# Electronic monitoring in the New Zealand inshore trawl fishery

## A pilot study

DOC MARINE CONSERVATION SERVICES SERIES 9

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## A pilot study

H. McElderry[1], M. Beck[1], M.J. Pria[1] and S.A. Anderson[2]

[1] Archipelago Marine Research Ltd, 525 Head St, Victoria, British Columbia V9A 5S1, Canada. Email: howardm@archipelago.ca

[2] Lat 37 Ltd, PO Box 3058, Ohope 3161, New Zealand.

## ABSTRACT

Using on-board observers to monitor protected species (PS) interactions with the New Zealand inshore trawl fleet has a number of inherent difficulties. This study explores the use of Electronic monitoring (EM) as an alternative to observers. EM systems were deployed on two inshore vessels fishing off the NE coast of New Zealand's North Island. A total of 14 months, 65 fishing trips, over 260 vessel days at sea and 1022 fishing events were recorded. Overall, sensor data capture success averaged 84% and image recording was complete for 83% of fishing events. Detailed image analysis was conducted for six protected species monitoring objectives on all usable fishing events recorded, including 60 events where an observer was also on board. Image quality was medium to high for most (98%) of the image data and usability for specific monitoring objectives varied from 0% for warp interactions to 73–97% for the remaining five objectives. EM has tremendous potential for monitoring PS catch occurrences, providing a general index of seabird abundance, and routine monitoring for mitigation practices. The use of EM for detailed observations of warp strikes or for providing a detailed census of seabirds astern of the vessel would likely be ineffective. The project demonstrated the need to prioritise monitoring objectives to enable better configuration of the EM system. It also highlighted the value of industry involvement in project design and potentially significant cost savings of EM over human observer programmes. Implementation of EM-based monitoring in New Zealand would require establishment of New Zealand-based infrastructure for improved timeliness, coordination and data quality.

Keywords: electronic monitoring, observer programmes, trawl fisheries, protected species, mitigation practices, seabirds, dolphins, New Zealand


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# 1. Introduction

Worldwide, trawl fisheries are coming under increased pressure to minimise the impact of their activities on ecosystems, including non-target species and the habitats target catch occur in. Protected species interactions with trawl vessels generally occur during the deployment and retrieval of trawl gear or during catch processing, when offal is being discharged. Enumerating captures of seabird and marine mammals is vital for understanding the effects of fishing-related mortalities on the population viability of protected species caught as bycatch and for assessing the ability of fisheries to meet sustainability requirements. On-board observers are currently the primary method for monitoring protected species interactions in these fisheries. However, the use of on-board observers has a number of problems, especially the small size of inshore vessels which may not have room to accommodate extra personnel, unpredictable fishing schedules and the lack of governance structure to liaise with over placements. These problems mean that only limited data on protected species interactions in inshore fisheries can be obtained by using observers. For example, 250 days of observer coverage were planned during the 2007/08 observer year, but only 81 days (32%) were achieved across ten vessels (Conservation Services Annual Plan 2009/2010[1]). There is a need for more effective monitoring techniques.

Over the past decade, Archipelago Marine Research Ltd has pioneered the development of electronic monitoring (EM) technology for fishing vessels, and a number of pilot studies have been carried out to test the efficacy of this technology. Table 1 provides details of 43 EM studies, indicating the diverse geographies, fisheries, fishing vessels and gear types, and fishery monitoring issues that have been targeted. The capabilities of EM have been reviewed in McElderry (2008).

## 1.1 AIMS AND OBJECTIVES

In March 2008, Lat 37 and Archipelago began a pilot study, funded by the Department of Conservation (DOC), using EM on two inshore trawl vessels, to assess the use of EM for monitoring protected species interactions in this fishery. The field study was extended from 6 to 8 months and additional funding was provided to allow a detailed analysis of the full EM dataset to be carried out, as the analysis was initially based on a sample of the total collected data. The project results are presented in this report with emphasis on the following objectives:

1. Provide a complete listing of activities and data products resulting from EM monitoring on the two trawl vessels.
2. Provide a summary of the industry comments, advice and issues encountered resulting from deployment of EM systems on the two vessels.
3. Provide detailed recommendations for improvements to field operations including installation, deployment, operation, service intervals, industry and vessel communications, etc.

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[1] Available online at: www.doc.govt.nz/publications/conservation/marine-and-coastal/marine-conservation-services/csp-plans/csp-annual-plan-2009-10/

TABLE 1. SUMMARY OF ELECTRONIC MONITORING STUDIES BY ARCHIPELAGO MARINE RESEARCH LTD.

| YEAR | REGION | FISHERY | TARGET SPECIES | GEAR | MONITORING ISSUE* | | | | | | VESSELS | DAYS | STATUS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | EM | CM | DM | CH | PS | MP | | | |
| 1999 | Canada | BC Area A Crab Trap | Crab | Trap | X | | | | | | 50 | 2500 | Adopted |
| 2002 | Canada | BC Salmon Seine | Salmon | Seine | X | | X | X | X | X | 1 | 19 | Pilot |
| 2003 | Canada | BC Halibut Longline | Halibut | Longline | X | X | X | | X | | 19 | 459 | Pilot |
| 2003 | Canada | BC Salmon Troll | Salmon | Troll | X | X | | | | | 4 | 60 | Pilot |
| 2003 | Canada | BC Prawn Trap | Prawn | Trap | X | | | | | | 1 | 60 | Pilot |
| 2005 | Canada | BC Groundfish Longline | Groundfish | Longline | X | X | | | | | 230 | 12000 | Adopted |
| 2006 | Canada | BC Midwater Trawl | Hake | Trawl | X | | X | | | | 35 | 2500 | Adopted |
| 2007 | Canada | BC Inshore Trawl | Groundfish | Trawl | X | X | X | | | | 12 | 1000 | Adopted |
| 2002 | USA—Alaska | Alaska Halibut Longline | Halibut | Demersal longline | X | X | X | | X | X | 2 | 120 | Pilot |
| 2003 | USA—Alaska | Alaska Groundfish Factory Trawl | Groundfish | Trawl | X | | | | X | X | 5 | 200 | Pilot |
| 2005 | USA—Alaska | Alaska Rockfish Trawl | Rockfish | Trawl | X | | X | | | | 10 | 40 | Pilot |
| 2006 | USA—Alaska | Alaska Groundfish Factory Trawl | Groundfish | Factory trawl | X | X | | | | | 8 | 1600 | Adopted |
| 2006 | USA—Alaska | California Drift Gillnet (swordfish) | Swordfish | Drift gillnet | X | X | X | | X | X | 5 | 58 | Pilot |
| 2007 | USA—California | California Groundfish Fixed Gear | Groundfish | Longline/trap | X | X | X | | X | | 4 | 200 | Pilot |
| 2010 | USA—California | California Groundfish Fixed Gear | Groundfish | Longline/trap | X | X | X | | X | | 6 | 250 | Pilot |
| 2007 | USA—Florida | Gulf of Mexico Snapper/ Grouper Longline | Snapper/grouper | Demersal longline | X | X | X | | X | | 6 | 250 | Pilot |
| 2008 | USA—Hawaii | Hawaii Pelagic Longline (tuna, swordfish) | Pelagics | Pelagic longline | X | X | | | X | X | 4 | 250 | Pilot |
| 2010 | USA—N. Carolina | South Atlantic Snapper/ Grouper Longline/Bandit | Snapper/grouper | Longline/bandit | X | X | X | | