>
<td>McElderry et al. 2002</td>
</tr>
<tr>
<td>2004</td>
<td>McElderry et al. 2004</td>
</tr>
<tr>
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<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>2009</td>
<td>Cowan et al. 2010</td>
</tr>
<tr>
<td>2010</td>
<td>Archipelago Marine Research 2011</td>
</tr>
</tbody>
</table>
2.0 Materials and Methods

2.1 EM Technology

EM System Specifications

The EM systems used for this project were manufactured by Archipelago in Victoria, BC, Canada and are designed for the automated collection of sensor and image data which can be used to produce fisheries information. While different equipment models were used over the seven-year period, the basic configuration was the same, as schematically shown in Figure 2-1. This equipment has been used on a variety of fishing gear types and boats around the world, and have been in use as a key source of fishery data in the British Columbia Groundfish Fishery since 2006 (McElderry 2008, Stanley et al. 2011). The EM system is comprised of a system control centre, up to four closed circuit television cameras, a GPS receiver, a hydraulic pressure sensor, and a winch rotation sensor. The sensor configuration was the same for the entire program period, as were the analog CCTV cameras. The control central computer software manages the collection and storage of high-frequency sensor data and CCTV image data at specified settings throughout the fishing trip. Image and sensor data are stored digitally on a removable hard drive that can be exchanged at intervals during the fishery.

The control centre software was set to collect and store sensor data (GPS, hydraulic pressure and drum rotation) every ten seconds. This recording frequency delivered an accurate account of vessel activity that could be used to develop a distinctive digital “signature” of vessel activities including transit, gear setting, net towing, net retrieval, and catch stowage. Image data was generally recorded at a rate of one frame per second and the control centre was set up to record imagery from all cameras when the first fishing activities occurred on the trip, and continue image recording until the vessel returned to port. Detection of fishing activity was evidenced by either or both hydraulic pressure and winch...
sensors. A geo-fence of port locations and vessel GPS data was used to determine vessel location in relation to port.

**EM Technology Evolution**

Over the seven-year EM monitoring program period, EM systems evolved with improvements in technology. Table 2-1 provides a summary of the key improvements to the EM equipment over the duration of the program. From 2004 to 2006, a V3.0 control centre was used. This system consisted of a small industrial computer, paired with a CCTV system, commercially available from the security industry. The industrial computer managed the sensor data while the CCTV system managed and recorded the image data. Starting in 2007, a V4.0 platform was introduced, which consisted of a single computer platform that recorded sensor and image data in a more integrated fashion. This newer equipment was fully adopted for 2008 to 2010 program years.

Table 2-1. EM system components used for the 2004 to 2010 program years.

<table>
<thead>
<tr>
<th>Components</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
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<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>EM Hardware</td>
<td>V3.0</td>
<td>V3.0</td>
<td>V3.0</td>
<td>V3.0 &amp; V4.0</td>
<td>V4.2</td>
<td>V4.2</td>
<td>V4.2</td>
</tr>
<tr>
<td>EM Software</td>
<td>VDL 1.0</td>
<td>VDL 1.0</td>
<td>VDL 1.0</td>
<td>VDL 1.0</td>
<td>V5 2.0</td>
<td>V5 2.0</td>
<td>V5 2.0</td>
</tr>
<tr>
<td>Image Data Player</td>
<td>Proprietary player</td>
<td>Proprietary player</td>
<td>Proprietary player</td>
<td>WMP</td>
<td>WMP</td>
<td>Video Analyzer</td>
<td>Video Analyzer</td>
</tr>
</tbody>
</table>

The earlier V3.0 system recorded image data in a proprietary non-PC format, which limited the ability to view and manage image data files. The later V4.0 system recorded in the standard PC file formats (MP3 and WMP) which provided greater flexibility for viewing, storing and managing image files. A standardized sensor data format occurred throughout the program but starting in 2008, the method of sensor polling changed to improve the ability to detect gaps in the data set. Prior to 2008, a sensor record could be delayed if the GPS signal was poor, whereas afterwards this was forced to provide precise 10 second recording intervals. Thus, time intervals greater than 10 seconds between adjacent records represented a ‘data gap’ which could easily be detected for investigation.

There were also changes with the software tools used to process EM data sets. As mentioned, the image data format of the V3.0 system was proprietary and could only be viewed using the CCTV platform provided by the vendor. The change to the more common MP3 and WMP formats provided more options for handling image data, starting with simple commercially available viewing software (e.g., Window Media Player), then moving a custom built viewing software that allowed for viewing of multiple camera images simultaneously. The sensor data was initially displayed in graphical format, but later was integrated with the viewing software to enable direct referencing between sensor signatures and image data. Interpretations from raw EM data sets such as set time and location, catch events, etc. were initially recorded in a separate spreadsheet. Later, these data entry functions were integrated using the custom
viewing software, providing a single platform for loading a raw EM data set, navigating through different parts of a fishing trip to review pertinent monitoring activities, then directly record observations into a database (Figure 2-2). This evolution to a single analysis platform greatly improved the quality and reliability of EM data, as well as significantly improved the efficiency of data processing activities.

![Figure 2-2. EM analysis software display of whiting fishing trip. Upper left shows time series graph of vessel speed, hydraulic pressure, winch (drum) and voltage. Lower left shows vessel cruise track and right panels show CCTV camera imagery.](image)

### 2.2 EM Program Operations

An EM program is more than the underlying technology itself and includes a variety of service elements, as summarized in Figure 2-3. The diagram outlines the service elements associated with a typical seasonal cycle for the shore-based whiting fishery. The EM program service elements occurred before, during and after the fishery took place and related to the effort needed to: ensure that the technology was in place to achieve its stated objective; ensure that there was the appropriate level of feedback and coordination between all the program participants (e.g., industry, agency, service provider); and to ensure there was appropriate and timely effort to interpret and report on fishery data derived from the EM data set. Each of the operational program elements are described in the following sections.
2.2.1 Field Operations

Outreach
The EM program was integrated with NMFS staff and industry through several outreach processes. Program planning took place between Archipelago and NMFS in advance of scheduled outreach meetings with industry, and usually in conjunction with finalization of the EFP and operational planning for the season. In later years of the program, there was a higher level of interaction with NMFS Office of Law Enforcement (OLE) staff that included training with the operation of EM systems and analysis software.

The main instrument for launching the program and creating alignment among the different program participants were outreach meetings scheduled in advance of the early and main season fishery. The meetings involved representatives from the active fishing vessels, agency staff and service delivery staff and served to provide information about the program for the coming season, provide an overview of the EFP, provide summary information from previous program years and gather specific input to improve program coordination. Participation in the outreach meetings was a mandatory condition of the EFP. In addition to the pre season meetings, program staff also conducted outreach by phone and during regular service visits to the vessel. Upon completion of the fishery in 2004 and 2005, a questionnaire was administered to participating vessels in order to solicit feedback on the EM program and issues in the fishery.

EM Equipment Provision
The EM systems were provided by Archipelago (described in Section 2.1), available on a sale or lease basis. The year-to-year tenure of the EM program for the fishery resulted in most participants choosing to lease EM equipment. In advance of each season program staff prepared and tested all the EM systems expected for the upcoming season. This equipment was transported to the various ports for deployment on participating vessels. EM system provision
included ensuring an inventory of spare parts was available to ensure continuous operation of EM systems during the fishery.

**Installation and Removal of EM Systems**

Each year of the program usually involved a significant field effort to install equipment prior to the start of the fishery. The mobilization efforts included deploying a mobile crew of service technicians traveling with EM systems to the ports, working under tight timelines of vessel availability prior to the start of the fishery. The process was repeated at the conclusion of the fishery, or when vessels exited the fishery. The 2008 and 2010 fishing season length was extended (148 and 180 days, respectively) with closure periods to avoid by-catch. In these cases, EM systems were often left in place until the vessel completed fishing for the season. As mentioned, there were a few vessels with purchased EM systems, but numbers were not significant to alleviate the hectic pre-season equipment mobilization effort.

The installation procedure on each fishing vessel began with consultations with vessel personnel regarding the layout of the vessel, fishing deck configuration, onboard electrical system, hydraulic systems and wire access routes. Vessels were typically fitted with two to three CCTV cameras. The GPS sensor was mounted at a high point away from other electronics, with a clear sky view. Hydraulic pressure sensors were usually mounted on a winch hydraulic supply line or in the engine room. Winch rotation sensors were mounted on either a warp winch or the stern net drum. Beginning in 2005, the EM system was fitted with an uninterruptible power supply unit (UPS), which was intended to stabilize power interruptions and reduce data loss caused by brief power interruptions. Upon completion of installation and testing, technicians briefed vessel personnel on the operation of the EM system and their duty of care responsibilities (see Section 2.2.4). Installation crews also photographed and measured fish holding areas on the deck (e.g., trawl alley, fish checkers) to enable density-volume catch estimations by image analysis staff.

Shortly after the close of the fishery, service technicians removed EM systems from the vessels. Often, participating vessels departed the area for other fisheries, causing an intense busy period to demobilize many vessels over a short time period. EM sensor and camera wiring was often left in place (with permission by vessel operators) to simplify future installations of EM equipment.

**In-season Servicing**

During the first week of the fishery, technical staff attempted to visit each vessel to confirm the functionality of the EM system. Thereafter, service visits occurred every two to four weeks as either a scheduled visit, or if the technician was in port for another vessel they would try to service as many available vessels as possible. EM service events were typically done while the boat was offloading or while the vessel was waiting to offload. EM servicing involved removing sensor and image data from the EM system and refreshing data storage capacity by
installing a new hard drive. Servicing also involved an evaluation of system performance to ensure that all systems were functioning correctly. This included an examination of recorded data and a visual inspection of all components for wear and damage. Technicians also obtained photograph copies of the vessel logs during the service trips.

The program goal was to ensure vessels participating in the fishery had EM systems operational for 100% of their fishing operations. Vessel operators had several ‘duty of care’ responsibilities toward the EM system, which included:

- Keeping the system continuously powered while the vessel was at sea;
- Regularly cleaning camera dome surfaces to ensure sharp image resolution;
- Conducting periodic inspections of system components and conducting regular system checks to ensure the EM system was performing properly;
- Ensuring that camera view areas were adequately lit during night operations;
- Immediately contacting program staff and NMFS if the EM system stopped operating; and
- Maintaining regular contact with service provider for data retrieval and service scheduling.

Program staff was available to address service issues during the fishery. As well, information from EM data analysis alerted staff of any changes to the EM configuration or special duty of care needs aboard the vessel. This information was directed to vessel personnel and technical service staff in order to improve data quality.

### 2.2.2 Data Analysis Operations

The volume of data for a four week period of active fishing was approximately 120 GB from a typical vessel, large image data files accounting for most. This resulted in data from the fishery being stored on several hard drives, each drive representing a period of fishing operations for a single vessel.

Figure 2-4 illustrates the data processing operations that are described in the following sections. EM program data were assembled and managed in a relational database, linking operational elements of the program with specific service, trip and fishing event level data. Data summaries were designed to examine operational performance issues, as well as to examine compliance with the specific fishery monitoring objectives.
EM data processing consisted of examining all the data products collected from a service event and compiling summary reports. The analysis objectives were as follows:

- **Sensor data:**
  - Evaluating data set completeness,
  - Identifying fishing events, and
  - Compile detailed fishing tow tracks.
- **Image data:**
  - Confirm fishing events,
  - Examine catch stowage operations to assess compliance with maximized retention requirements, and
  - Document the characteristics of discard events.
- **Vessel logs:**
  - Verify that trips and fishing events aligned with that recorded from the sensor data, and
  - Compare skipper records of discard information as compared with EM data.

**Service Coordination**

Data service coordination ensured that hard drives and data sets created by active fishing vessels were tracked throughout the operational cycle. Hard drive management involved the use of an inventory management system to track hard drives throughout their use cycle. During 2004, hard drives were deleted once analyzed and returned for use in the fishery. From 2005 to 2010, hard drives were kept for the entire duration of the fishery, enabling archiving of compliance events, and re-analysis as needed. From 2007 to 2010, hard drives were kept for a year following the fishery, and drives showing compliance could be kept longer,
if desired by OLE. During these years, the entire hard drive was delivered to OLE when compliance events were identified. Other drives were kept in the project office and turned over to OLE at the end of the fishing season.

Data tracking was also carried out to monitor data set progress through the processing cycle. This included tracking the transit of the hard drive from the vessel to the office, through sensor and data processing, data consolidation and data reporting.

### 2.2.2.1 Primary Data Processing

**Sensor Data**

A preliminary analysis of sensor data occurred during each vessel servicing event to verify quality and identify possible service needs. Later, the data set was examined in greater detail to further examine data quality and identify vessel activities. Sensor data (GPS, hydraulic, winch rotation) for fishing episodes were simplified to one-minute intervals (versus 10-second intervals) to enable compilation of fishing event spatial data. Fishing trips were defined as the time from when a vessel left port until the time the vessel returned to port. Port location and vessel speed were used to define trip start and end. The start and end of fishing events was discernible from sensor data although fish stowage also required referencing the image data.

**Image Data**

Technicians reviewed all recorded image data (i.e., from the first set of a trip until the vessel returned to port). The following definitions were used to describe fishing operations:

- **Set Interval** - the period from when the trawl doors entered the water until they were returned and stowed.

- **Catch Stowage Interval** - the period from when the codend was winched on deck until when the all fish were stowed in the hold, or (rarely) when the vessel holds were full and the remaining catch stowed as a deck load.

**EM Data Completeness**

Data collection performance of EM systems was assessed in several ways. On a trip by trip basis, the quantity of sensor data expected (i.e., the duration between beginning and end) was compared with what was actually recorded by the EM system. EM data sets from each fishing trip were categorized as follows:

- **Complete** – Complete data record for the entire trip;
- **Incomplete** – Data record for trip has intermittent breaks;
- **No data** – No data recorded from the trip; and
- **Post-collection data loss** – Data was recorded successfully by the EM system but could not be accessed later. This problem was specific to the V3.0 CCTV system used until 2007.
EM data sets from each fishing trip were also assessed for sensor performance. The GPS, hydraulic and winch sensor data were examined and performance for a trip was considered complete if all data were present with intelligible (uncorrupted) results. CCTV camera image data quality was assessed as an average for the entire trip, using the following scale:

- **High** – the imagery was properly focused, the viewing area was clearly visible and net retrieval and catch stowage operations were easily assessed;
- **Medium** - there was a loss of image clarity, poor camera positioning or minor obstructions, but the analyst was able to confidently assess net retrieval and catch stowage operations;
- **Low** – there was low image quality due to reduced light, water droplets, poor focus or major obstruction of view and fishing operations were difficult to monitor; and
- **No Data** – image data were missing or when the quality was obstructed or insufficient to reliably assess fishing operations.

The data sets for each fishing trip were also evaluated for data gaps, or breaks in the data record. The data gap threshold was one minute, allowing consistency across all program years. Data gaps, often related to power interruptions, provided a measure of overall data success rate. Starting in 2008, time gaps were further categorized according risk as follows:

- **Minor** - Time gap occurred during the trip, but fishing activity had not yet begun;
- **Moderate** - At least one set had been completed when the time gap occurred, but the gap did not overlap with catch stowage operations;
- **Critical** - Time gaps occurred while catch stowage operations were underway; and
- **Major System Failure** - Any time gaps lasting more than half the duration of a fishing trip.

**Discard Estimation**
All catch stowage operations were examined to assess vessel compliance with the maximized retention requirements. It is normal that some fish will be discarded on nearly all catch stowage operations, owing to the high catch volumes and some fish being damaged or gilled in the net. A threshold of 0.045 mT (100 lbs) was used as a standard to distinguish normal operations from discarding events. In 2004, confidence in discard quantification was uncertain and hence discard quantities were categorized only by relative magnitude (<0.045 mT, 0.045-0.45 mT, 0.45-4.5 mT, and >4.5 mT). In 2005, discard quantities were estimated and recorded using finer intervals (<0.045, 0.045-0.450 mT, 0.450-2.2 mT, then ~2.0 mT.
intervals to 18.1 mT, >18.1 mT), and from 2008-2010, discards were recorded as the estimated quantity, rather than as interval data.

Two methods were used for estimating discard quantities. The preferred and most common method was using a standard volume-density approach, based on deck measurements, codend straps, or other references. Both trawl alley and codend volumes were estimated directly from image data, based on deck dimensions obtained by technicians at the start of the season. Height estimates were determined based on the height of comparable objects, such as bin boards or people. The volume-density formula \((0.7854 \times \text{length} \times \text{width} \times \text{height})\) was applied to fish holding areas on deck and a standard ellipsoidal cylinder density volume formula \((0.7854 \times \pi \times \text{diameter (min)} \times \text{diameter (max)} \times \text{length} / 4)\) was applied for net codends. In some cases, such as for incidents of bleeding, the only estimation method possible was visual, estimating the change in net volume before and after discarding using net dimensions and codend straps for reference.

The following terminology was used in 2004 to describe the catch retention activities:

- **Maximized Retention** – All catch was brought aboard and transferred to the fish holds. Any discards were less than a 0.045 mT threshold;
- **Discarding** – Some (or all) of the catch was released back into the sea in one of the following ways:
  - **High Grading** – species that were selectively discarded from the entire catch on deck. Criteria for selectively discarding fish were size, quality and species.
  - **Bleeding** – catch that was non-selectively discarded from the net via a “zipper” that the crew opened to release excess fish before the net was brought aboard (bleeding is also referred to as slipping).
  - **Dumping** – catch that was non-selectively discarded from the deck after the net was brought aboard. Dumping occurred in two ways: from the deck, or by towing the codend to flush fish from a full or partially full net.

From 2005 to 2010 discarding was categorized as follows:

- **Selective** – As above.
- **Non-Selective** – Non-selective discarding occurred when fish were discarded and no selection was apparent, usually connected with a vessel being full to capacity and excess fish are released. Four non-selective discarding categories were used:
• **Bleeding** – catch that was non-selectively discarded from the net via a “zipper” that the crew opened to release excess fish before the net was brought aboard. * Bleeding is also referred to as slipping.

• **Codend flushing** – when a partially filled codend is opened, lowered into the water and flushed by the forward motion of the vessel.

• **Deck disposal** – when catch is discarded directly from the deck, usually by using a water hose to flush fish overboard.

• **Net Cleaning** – discards of fish that were entangled in the net. Crew would usually pick the net to removed fish gilled in the mesh.

**Vessel Log Data**

Data processing also included processing vessel logbook data. Trips recorded in vessel logs were assigned a unique identifier and entered into an MS Access database. Data entry included trip and set information, as well as catch and discard quantities. Discard events were not always recorded at the set level, cases where discards were only recorded at the trip level were flagged as such and discards assigned to the last set. Vessel log data were primarily used to compare with fishery data as determined from information analysis of the EM data set.

**2.2.2.2 Secondary Data Processing**

Secondary data processing involved a series of steps to produce finished data sets from the interpreted EM data. Data consolidation involved making comparisons of data from EM sources with vessel logs to verify completeness of the EM data set and assess quality of self-reported data. Inconsistencies identified from this comparison could result in further review of original EM data. These comparisons could then be used for program feedback.

**2.2.2.3 Reporting**

Reporting evolved over the seven program years. In-season reporting was intended to provide timely analysis information to assist with in-season management of the fishery. From 2004 to 2006, in-season reporting occurred weekly (or bi-weekly in 2004) and consisted of a summary of vessel discarding activity for processed data sets, delivered to NMFS. No in-season reporting occurred in 2007 as efforts were focused toward development of a more standardized post season report which included more comprehensive vessel specific information. From 2008 onwards in-season reports followed each batch of completed data analysis, and a post season report was delivered to NMFS. Vessel specific in-season reports were delivered to participating vessels. In addition to data reports, NMFS received copies of EM data and summary data, provided in database format.

In addition to structured reporting, feedback among program participants often resulted from analysis of a data set in order to improve the quality and effectiveness of the EM deployment on the fishing vessel. Common feedback
would be adjustments to system settings, changes to camera positions, advice to vessel personnel on duty of care responsibilities, or catch handling practices.

2.2.2.4 Discard Accuracy Study

In an effort to assess the accuracy of estimating discard quantities, comparisons between EM volumetric estimates and vessel weight estimates were conducted. An EM system was installed aboard NOAA’s R/V Miller Freeman and the scientific crew weighed and sorted all whiting catch during the 2005 research cruise. This made it possible to compare direct weights with density volume estimates determined from EM image data. EM and vessel comparisons were made only for sets with catch large enough to fill the 1.8 m by 2.6 m sorting table, allowing the viewer to estimate only one parameter of volumetric estimation: height.
3.0 Results

3.1 Fishery Overview

The following three sections provide an overview of the 2004 to 2010 fishery in terms of key characteristics, the spatial footprint of the fishery and the management regime. This information provides an overall context to the monitoring program.

Key Characteristics

Key elements of the shore-based whiting fishery from 2004 to 2010 are presented in Table 3-1. Except for the first two years, fishery participation included about 35 vessels and fleet activity (days at sea, fishing trips and fishing events) was generally aligned with the total catch allocation, with the total catch ranging from 40,294 mT to over 972,677 mT. The season length varied by program year; partially in relation to catch allocation but also bycatch avoidance. In particular, the season in 2008 and 2010 was extended to over 140 days with voluntary closures in order to reduce the risk of exceeding bycatch limits. This was in contrast to season lengths of 24 to 60 days for other years.

As mentioned previously, the fishery typically consists of an early, main and late season component; the former involving 5-8 vessels fishing off the northern California coast, taking about 5% of the catch allocation. The EM program captured all phases of the shore-based fishery except for 2004 and 2005 where program initiation was delayed and the early season was missed.

Table 3-1. Summary of the shore-based whiting fishery during the 2004 to 2010 program years. Fishery characteristics were derived from program data except that denoted as “*” (source PFMC, 2011). Sea days are calendar days vessels are at sea as per Northern Economics (2011).

<table>
<thead>
<tr>
<th>Fishery Characteristics</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seasons Monitored</td>
<td>M</td>
<td>M</td>
<td>E/M</td>
<td>E/M/L</td>
<td>E/M/L</td>
<td>E/M</td>
<td>E/M</td>
</tr>
<tr>
<td>Vessels Participating</td>
<td>24</td>
<td>28</td>
<td>35</td>
<td>36</td>
<td>36</td>
<td>33</td>
<td>35</td>
</tr>
<tr>
<td>Season Length (days)</td>
<td>60</td>
<td>60</td>
<td>48</td>
<td>41</td>
<td>148</td>
<td>24</td>
<td>180</td>
</tr>
<tr>
<td>Sea Days</td>
<td>1,489</td>
<td>1,834</td>
<td>1,513</td>
<td>1,449</td>
<td>1,281</td>
<td>887</td>
<td>1,984</td>
</tr>
<tr>
<td>Total Trips</td>
<td>1,019</td>
<td>1,105</td>
<td>1,113</td>
<td>902</td>
<td>609</td>
<td>478</td>
<td>728</td>
</tr>
<tr>
<td>Total Sets</td>
<td>1,762</td>
<td>2,013</td>
<td>2,197</td>
<td>1,968</td>
<td>1,248</td>
<td>940</td>
<td>1,843</td>
</tr>
<tr>
<td>Whiting Catch (mT)*</td>
<td>89,251</td>
<td>97,378</td>
<td>972,677</td>
<td>73,277</td>
<td>50,760</td>
<td>40,294</td>
<td>62,655</td>
</tr>
<tr>
<td>Catch Value ($000's)*</td>
<td>n/a</td>
<td>n/a</td>
<td>13,617</td>
<td>12,078</td>
<td>11,914</td>
<td>5,536</td>
<td>10,038</td>
</tr>
</tbody>
</table>

Spatial Footprint

The spatial footprint of the fishery is shown in Figure 3-1, showing fishery location based on EM tow track data. Fishing locations ranged from Northern California to Northern Washington, with the bulk of the activity occurring off the coast of Oregon. During 2004 to 2007, vessel-fishing tracks were located closer to shore as compared with 2008 to 2010 where vessels were required to fish further offshore. Fishing activity inshore also appeared to be more dispersed as compared to years prior to 2008. In 2010 fishing activity was the furthest offshore and most dispersed as compared to previous years.
Figure 3-1. Spatial plots showing fishing locations during the main season for the shore-based whiting fishery for each of the program years (2004-2010). Fishing location data were taken from EM data when fishing gear was deployed.

Management Regime

As mentioned earlier, the fishery was managed under recurring Exempted Fishing Permits (EFP) for the 2004 to 2010 seasons. This annual permit process is generally used for experimental research or special cases that fall outside the normal regulatory process. The EFP process was not intended for ongoing fishery management and was instituted primarily to exempt vessels from the on-board catch sorting required under regulation. The EFP was a convenient tool for implementing EM-specific requirements because of the ease in which EFP wording could be updated to accommodate program specific needs. Over the 2004 to 2010 period, the specific language in the EFP changed in response to a growing understanding of the fishery and building more specific regulations aimed at addressing key fishery issues.

Changes in the EFP wording over time included more specific language concerning EM program requirements. Mostly, this related to increasing vessel responsibility toward monitoring the functionality of the EM system. Vessel operators were required to ensure the EM system was functioning properly, following specific ‘duty of care’ requirements (see Section 2.2.1), and immediately contact a service technician and OLE if problems were identified.

Most EFP changes related to catch and discard issues. In 2004, the requirements were to retain and land all catch caught during fishing operations. Discards due
to emergency or safety situations were the only exceptions permitted. In 2005, the language changed to “maximized retention”. Discarded amounts for each species and reason for discarding were to be recorded in the logbook as required by the State of landing. In 2006, the language describing discards remained the same, but cumulative limits were listed for Pacific cod, lingcod and various rockfish.

In 2007 area restrictions were put in place limiting retention of more than 4.5 mT (10,000 lbs) of Pacific whiting per trip shoreward of the 100-fathom contour in the Eureka area (43°00’ N. lat. - 40°30’ N. lat.). Increased emphasis toward compliance resulted in the following revisions concerning discard events.

- **Large marine organisms (2008–2010)** - Large individual marine organisms, such as marine mammals or fish species longer than 6 ft (1.8 m) in length, may be discarded. If a large marine organism is discarded, the species and the reason for discarding must be recorded and labeled as “discard” in the required logbook.

- **Avoidable discards (added in 2006, removed in 2008)** - Discards that resulted from malfunctioning net sensors and catching more than the vessel hold capacity were considered avoidable and must be minimized to the extent practicable. Vessels were encouraged to modify gear and fishing practices to limit occurrences of avoidable discards.

- **Unavoidable discard (2004–2007)** - Discard events that resulted from hazardous weather conditions, unusual codend condition (i.e., over full codend), school density, and net cleaning, must be minimized to the extent practicable. If unavoidable discarding occurred, the discard event must be clearly recorded in the vessel logbook, detailing total discard amount by species, location and reason for discarding.

- **Unavoidable discards (2008–2010)** - Same as above, plus: Immediately following an unavoidable discard event, the vessel must stop fishing and immediately return to port, with notification to NMFS, OLE being made prior to arrival in port.

- **Operational discards (added in 2008)** - Pacific whiting removed from the deck and fishing gear during cleaning may be discarded, provided that the total operational discards must not exceed one basket from any single haul, with the maximum dimensions of the basket being 24 inches by 16 inches by 16 inches. If net cleaning resulted in a greater amount, all catch in excess of the one basket must be placed into the fish hold. Discarding operational discards of more than one basket of Pacific whiting per haul is prohibited. Discarding any quantity of groundfish species other than Pacific whiting is prohibited.
3.2 EM Data Collection Success

It is useful to evaluate overall data collection success prior to examining monitoring results, as gaps and poor quality source data can potentially bias the results. As mentioned previously, the goal of the program for each year was to monitor 100% of all participating vessels for the entire time they were at sea. Data collection success is summarized in two tables (Table 3-2 and Table 3-3), for sensor and image data collection, respectively.

The total expected sensor data for most program years exceeded 20,000 hours (Table 3-2). Based on EM data, the annual totals for fishing time (time gear in the water) was over 5,000 hours for most years, while catch stowage time was usually greater than 1,500 hours per season. This equates to approximately 20% and 6%, respectively, of the total vessel time at sea (the balance of time spent in transit and searching).

The sensor data success rate (i.e., percentage of hours recorded versus the total fishery hours) exceeded 98% for all but one year. The sensor data collection success rate was lowest in 2006 at 94.6%, or 1,347 hours of missing sensor data from a total expected of 25,030 hours. The causes were primarily (57%) source power related (interruptions to power, UPS compatibility issues), with the balance mostly attributed to a removable hard drive seating problem (poor electrical connection). While UPS devices were present on many vessels, compatibility issues with generated AC electrical power resulted in them not being effective on certain vessels.

Sensor component performance was evaluated differently, as the percentage of fishing trips in which the specific sensor was fully functioning. The GPS receiver showed the highest performance level, ranging from 91% to 100% across program years. The winch sensor had the most variable performance level, ranging from 82% to 100%. The winch sensor was usually located on the fish deck and more easily fouled, making it more prone to failure than other sensors.
Table 3-2. Summary of EM sensor data collection performance across the 2004 to 2010 program years. Sensor performance includes both complete and incomplete trips.

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Trips</td>
<td>1,019</td>
<td>1,105</td>
<td>1,113</td>
<td>902</td>
<td>609</td>
<td>478</td>
<td>728</td>
</tr>
<tr>
<td>Complete Trips (%)</td>
<td>98.4%</td>
<td>99.0%</td>
<td>88.5%</td>
<td>87.5%</td>
<td>91.6%</td>
<td>93.3%</td>
<td>93.3%</td>
</tr>
<tr>
<td>Incomplete Trips (%)</td>
<td>0.7%</td>
<td>1.0%</td>
<td>7.0%</td>
<td>11.6%</td>
<td>7.9%</td>
<td>6.7%</td>
<td>6.7%</td>
</tr>
<tr>
<td>Trips No Data (%)</td>
<td>0.9%</td>
<td>0.0%</td>
<td>4.5%</td>
<td>0.9%</td>
<td>0.5%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

The success rate of recorded image data, expressed as hours recorded versus hours expected, exceeded 95% for five of the seven program years (range 87.1% to 99.0%, Table 3-3). As with sensor data, image data recording success rates were lowest in 2006 at 87.1%, or 2,752 hours of missing data. The lower image recording success for 2006 was due to power loss (10%), drive seating failure (41%), ‘post collection data loss’ (12%) and technician error (15%). The V3.0 equipment was phased out in 2007, which resulted in marked improvements to sensor and image success rates in the latter years of the program. A single incident in 2008 represented over half the total annual data loss. With this removed, the rate was over 98%. Success rates (as hours recorded versus hours expected) were highest in the final two years of the program at 99.0% and 99.6%.

In terms of the proportion of the fishing trips with complete data, the values for 2008 to 2010 were 93% to 96%, while years prior were 83% to 91%. In terms of image quality, over 80% of the total trips were rated as either high or medium for five of the seven program years. The higher rate of medium quality image data in 2007 was likely associated with differences between EM reviewers in making quality assessments. Across all seven years of the program low quality image data made up 10% or less of the total trips.
Table 3-3. Summary of image data collection performance across the 2004 to 2010 program years.

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Trips</td>
<td>1,019</td>
<td>1,105</td>
<td>1,113</td>
<td>902</td>
<td>609</td>
<td>478</td>
<td>728</td>
</tr>
<tr>
<td>Complete Trips (%)</td>
<td>87.9%</td>
<td>91.1%</td>
<td>82.6%</td>
<td>84.0%</td>
<td>92.9%</td>
<td>95.8%</td>
<td>94.8%</td>
</tr>
<tr>
<td>Incomplete Trips (%)</td>
<td>2.5%</td>
<td>1.1%</td>
<td>2.6%</td>
<td>7.2%</td>
<td>5.1%</td>
<td>4.2%</td>
<td>5.2%</td>
</tr>
<tr>
<td>Trips No Data (%)</td>
<td>9.6%</td>
<td>2.5%</td>
<td>10.6%</td>
<td>8.8%</td>
<td>2.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Post Collection Loss (%)</td>
<td>0.0%</td>
<td>5.2%</td>
<td>4.2%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Image Data Quality (by % of total trips)

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>82.6%</td>
<td>87.7%</td>
<td>69.1%</td>
<td>44.6%</td>
<td>94.6%</td>
<td>87.4%</td>
<td>82.4%</td>
</tr>
<tr>
<td>Medium</td>
<td>7.8%</td>
<td>4.2%</td>
<td>14.1%</td>
<td>37.5%</td>
<td>2.5%</td>
<td>11.5%</td>
<td>8.1%</td>
</tr>
<tr>
<td>Low</td>
<td>0.0%</td>
<td>0.4%</td>
<td>2.0%</td>
<td>9.2%</td>
<td>0.3%</td>
<td>1.0%</td>
<td>2.7%</td>
</tr>
<tr>
<td>Not rated/No Data</td>
<td>10.0%</td>
<td>8.0%</td>
<td>15.0%</td>
<td>9.0%</td>
<td>2.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Image Data Success (by % of total hours)

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Hrs Expected</td>
<td>12,896</td>
<td>20,471</td>
<td>21,250</td>
<td>21,578</td>
<td>15,577</td>
<td>9,734</td>
<td>26,763</td>
</tr>
<tr>
<td>Total Hrs Recorded</td>
<td>12,347</td>
<td>19,967</td>
<td>18,498</td>
<td>19,463</td>
<td>15,026</td>
<td>9,633</td>
<td>26,643</td>
</tr>
<tr>
<td>Success Rate (%)</td>
<td>95.7%</td>
<td>97.5%</td>
<td>87.0%</td>
<td>90.2%</td>
<td>96.5%</td>
<td>99.0%</td>
<td>99.6%</td>
</tr>
</tbody>
</table>

EM sensor and image data gaps are further summarized in Table 3-4, showing missing data by both hours and events by program year. In the most common instance where the entire EM system was down, there were gaps in the sensor data record and, if image recording was activated, gaps in the image data set as well. Sensor data gap events were nearly twice as common as image data gaps, reflecting time breaks at the start of fishing trips where image recording had not yet been triggered. In some cases, as in 2009, there were more gaps in the image data set because the EM system was operating but image recording had failed to activate, as would occur with a faulty hydraulic sensor. The very high amount of image data loss in 2006 and 2007 related to post collection data loss, mentioned previously. The lowest levels of missing sensor and image data, in terms of both number of events and hours, were in 2009 and 2010. Data gaps were not a fleet-wide phenomenon, but concentrated to a portion of the fleet. For example, during 2008 to 2010 program years, about 60% of the fleet showed 100% sensor data capture success and the five vessels with the most sensor data loss accounted for over 80% of the total.
Table 3-4. Summary of sensor and image data gap events across 2004 to 2010 program years.

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Events</strong></td>
<td>1,762</td>
<td>2,013</td>
<td>2,197</td>
<td>1,968</td>
<td>1,248</td>
<td>940</td>
<td>1,843</td>
</tr>
<tr>
<td><strong>Total Sensor Hours Recorded</strong></td>
<td>19,377</td>
<td>23,524</td>
<td>23,683</td>
<td>24,182</td>
<td>17,645</td>
<td>11,593</td>
<td>29,974</td>
</tr>
<tr>
<td><strong>Total Video Hours Recorded</strong></td>
<td>12,347</td>
<td>19,967</td>
<td>18,498</td>
<td>19,463</td>
<td>15,026</td>
<td>9,633</td>
<td>26,643</td>
</tr>
<tr>
<td><strong>Sensor Data Gaps</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Hours</td>
<td>386</td>
<td>52</td>
<td>1,347</td>
<td>396</td>
<td>231</td>
<td>72</td>
<td>219</td>
</tr>
<tr>
<td>Total Events</td>
<td>565</td>
<td>368</td>
<td>250</td>
<td>239</td>
<td>146</td>
<td>59</td>
<td>83</td>
</tr>
<tr>
<td><strong>Image Data Gaps</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Hours</td>
<td>549</td>
<td>504</td>
<td>2,752</td>
<td>2,115</td>
<td>551</td>
<td>100</td>
<td>119</td>
</tr>
<tr>
<td>Total Events</td>
<td>N/A</td>
<td>N/A</td>
<td>243</td>
<td>113</td>
<td>89</td>
<td>37</td>
<td>71</td>
</tr>
</tbody>
</table>

Table 3-5 provides a risk-based view of missing image data from the 2008 to 2010 program years, in terms of hours, number of events and vessels involved. In 2008 and 2009, over three-quarters of the image data loss was from ‘major system failure’ events and these represented less than 14% of the total events and a small number of vessels (4 and 2, respectively). In 2010, about half the missing time was classified as critical, most of which (80%) was from two events by one vessel on a single trip. There were five events by four vessels, ranging in length from six minutes to six hours, and a further seven events by five vessels, ranging from 1 to 3 minutes in length. The latter events correspond to the reboot cycle time of the EM control center, caused by a brief power interruption or the error detection (watchdog) software. In our view, it is unlikely that unreported discarding could occur with these events.
Table 3-5. Summary of image data gaps for the 2008 to 2010 program years by hours, events and vessels involved. See text for risk category definitions.

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Image Hours Recorded</strong></td>
<td>15,026</td>
<td>9,633</td>
<td>26,643</td>
</tr>
<tr>
<td>Critical</td>
<td>60</td>
<td>17.9</td>
<td>58.5</td>
</tr>
<tr>
<td>Moderate</td>
<td>54.2</td>
<td>6.5</td>
<td>23.2</td>
</tr>
<tr>
<td>Minor</td>
<td>18.9</td>
<td>0</td>
<td>37.6</td>
</tr>
<tr>
<td>Major System Failure</td>
<td>418</td>
<td>75.6</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Missing Hours</strong></td>
<td>550.8</td>
<td>100</td>
<td>119</td>
</tr>
<tr>
<td><strong>Total Number of Events</strong></td>
<td>1,248</td>
<td>940</td>
<td>1,843</td>
</tr>
<tr>
<td>Critical</td>
<td>11</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>Moderate</td>
<td>36</td>
<td>22</td>
<td>21</td>
</tr>
<tr>
<td>Minor</td>
<td>30</td>
<td>0</td>
<td>37</td>
</tr>
<tr>
<td>Major System Failure</td>
<td>12</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Events Missing</strong></td>
<td>89</td>
<td>37</td>
<td>71</td>
</tr>
<tr>
<td><strong>Number of Participating Vessels</strong></td>
<td>36</td>
<td>33</td>
<td>35</td>
</tr>
<tr>
<td>Critical</td>
<td>4</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Moderate</td>
<td>9</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Minor</td>
<td>15</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Major System Failure</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Vessels With Data Gaps</strong></td>
<td>32</td>
<td>15</td>
<td>30</td>
</tr>
</tbody>
</table>

### 3.3 Maximized Retention Compliance

The primary monitoring goal of the EM program was to monitor vessel compliance with the requirement to retain all catch aboard during the fishing trip. Recognizing that there are periodic needs for operational discards, the program goal was not only to detect discard events but also to characterize these in terms of estimated quantity and discard type. Finally, the program goal was to ensure that instances of discarding were properly recorded in the vessel logbooks. In the following sections, these issues are examined collectively for the fleet across program years, then in terms of individual vessel performance across program years.

**Fleet-wide Performance**

In terms of absolute quantities of fish, discards of fish declined markedly across the seven program years, starting at an estimated 1,400 mT in 2004 to under 180 mT in 2010 (Figure 3-2). The decline in discard quantity was most pronounced after 2007 when the EM program became more compliance focused. In 2009 there was a two-fold increase in discarding activity from the 2008 levels (288 mT versus 125 mT) and the percentage of sets with discards rose to 15%, as compared with 4% in 2008. This was mostly due to an increase in high volume discards (>4.5 mT) which accounted for 84% of the total discard volume in 2009. It should be noted that discarding accounted for a very low overall percentage of
the total catch in all program years, declining over time from 1.7% to below 0.3%, the most marked decline occurring in 2008.

In a pattern similar to discard quantities, there was also a decline in the number of discard events: 250 to 350 events per annum between 2004 and 2007 versus 50-125 events per annum for 2008 to 2010 (Figure 3-3). In 2004 and 2005, discard events were almost exclusively on the last fishing event of the trip, indicative of the vessel being full to capacity and excess fish being discarded. Discarding during fishing events other than the last event of the trip became increasingly common in later years, indicative of unavoidable discard situations.
In terms of the quantity of fish discarded per event, there was a marked change across program years (Figure 3-4). In 2005 and 2007, over a third of the total discard events were more than 4.5 mT, whereas these events were much less common after 2007. Discard events less than 0.45 mT varied by year in no obvious trend, however these events made up almost two thirds of the total discard events in 2010, much higher than any other year. The pattern is likely due to variability in viewers between years, more structured vessel catch accounting in later years (using a fish basket) and annual differences in whiting size, affecting amounts gilled in the net. Looking only at discard events greater than 0.45 mT, the decline in discard events across program years becomes much more marked, declining by nearly an order of magnitude between 2005 and 2010. One notable change in discarding activity in 2009 was the increase in discards greater than 4.5 mT. However, over 50% of the total discard volume in that year came from four vessels, indicating this was a localized issue.
The frequency and type of discard events are shown by program year in Figure 3-5. Selective discarding consistently made up less than 1% of the total discards from 2005-2010. Likewise, discards resulting from net cleaning made a small contribution to the total discard quantity. Net flushing, bleeding, and deck discards were the main discard methods, all three of which declined between 2005 and 2010. Deck discarding declined most markedly of the three (475 mT to 1.1 mT), followed by net flushing. Discard quantities from net bleeding were higher before 2008, as compared with after, and the proportion of discards from net bleeding increased from 10% to 60% as a consequence of declines in the other methods.
Figure 3-5. Summary of the total discard amount (mT) by discard type for the entire duration of the program (2004-2010). Data for 2004 were not available by discard type.

Vessel Specific Performance

Compliance with the maximized retention requirement by individual vessels was examined in a few different ways. Quantities discarded by individual vessels are shown in Figure 3-6 and Figure 3-7. Interestingly, across program years there was a marked decline in both the number of vessels discarding catch and in the proportion of catch discarded. In 2005, nearly all vessels discarded and most discarded 1.5% or more of their catch (Figure 3-6a). In 2010, a third of the fleet had no observed discards, and all but three vessels discarded less than 0.6% of their total catch (Figure 3-6f). Vessel reference numbers were unchanged between program years and vessels showed no consistent discard patterns. Vessels high in discards in one year were more often low in others. This is possibly the result of different skippers on the same vessel over time, but more likely the common challenge by all skippers of avoiding occasional instances of high catch. As was evident with the fleet-wide results, there was a marked difference in vessel discard patterns for the years prior to 2008 as compared to the three years from 2008 to 2010.
Table 3-7 examines the relationship between discard quantity (total for season and average for fishing events) and the level of vessel activity. The plots suggest that discard quantity was unrelated to the level of fishing activity for all program years. For example, in 2005 Vessel 8 that fished for ~60 trips discarded around the same percent of total catch (~2%) as Vessel 5 that fished for ~5 trips (Figure 3-7a). The plots also show that the average discard quantity per set (bubble size) did not vary with total catch or level of activity. As observed in Figure 3.6 there were no consistent vessel specific patterns; vessels showing high discard levels observed in one year were often lower in other years.
Discard Estimation Accuracy

During the 2005 Miller Freeman research cruise, crewmembers weighed and sorted all catch, making it possible to directly compare estimates of volume as determined from EM imagery to actual weights from the Miller Freeman. Among the 65 hauls taken, most were either too small or too large, leaving 10 hauls where the quantity was suited to volumetric estimation on the sorting table (Table 3-6). On average, volumetric estimation by EM resulted in a 8.5% lower amount than the actual weight taken aboard the vessel. The average catch estimates did not differ significantly between EM and the Miller Freeman (paired one-way t-test P=0.238). However, variability on individual hauls was considerable (range 1.2% to 62.6%), with only 4 of 10 estimates within 5%. The largest difference was unrelated to the volume estimation but came from the EM viewer not detecting that the sorting table was filled twice instead of the usual practice of filling once. The comparison showed that the EM estimate made from these tests was not very precise, but unbiased in estimating the vessel catch volume across the full data set.
Table 3-6. Summary of EM weight estimates by volumetric method and Miller Freeman actual weight (kg). A negative difference indicated that the EM estimate was greater than the actual weight, and vice versa.

<table>
<thead>
<tr>
<th>Haul #</th>
<th>EM Weight Estimate (kg)</th>
<th>Actual Weight (kg) (Miller Freeman)</th>
<th>Difference (kg)</th>
<th>Difference %</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>1,012</td>
<td>1,199</td>
<td>187</td>
<td>15.6%</td>
</tr>
<tr>
<td>14</td>
<td>1,012</td>
<td>972</td>
<td>-40</td>
<td>-4.1%</td>
</tr>
<tr>
<td>22</td>
<td>1,012</td>
<td>1,103</td>
<td>91</td>
<td>8.3%</td>
</tr>
<tr>
<td>23</td>
<td>1,380</td>
<td>1,183</td>
<td>-197</td>
<td>-16.7%</td>
</tr>
<tr>
<td>24</td>
<td>1,503</td>
<td>1,358</td>
<td>-145</td>
<td>-10.7%</td>
</tr>
<tr>
<td>25</td>
<td>767</td>
<td>737</td>
<td>-30</td>
<td>-4.1%</td>
</tr>
<tr>
<td>32</td>
<td>1,135</td>
<td>1,167</td>
<td>32</td>
<td>2.7%</td>
</tr>
<tr>
<td>47</td>
<td>1,012</td>
<td>623</td>
<td>-389</td>
<td>-62.4%</td>
</tr>
<tr>
<td>58</td>
<td>1,135</td>
<td>1,121</td>
<td>-14</td>
<td>-1.2%</td>
</tr>
<tr>
<td>63</td>
<td>1,258</td>
<td>1,115</td>
<td>-143</td>
<td>-12.8%</td>
</tr>
<tr>
<td>Total</td>
<td>11,226</td>
<td>10,578</td>
<td>-648</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td>-</td>
<td>-</td>
<td>-65</td>
<td>-8.5%</td>
</tr>
</tbody>
</table>

3.4 EM and Vessel Logbook Data Comparison

Starting in 2005, vessel log data were compared with the EM data for discarding activity (Table 3-7). The proportion of comparable events (i.e., where the data sets could be aligned) varied across the program years from 73% to 94%, showing a clear improvement over time. The data sets were considered in agreement if both EM and log data recorded a discard event (EM+Log+) or if neither recorded a discard event (EM-Log-). The level of agreement (% match) ranged from 86% to 96%, the majority (74% to 95%) of which were from fishing events that did not involve discarding. Cases where both EM and vessel logs recorded discards (EM+Log+) ranged between 1% and 15%, while the percentage of discard events that did not match (EM-Log+ or EM+Log-) varied between 1% and 8%. Discard events that were recorded in the vessel log and not by EM (EM-Log+) in 2006 and 2007 likely related to small volume discards (<450 kg) such as net cleaning that were more commonly reported in the vessel logs than by EM reviewers.
Table 3-7. Comparison of Vessel logbook (Log) and EM data (EM) sets across the 2005 to 2010 program years. The proportion of matched and unmatched sets is from comparable sets. See text for description of EM/Log detection categories.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Sets</th>
<th>% Comparable Sets*</th>
<th>% Match EM-Log-</th>
<th>EM+Log+</th>
<th>% Not Matched EM-Log-</th>
<th>EM+Log+</th>
<th>EM+Log-</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>2,013</td>
<td>89%</td>
<td>96%</td>
<td>85%</td>
<td>11%</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>2006</td>
<td>2,197</td>
<td>73%</td>
<td>89%</td>
<td>74%</td>
<td>15%</td>
<td>7%</td>
<td>4%</td>
</tr>
<tr>
<td>2007</td>
<td>1,968</td>
<td>89%</td>
<td>86%</td>
<td>77%</td>
<td>9%</td>
<td>8%</td>
<td>6%</td>
</tr>
<tr>
<td>2008</td>
<td>1,248</td>
<td>83%</td>
<td>96%</td>
<td>95%</td>
<td>1%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>2009</td>
<td>940</td>
<td>93%</td>
<td>89%</td>
<td>86%</td>
<td>3%</td>
<td>3%</td>
<td>8%</td>
</tr>
<tr>
<td>2010</td>
<td>1,843</td>
<td>94%</td>
<td>95%</td>
<td>93%</td>
<td>2%</td>
<td>2%</td>
<td>3%</td>
</tr>
</tbody>
</table>

*The percent of comparable sets are sets where either one or both of EM and vessel log record a discard event

In order to further examine discard events missed by the EM viewer (EM-Log+), events logged by vessels with discards >0.45 mT were re-examined. For the 2010 data set, this resulted in five events where EM did not record a discard (EM-Log+) out of a total of 34 events with discards >0.45mT. In three instances, no discarding was observed but the reviewer noted image quality issues (sun glare, poor image, and poor lighting conditions). In one instance the image quality was very good and no discarding was evident, likely a vessel log recording error, while in another discarding was evident, indicating a viewer error.

The reverse situation where events missed by the vessel log were also re-examined (EM+Log-), taking events logged by EM viewer with discards >0.45 mT. This resulted in a total of eight events of 53 in the 2010 data set. In four instances, the vessel log notes that discarding occurred but no quantity was recorded. Among the remaining four events, three recorded catch but no discs and one recorded the event but no catch or discard quantity.

Table 3-8 provides a summary of regression tests between EM and vessel log estimates of discard events, according to different discard types. The data used for this comparison was drawn from 2005 to 2010 program years, from cases where discards were recorded by both EM and vessel logs. While the correlation was significant (Pearson’s Correlation test, p<0.05) for all three discard types, the correlation coefficients were low (R²<0.43) in all cases, indicating there is a high level of variability between the two data sources. Interestingly, the deck discard estimates showed the strongest correlation, yet the EM estimate was 33% below the vessel log estimate. Keeping in mind that both EM and vessel logs are estimates, the results do not attribute error to one source over the other.
Table 3-8. Summary statistics for comparisons between EM and vessel log discard estimates by type of discard. * Denotes a statistically significant Pearson Correlation value (P<0.05).

<table>
<thead>
<tr>
<th>Discard Type</th>
<th>Sample Size (n)</th>
<th>EM Discards (mT)</th>
<th>Log Discards (mT)</th>
<th>% Difference (EM:Log)</th>
<th>$R^2$</th>
<th>Y-Int.</th>
<th>Slope</th>
<th>Pearson's Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck Discards</td>
<td>270</td>
<td>531.2</td>
<td>797.1</td>
<td>-33.4%</td>
<td>0.43</td>
<td>1.15</td>
<td>0.92</td>
<td>0.657*</td>
</tr>
<tr>
<td>Bleeding</td>
<td>71</td>
<td>361.1</td>
<td>374.1</td>
<td>-3.4%</td>
<td>0.32</td>
<td>1.94</td>
<td>0.66</td>
<td>0.568*</td>
</tr>
<tr>
<td>Net Flushing</td>
<td>108</td>
<td>698.9</td>
<td>566.6</td>
<td>18.9%</td>
<td>0.35</td>
<td>1.11</td>
<td>0.64</td>
<td>0.593*</td>
</tr>
<tr>
<td>Total</td>
<td>449</td>
<td>1,591.2</td>
<td>1,737.8</td>
<td>-8.4%</td>
<td>0.35</td>
<td>1.22</td>
<td>0.64</td>
<td>0.65</td>
</tr>
</tbody>
</table>

3.5 EM Program Operational Considerations

In addition to the fishery specific program results, there was a progression in the operational aspects of the program, which affected the quality of data, operational efficiencies and program cost. The salient aspects of this program evolution are summarized in the following sections.

Industry Outreach

Results from the 2004 and 2005 questionnaire surveys to industry demonstrated support for the EM program and its effectiveness as a monitoring tool. Among the responses received (about half the fleet), there was consensus that EM was an effective monitoring tool (86% and 100% for the two years, respectively), the majority supported the use of EM (73% and 75%) and the majority did not experience technical difficulties with EM technology (80% and 75%). Interestingly, the majority of respondents also felt that EM did not cause changes to their fishing practices (73% and 58%), but it is suspected that this result would be very different during the period from 2008 to 2010.

Industry outreach was also useful in communicating program specific results. At the annual pre-season meeting, skippers received copies of prior year fleet performance graphs (Figure 3-6). The vessel names associated with reference numbers were confidential, except on an individual basis. Vessel owners or skippers were provided with the reference number of their vessel in order to determine their performance in relation to the rest of the fleet. This information served to create an understanding of general discard patterns in the fishery and helped fishery participants compare their vessel performance in relation to the rest of the fleet. The feedback focused discussion on problem areas and helped shape opinions of acceptable discard practices in the fishery. Starting in 2008, participating vessels received in-season reports showing EM analysis results including EM data collection success, compliance with maximized retention, vessel logbook recording practices, and comments regarding corrections needed. This feedback process was considered useful but not very timely, given the time delays in collecting EM data sets and completing data processing. Other feedback, showing vessel specific bycatch information was published on shore-based fishery website, hosted by the Oregon Department of Fish and Game. This information, while not part of the EM program, served to keep attention focussed on bycatch issues and compliance with full retention requirements.
Field Services
A consistent issue across the program years was the large mobilization and
demobilization effort required to deploy EM systems. Timelines were short
because access to the whole fleet was usually limited to a narrow time window at
the start and end of the fishery. This component of field services required a large
service staff, and was logistically complex and costly. In-season field service
efforts were also challenging because the fleet activity was distributed across
several ports and access to vessels was often limited to the brief time when they
were in port to offload. With offloads scheduled to provide a steady supply of
fish to plants, only a portion of the fleet was accessible at any point in time
during a port service visits. There was no single best way to cover the fleet;
technicians could either stay in a single port waiting for vessels to land, or travel
from port to port, meeting vessels opportunistically. Vessels requiring technical
support were usually given service priority and collection of hard drives was
opportunist, based on vessel accessibility. This resulted in a variable supply of
hard drives for data analysis.

The seasonal nature of the fishery, the fact that no single location had sufficient
activity to justify establishing dedicated port-based services, and the challenge to
provide responsive field services with qualified technicians across a broad
geographic area created ongoing logistical challenges across the seven program
years. From 2004 to 2006, technicians were based in Newport, Oregon, which is
more central to many of the active ports. This staffing effort satisfied in-season
field service requirements but was insufficient at the start and end of the fishery
when a larger number of technicians were needed. This Newport-based
approach was abandoned in 2007 in recognition that gains in efficiency did not
justify the expense and complexity of establishing a program-dedicated EM
technician for the short fishery duration. Field services were then based from
Archipelago’s head office in Victoria, BC, where there was a larger pool of
qualified EM technicians who could more easily be tasked to the fishery as
required.

EM Data Processing
EM data processing followed the same general method but there were
differences across program years. The most significant change came from the
evolution of the EM technology, mentioned previously, that affected both
operational efficiency and accuracy. The integrated data analysis software (used
from 2008 to 2010) enabled technicians to easily work through EM data sets,
distinguishing trips and sets, viewing multiple camera images simultaneously,
and recording their observations into a database directly from the analysis
software. These efficiencies significantly improved the data analysis processes.

Data processing efficiency is often expressed with analysis ratios, defined as the
amount of time required to review imagery divided by actual time of the event.
Analysis ratios from the 2010 project year (Table 3-9) showed an average ratio for
catch stowage time of 0.249 (i.e., one hour of catch stowage operation takes 15
minutes to review). The analysis ratio for transit and fishing was much lower at 0.048, reflecting the higher speed that imagery can be reviewed when no fish handling activities are occurring. The higher rate for catch stowage operations related to the more careful examination required from different cameras to monitor for discard events. When discarding was evident, more time was needed to examine the event and data enter observations, hence the wide range in analysis ratios.

Sensor data processing time on average took 15 minutes per trip, and was not affected by the duration of the trip. In contrast image data review time was dependant on the duration of the trip, number of cameras, image quality, complexity of deck operations, and other factors. The data review time for a fishing trip varied considerably but in general, less than an hour was required to process an average trip of 41 hours in duration.

Table 3-9. Summary of analysis ratios (viewing time/actual elapsed time) for imagery review during catch stowage operations versus transit and fishing time for the 2010 project year.

<table>
<thead>
<tr>
<th></th>
<th>Catch Stowage (fish on deck)</th>
<th>Transit and Fishing (no fish on deck)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Events Reviewed (n)</strong></td>
<td>128</td>
<td>73</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>0.249</td>
<td>0.048</td>
</tr>
<tr>
<td><strong>Min</strong></td>
<td>0.001</td>
<td>0.013</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>0.643</td>
<td>0.087</td>
</tr>
</tbody>
</table>

While improvements in analysis tools streamlined the data services components of the program, it was difficult to provide timely monitoring results throughout the seven program years. In 2005, there was approximately a five-week delay from initial data collection to finished results which, given bi-weekly hard drive collection, translated to a delay of as much as seven weeks from when an event occurred. In 2010 the delay averaged 3.5 weeks (range of 0.5 to 7.4 weeks) following collection, or about 5.5 weeks from when an event occurred. With usually less than 60 day fishery duration and 30 or more active vessels, there are significant challenges with the field and data services operational components if the goal were to produce EM monitoring results for in-season management.

**Program Cost Analysis**

The EM program was co-funded by industry and NMFS throughout the 2004 to 2010 period and, owing to a number of circumstances, the proportional contribution varied from year to year. A cost summary for the 2007 to 2010 program years is presented in Table 3-10, showing total program cost, the contribution by industry, and program cost in relation to catch and vessel days. The program costs represent the total fees paid to the contractor for the delivery of the EM program and represent the true total cost of an ongoing EM program. It should be noted however, that program start up costs are not included and
these would vary considerably depending upon program design and the service delivery approach used. Table 3-10 shows that program costs varied from year to year, the fluctuation driven by season length, catch quantity, the number of participating vessels and the number of vessel days at sea. Season length was the most significant cost driver: 2008 and 2010 program years were over 140 days, while 2009 and 2007 were 24 and 40 days, respectively. The four year average program cost was $6.03 per mT, or $254 per sea day. The number of sea days per season is equivalent to the total number of calendar days that fishing vessels are at sea (i.e., partial days count as a full day), in line with how the term is generally defined by observer programs.

Table 3-10. Summary of total EM program costs for the 2007 to 2010 program years. See text for definition of sea days.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Program Cost (000's)</th>
<th>% Industry Funded</th>
<th>Cost per mT</th>
<th>% Catch Value</th>
<th>Cost per Sea Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>$346.3</td>
<td>64.0%</td>
<td>$4.58</td>
<td>2.9%</td>
<td>$239.0</td>
</tr>
<tr>
<td>2008</td>
<td>$434.8</td>
<td>76.0%</td>
<td>$7.87</td>
<td>3.6%</td>
<td>$339.0</td>
</tr>
<tr>
<td>2009</td>
<td>$228.4</td>
<td>66.0%</td>
<td>$5.37</td>
<td>4.1%</td>
<td>$258.0</td>
</tr>
<tr>
<td>2010</td>
<td>$412.2</td>
<td>79.0%</td>
<td>$6.61</td>
<td>4.1%</td>
<td>$208.0</td>
</tr>
<tr>
<td>4yr Average</td>
<td>$355.4</td>
<td>72.0%</td>
<td>$6.03</td>
<td>3.6%</td>
<td>$254.0</td>
</tr>
</tbody>
</table>

Figure 3-8 provides a breakout of program costs for 2009 and 2010, according to the program components defined in Section 2.2. The largest single cost factor (40-42%) was the service effort relating to installation, in-season servicing and post season removal of EM equipment for the fishery. In 2010, EM system provision cost was the second largest cost factor (36%), where as this was only 15% in 2009, owing to season length differences. As mentioned previously, most vessels leased EM systems as opposed to purchasing them. Had purchased systems been used, savings would occur with both EM system provision and mobilization and demobilisation costs, resulting in about a 15% program cost savings. Analysis and reporting was proportionately higher in 2009, as a significant portion of the fishery analysis and reporting effort was independent of season length.
Figure 3-8. Distribution of 2009 and 2010 EM program costs by component.
4.0 Discussion

The purpose of this paper was to compile the results of the seven-year EM program in order to review the operation of the monitoring program and how it evolved over time. The paper was also intended to document the operational aspects to demonstrate that effective EM programs are a lot more than the underlying technology. As well, the intent of the paper was also to summarize what we learned, with the aim of evaluating the merits of the program and providing insights that would assist in other fisheries where EM is being considered. The following key questions are relevant for this purpose:

- Was EM effective?
- Was EM cost-effective?
- What were the ingredients to success?
- What are the lessons learned?

4.1 Was EM Effective?

One of the challenges when evaluating the role of EM in contributing to the change in fleet-wide discarding activity is the lack of other monitoring methods that can be directly compared to EM, or understanding the discarding practices occurring in the fishery when no monitoring was in place. As well, the EM program was just one of a few initiatives that increased the level of attention toward discarding practices and the relative role of EM would be difficult to isolate. Clearly, EM had a role in building a level of awareness and other factors such as stakeholder engagement, feedback, more stringent EFP regulations and OLE involvement all played a role in creating change in the fishery.

4.1.1 EM Data Collection Success

The effectiveness of EM as a fishery monitoring tool can be evaluated from both a fishery management and operational perspective. The seven-year program consistently demonstrated that it was possible to cover nearly all, of the fishery using EM technology, without any significant loss of fleet monitoring coverage. Over the seven-year program period, technology and program efficiencies improved to a level where over 99% of the fishery was monitored, creating confidence that results from the EM program were a true reflection of the fishery. The technology was well suited for this application and, for the most part, provided consistently high reliability. The sensor data success rate exceeded 98% for all but one year and the success rate for image data exceeded 95% for five of the seven program years. EM sensor data provided a very precise time and area footprint of the fishery.

Some data loss occurred in all program years which raises the question of the risk posed by missing key events in the fishery. While missing data is a component of any monitoring program, EM should probably be held to a different standard than observers because of the potential hidden bias with
potentially purposeful data gaps. Put another way, fishery participants can alter the fishery results by ‘accidentally’ shutting the system off when undesirable events occur. In July 2007, an enforcement incident, reported by Matthews (Pers. Comm.), highlighted the potential harm of minor breaks in the data record. A large quantity of groundfish, consisting of whiting and widow rockfish (Sebastes entomelas), was reported washed ashore in Southern Washington. Using VMS data, OLE officials were able to narrow the potential suspects to a vessel whose skipper admitted to turning the EM system off in order to discard approximately 17 mT of fish, including about 3 mT of widow rockfish. The EM data record for this incident showed a data gap thereby preventing the discarding incident from being detected. In a fishery with limited bycatch allowances, a capture event such as this could put the fishery at risk and would therefore motivate participants to conceal the event. This potential area of resource risk became even more relevant with the 2011 implementation of the groundfish IFQ program, where bycatch was individualized to single quota holders or groups of quota holders.

The above incident prompted a change in EM data analysis methodology where greater attention was given to data record gaps. In 2008, changes to wording in the EFP, greater emphasis by OLE, and more detailed analysis of data gaps resulted in a sharp decline in missing data. In the 2008 to 2010 program years, success rates were greater than 99% and the vast majority of data gaps were attributed to moderate or low risk events (i.e., data gaps were not during fish stowage operations), where an event such as described above could not have taken place. In 2010, 13 data gap events occurred during fish stowage operations and eight were considered as potential candidates for unrecorded discarding. As there were over 1,800 fishing events in 2010, the EM program was effective at reducing the likelihood of such discard events to less than 0.5% of the total.

Despite these low levels of EM data loss, the question remains of the potential risk to sensitive species. In order to assess this risk, we examined landings data from the 2011-2013 whiting fishery (Colpo, Pers. Comm.) to construct a worst case scenario of the amount of unrecorded catch that would be associated with various levels of missing EM data. The 2011-2013 years correspond to a period of 100% catch accounting using 100% at-sea observers and 100% shore-based landings monitoring. We examined catch quantities of sensitive species from the landings data to identify the highest bycatch incidents and selected the year of highest bycatch for each sensitive species. We then estimated a ‘worst case’ catch quantity associated with EM data loss rates of 0.5% by summing 0.5% of the highest catch events from the highest of the three years for each sensitive species. This was repeated for EM data loss rates of 1% and 5% and the results are shown in Table 4-1. Other than widow rockfish, bycatch levels of most sensitive species is low, both in terms of the percentage of fishing when present (percent occurrence) and catch quantity. Taking the highest catch rates from the three years and using a 0.5% EM data loss rate, the worst case amount of missing catch
would be less than 1% of the ACL for all species but widow rockfish and POP. The missing catch for these species would still be below 2% of the ACL with a 5% EM data loss. As compared with other species widow rockfish has a much higher occurrence rate and therefore, missing EM data is more critical for this species. As much as 5% of the ACL could be missed at a 0.5% EM data loss and 14% at a 5% EM data loss. POP, with much lower fishery occurrence pattern and lower ACL, would have as much as 3% of the ACL missing at a 0.5% EM data loss. This analysis was a ‘worst case’ assessment where missing catch data would result if only the highest bycatch events were excluded from the EM data record. Also, the species results are mutually exclusive; that is, selecting the worst case for one species would not likely result in the worst case catch rates for other species. In our view, these results suggest that, at the data loss rates experienced for most program years, the hidden bias from missing EM data is more likely to impact management of individual IFQ holdings than pose a risk to the resource caused by large amounts of unaccounted catch. However, these results underscore the need to ensure that EM data loss is monitored and actively managed in an EM program.

Table 4.1. Risk assessment of worst case missing catch data for sensitive species associated with different levels of EM data loss based on 2011 to 2013 landings data (Colpo, Pers. Comm.).

<table>
<thead>
<tr>
<th>Sensitive Species</th>
<th>2012 ACL (mt)</th>
<th>Highest Catch Year</th>
<th>Percent Occurrence (%)</th>
<th>Max Catch Event (mT)</th>
<th>0.5% Data Loss</th>
<th>1% Data Loss</th>
<th>5% Data Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Widow</td>
<td>600</td>
<td>2012</td>
<td>75.0%</td>
<td>14.04</td>
<td>28.23</td>
<td>4.7%</td>
<td>6.5%</td>
</tr>
<tr>
<td>Darkblotched</td>
<td>296</td>
<td>2012</td>
<td>28.5%</td>
<td>0.78</td>
<td>1.44</td>
<td>0.5%</td>
<td>0.7%</td>
</tr>
<tr>
<td>POP</td>
<td>183</td>
<td>2012</td>
<td>25.8%</td>
<td>3.28</td>
<td>5.76</td>
<td>3.1%</td>
<td>4.2%</td>
</tr>
<tr>
<td>Canary</td>
<td>107</td>
<td>2013</td>
<td>13.7%</td>
<td>0.12</td>
<td>0.34</td>
<td>0.3%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Bocaccio</td>
<td>274</td>
<td>2011</td>
<td>0.9%</td>
<td>0.03</td>
<td>0.03</td>
<td>0.0%</td>
<td>0.05</td>
</tr>
<tr>
<td>Petrale</td>
<td>1,160</td>
<td>2013</td>
<td>0.1%</td>
<td>0.00</td>
<td>0.00</td>
<td>0.0%</td>
<td>0.009</td>
</tr>
<tr>
<td>Pacific Halibut</td>
<td>-</td>
<td>2013</td>
<td>5.8%</td>
<td>0.07</td>
<td>0.28</td>
<td>-</td>
<td>0.45</td>
</tr>
<tr>
<td>Chinkok</td>
<td>-</td>
<td>2012</td>
<td>37.4%</td>
<td>0.77</td>
<td>1.93</td>
<td>-</td>
<td>2.93</td>
</tr>
<tr>
<td>Coho</td>
<td>-</td>
<td>2011</td>
<td>2.7%</td>
<td>0.09</td>
<td>0.16</td>
<td>-</td>
<td>0.21</td>
</tr>
<tr>
<td>Pink</td>
<td>-</td>
<td>2011</td>
<td>7.1%</td>
<td>3.34</td>
<td>7.23</td>
<td>-</td>
<td>8.71</td>
</tr>
<tr>
<td>Chum</td>
<td>-</td>
<td>2011</td>
<td>1.0%</td>
<td>0.03</td>
<td>0.03</td>
<td>-</td>
<td>0.05</td>
</tr>
<tr>
<td>Sockeye</td>
<td>-</td>
<td>2011</td>
<td>0.1%</td>
<td>0.00</td>
<td>0.00</td>
<td>-</td>
<td>0.00</td>
</tr>
</tbody>
</table>

4.1.2 Maximazed Retention Compliance

Importantly, the EM program provided individualized results of vessel compliance with maximized retention. In 2005, nearly all vessels discarded and most discarded 1.5% or more of their catch. Over time, the discard levels declined with increasing numbers of vessels showing very low levels of discards. By 2010, a third of the fleet had no observed discards, and among those vessels with discards, all but three discarded less than 0.6% of their total catch. Vessel-specific discard information showed that the majority of the discarding activity was caused by a minority of the fleet, and that many vessels could successfully
participate in the fishery with little or no discards. In our view, the data rich vessel-specific information system provided by the EM program was instrumental in helping drive this change in the fishery.

While not contributing directly to catch data, the EM program strengthened the veracity of the offload monitoring data collection system. Without at-sea monitoring, the landings data only report offloaded catch, leaving uncertainty for what was discarded at sea. The EM program provided estimates of discarded catch, and also corroborated information provided in vessel log data. Events of selective discarding were of particular concern, given the potential to bias overall species composition from landed catch. Very few selective discarding incidents were observed and the vast majority (>99%) were considered non-selective discarding events. These two categories were distinguishable more by crew behavior than by species recognition. Selective discarding could be damaged whiting, sharks or sensitive species and likewise, non-selective discarding could be mixed species or all whiting. Given the decline in large volume discard events and the shift to predominantly net bleeding and flushing methods over the seven year period, discarding seemed to be more related to an over-full or the vessel being full to capacity rather than discarding for species avoidance purposes. Hence, the level of at-sea discarding in this fishery (<0.03% in 2010) would likely contribute very little bias to the species composition obtained from landings data.

The results from the EM program identified the difficulties in quantifying discarded catch. The CCTV cameras provided an overall view of the fishing deck from various angles in order to monitor fish stowage operations and estimate discard quantities volumetrically. Using a similar set up on the R/V Miller Freeman, we observed no significant difference between weighed catch and estimates from EM imagery. However, these results must be interpreted with caution given the very small sample size (n=10 hauls) and different quantities between the fishery (.045 mT to >15.0 mT) and research vessel (~1 mT). As well, the discard accuracy study was conducted in the second year of the program and would not be representative of the seven-year program, particularly as technology and methods improved.

### 4.1.3 EM and Vessel Logbook Data Comparison

The comparisons of estimated discards by EM and vessel logs showed significant correlation across three discard types (deck discards, net flushing and bleeding), yet there was a high level of variability between the two data sets ($R^2 <0.4$). As both are estimates, it was not possible to attribute the error to vessel logs or EM estimation method but it is reasonable to conclude that density volume estimates from EM imagery were imprecise. Quantification of net bleeding events (no catch comes aboard) is difficult for EM reviewers, but also for observers and skippers. Without bringing fish aboard, it would be difficult to improve on estimates of fish discarded by net bleeding. The majority of catch was discarded in this manner in 2010. Discard events from the fishing deck were more easily estimated...
from referencing dimensions of deck features (e.g., checkers, trawl alley, etc.), yet this was still an imprecise process for skippers, observers and EM reviewers without more careful controls. Estimates of discard quantities could be improved with the use of more structured on board catch handling methods to facilitate more accurate volume estimation. This would entail placing fish intended to be discarded in containers such as baskets, totes or designated checker areas, the size being appropriate to the quantity desired. Other approaches including weigh scales, stereoscopic volume estimation (Ruff et al. 1995), and piece to weight conversion (Pria et al. 2012) should be considered in respect to cost benefit. Given the discard quantities declined to below 0.3% of total catch in this fishery (the majority by net bleeding), it is questionable whether more sophisticated catch quantification techniques would be justified. The importance of more precision is probably less important than ensuring that the species composition of discarded is unbiased.

One of the limitations of the EM system was with providing suitable imagery to identify individual species. The camera technology used in this program was analog, providing lower resolution (smaller file size) images that provide little detail when enlarged from the full deck perspective. Generally, fish that were distinctively different from whiting (i.e., different size, shape or color) could be distinguished but often could not be specifically identified. Close up cameras were not used in this study as was done by Bonney and McGauley (2008), which would have enabled species identification at a discard control point. This does limit the ability to use EM data for species specific enforcement and to collect biological data at the species level (i.e., species distribution information). However, species identification was not one of the monitoring objectives, instead, monitoring efforts were primarily directed at monitoring crew activities during catch stowage operations. Incidents of selective discarding could easily be detected, but were rarely observed. Generally, activities were non-selective with quantities of fish being transferred en masse from the net to the hold. More problematic were incidents where catch was discarded directly from the net to the water either as a bleeding event, or net flushing event. We examined such cases carefully, reasoning that such events occurring when the vessel was not full to capacity were considered suspect for having a higher bycatch composition than those of the last fishing event on a trip where the vessel was full to capacity. The EFP regulation in 2008 requiring vessels to end their trip and come to port if discarding occurred was intended to address this potential risk.

Program improvements to enable species identification would be beneficial. Recent technology provides much higher resolution digital imagery and much larger data storage devices, enabling much higher image quality than was previously possible. This would allow much greater image resolution during catch stowage operations. Designated discard control points and measures to control the rate of fish flow would still be necessary to distinguish among discards of predominantly whiting. The best application for EM for this high
volume fishery would be to verify maximized retention, and if limited
discarding were permissible (e.g., halibut, large sharks, etc), they be released
singly through a discard chute.

4.1.4  **EM Program Operational Considerations**
An ongoing challenge for the EM program related to the timeliness of data
reporting. These processes were improved over the program years, but with a
fleet size of ~35 vessels, seasonally intense fishing effort, sporadic access to
vessels for data collection, and a short season, it was very difficult to provide
data reports within 4-5 weeks of the fishery activity. We recognized that timelier
reporting of EM data would result in better overall program coordination,
 improved compliance, and greater responsiveness, yet this was countered by
managing program costs and logistics. More timely collection of hard drives is
possible but the analysis bottleneck still presents a challenge given the high but
seasonal data volume. Options for timely data collection and reporting could be
explored to determine if the additional cost and complexity could be justified.

In terms of meeting the fisheries management objectives of the EM program,
there are a number of aspects to consider. The EM program contributed to the
improvement of the fishery in several ways. The EM program addressed a
critical need to measure compliance with full retention; the estimates of discard
event frequency and quantity improved over time and showed significant
declines. The EM program reported discard events by type and apparent reason,
providing a better understanding of situations where discards occur. Program
results showed the estimated quantity of discards declined by nearly an order of
magnitude and there was a shift away from ‘top off’ discarding to less frequent,
apparently unavoidable overfull net circumstances when a portion of catch
needs to be discarded prior to bringing the codend aboard.

4.2  **Was EM Cost-Effective?**

4.2.1  **EM Program Costs**
An evaluation of EM cost effectiveness must take into consideration the value for
expenditure in relation to other available alternatives, which in this case is an
observer program. Based on the results of this study, we have a clear
understanding of the total cost of an EM program. Financial information
presented for the 2007 to 2010 program years showed the average EM program
costs to be about $6.00 per mT or 3.6% of the landed value of the catch. These
figures reflect the total cost of the monitoring program, including program
planning, field data collection and all the steps required to produce a finished
data set. The costs are also reflective of a mature program where startup costs
such as data base development, program design, and infrastructure development
have already taken place. As mentioned previously, the lease choice over the
purchase of EM caused by the lack of program tenure resulted in program costs
being elevated by as much as 20%. Including this, costs of an EM program could have been below $5 per mT, or less than 3% of the catch value.

4.2.2 EM vs. Observer Program Costs

It is very difficult to develop a like-for-like comparison with an observer program for cost comparison purposes. The sea day rate used in the 2011 groundfish IFQ observer program was $365, however the rate was not reflective of the true cost of observer deployments but derived by examining the average costs across several US observer programs (Colpo, Pers. Comm.). Furthermore, the sea day rate only includes the field portion of an observer program, not the overhead elements such as observer training, deployment management, briefing/debriefing, and data processing and reporting. We know from experience delivering the at sea observer program for the BC groundfish trawl fishery from 1995 to 2014 that overhead costs can easily contribute 30% or more of the total program cost. While this component can vary widely from one program and another, there is no reason to believe it to be less for the groundfish IFQ observer program. While the EM cost per sea day was about 30% less than the $365 rate, taking these other factors into consideration, we believe the cost of an EM program to be less than half the cost of an observer program.

In the case of the whiting fishery, it is reasonable to conclude that the cost of an EM program would be much less than an observer program, but was it more cost effective? The data available from an observer program is potentially much more comprehensive and likely more timely than that of an EM program, but is this level of detail necessary? Unlike an observer program, the EM program reduces the overall monitoring opportunity to a single purpose: monitoring compliance with full retention. Results from the seven-year program suggest that EM was very effective at monitoring full retention compliance and contributed to a significant decline in the level of discarding. Yet discarding still occurs in the fishery and EM will likely never capture 100% of all discard events. The data granularity provided by observers for these limited discard events is likely to be richer than what EM can provide and the choice of monitoring method comes down to a decision of whether the additional cost of an observer program is justified for the additional data collection opportunity. In our view, EM had a significant role reducing discarding to a level where the lower precision of the EM-based estimate becomes unimportant.

4.2.3 Future EM Program Cost

The issue of program cost effectiveness must also be considered in the context of other pertinent issues. We drew a comparison between the estimated total costs between EM and observer programs, yet there is no indication that the observer program overhead costs, currently funded by NMFS, would transfer to industry. As well, the EM program was co-funded by NMFS and industry and it is not known if future EM programs would also be partially funded by NMFS. Hence, the cost comparison between EM and observers from an industry perspective
would center on the portions of the program they would fund, rather than the total program cost.

Also factoring into future cost consideration with EM is the issue of the service delivery model. Service delivery refers to how the EM monitoring services within a program are organized and delivered, including options such as segregated roles for field and data services as well as single versus multiple service providers. The 2004-2010 EM programs were delivered as a single integrated program with all participants using the same technology and all service functions being carried out by a single service provider. Changes to the service delivery model will affect program efficiencies and resulting costs. The EM program costs shown for the 2007 to 2010 program period reflected a mature program, three years after implementation. A new program can expect to have implementation inefficiencies with higher costs during the start up years. With both EM and observer methods, there are ancillary issues that affect the total cost. For example, observer program costs also need to consider insurance, food, and logistical considerations associated with carrying an additional person aboard. EM programs need to consider additional power and other needs to host EM equipment, additional duty of care responsibilities, and changes to fish stowage operations if special catch handling methods are required.

One of the key factors that affected the overall equipment costs was that the majority of the fleet leased EM systems instead of purchasing. This decision resulted in increased mobilization and demobilization costs as the leased EM systems required installation and removal after each fishing season (and in some cases within the season during extended periods of non-fishing). It is important to consider how infrastructure costs would change under a long-term purchase amortization schedule in an operational program. Vessels are more likely to purchase EM systems in a long-term operational program, which leads to decreased servicing and equipment costs. In addition, as long-term programs mature, the local infrastructure develops to support the day-to-day program management needs, and subsequently further reduces the overall program costs. In long-term programs, it is also important to factor in the costs associated with replacing EM systems and parts over longer periods of time.

In conclusion, the results from this program showed that EM was lower in cost than an observer program, and given that monitoring reduced the incidence of discarding to a low level, EM was a more cost-effective method for this fishery. Future considerations of cost-effectiveness by EM will need to also consider the service delivery framework, the timeline to achieve results, and the ancillary impacts of the EM approach.

4.3 What Were the Ingredients to Success?
The 2004 to 2010 shore-side whiting EM program was essentially a fully implemented operational EM program. As opposed to the more than 30 EM pilot studies conducted on various US fisheries over the past decade the program was
an integral part of the management of the fishery. The program was in place to ensure compliance with full retention and to provide comprehensive information for better understanding of the fishery. Other than the seven-year program tenure as compared with the short duration pilot studies, there were many features of the program design that ensured its success.

4.3.1 EM Technology Evolution
Firstly, the technology itself was appropriately suited to the working environment and the monitoring objectives of the fishery. As mentioned, the EM technology became more effective and reliable over the program period, yet was consistently able to provide the level of data collection required to address monitoring issues in the fishery. There were no significant technology issues that compromised the monitoring objectives. Moreover, fishery participants were satisfied with the technology and felt that it was effective in achieving its purpose. Their confidence made it easier for the program to achieve industry acceptance. As shown by the questionnaire results, industry participants did not necessarily want EM-based monitoring but they felt it was effective.

4.3.2 Management Regime
Secondly, the EM program was a mandatory requirement for participation in the fishery. This requirement was enforced through the EFP and vessel operators risked expulsion from the fishery, future access, or fines if they failed to comply with the EFP. As a result, industry participants were directly compelled to cooperate, as compared to the voluntary nature of most pilot programs. Furthermore, the annual term of the EFP provided flexibility in wording, such that the program requirements could evolve. This resulted in improvements to the EM program over time, becoming more directly focused on the information needs in the fishery. From 2008 onward, the level of involvement by OLE and State Fisheries Officers increased, and staff received more training on the use of the EM system and became more directly involved in potential compliance events. The increased enforcement involvement in the program resulted in the most dramatic declines in discarding over the seven-year period.

As mentioned, the EFP provided annual flexibility and allowed for modifications to enforcement as the program evolved, which was integral to the success of the EM program. However, the EFP was not the only element of the program that evolved over the years. Improvements to the EM technology led to very high data collection success rates and consistent discard monitoring over the program years that was independent of the EFP. The increased flexibility was a very important aspect of the EFP which allowed for the evolution and success of the EM program. However, for fisheries that are not managed under an EFP, the key aspect of flexibility can be achieved by implementing a long-term EM program using a scaled approach. This can be achieved by starting the EM program on a small number of vessels in order to identify the primary monitoring objectives and the appropriate EM system configurations and data analysis procedures.
Once the program elements have been identified during the field trials then it can then be scaled up to a full operational program. Alternatively, EM operational programs can be implemented right away however the fishery will likely go through an initial learning curve that will require some modifications to EM system configurations and data analysis procedures.

### 4.3.3 Industry Outreach

Also important to the success was the level of information sharing established between agency, industry and the service provider. Information from the monitoring program provided for dialog on a variety of issues. Incorporation of vessel log data into the EM program was adopted early, recognizing that this information expedited EM data analysis as well as providing a way to audit vessel logs and potentially further streamline the monitoring process. Feedback to skippers on comparisons between EM and vessel log data resulted in improvements to data quality. In our view, vessel log data, corroborated by EM, could provide the most cost-effective, data rich information system for this fishery, as opposed to ‘mining’ the EM data set for the same information. Outreach processes also a high level of operational communication among the groups, providing responsive service for technical issues, providing feedback on monitoring information, leading to corrective action, and, to the extent possible by analysis timelines, directing OLE officials to potential problem areas in the fishery.

### 4.4 What Were the Lessons Learned?

With the aim of providing advice to those considering the use of EM in other fisheries, the following are a number of salient lessons with broad applicability:

- EM based monitoring should not be considered a “plug-and-play” alternative to observer programs as each has their own opportunities and challenges.

- The utility of EM for collecting fisheries data relies on a careful design process that integrates the EM technology, the vessel specifications, and specific on board catch handling and EM system duty of care requirements.

- EM programs are much more than the underlying technology. The majority of cost is with the service components and thus, a structured program design approach is needed.

- Successful use of EM often depends upon integration with other data collection processes and information sources. Data integration opportunities should be considered in the design process.

- Stakeholder engagement is an essential ingredient to EM program success. This should occur at a variety of levels in order to improve the program, optimize operations, and effect change.
• A key risk to EM is the hidden bias that can result from strategic intentional data loss (i.e., turning the system off to avoid recording). While some data loss is to be expected in any monitoring program, effective measures are needed to control, monitor and manage the level of missing data.

• EM technology will change over time and the program design needs to be flexible to include change, where appropriate.

• Effective EM programs require control measures through governance, regulations, incentives or disincentives. Instruments such as an EFP are particularly effective as they can be easily modified during the early stages of program implementation.

• EM programs take time to implement and a multi-year time horizon is needed to establish operations and infrastructure, and offset start up costs. Uncertainty of program tenure will slow the process and reduce cost efficiencies that can be achieved with EM approaches.

4.5 Conclusions

In our view, the EM program was successful for the shore-based whiting fishery. Comparing discard patterns in 2004 with those in 2010, they appear as though there were two different fisheries. EM contributed to change the fishery by providing vessel specific information on discarding practices, and showing that many vessels could successfully participate in the fishery with little or no discards. The cost of the EM program was lower than an observer alternative and in consideration of the monitoring objectives, EM is considered to be the most cost effective approach for this fishery.

In consideration of the applicability for other fisheries, it is important to recognize that EM based monitoring is more than the capabilities of the technology. A holistic perspective is needed, linking the fishery characteristics and monitoring needs with technology capabilities, monitoring options, regulatory framework, incentive systems, and program operational requirements (i.e., field service infrastructure, data analysis specifications, and other program components) to ensure the program is efficient, effective, cost effective, and integrated with management needs. Often overlooked is the importance of incentive systems to appropriately distribute responsibility toward the monitoring program within industry participants. This is reinforced through individualized vessel-specific performance reporting, feedback and engagement with industry. As well, missing data in an EM program requires active management to minimize hidden bias in the program results. Finally, timelines are important for success of an EM program as, compared to an observer program, it will take longer to achieve performance objectives and cost efficiencies as a result of the increased complexity of this type of fishery monitoring.
5.0 References


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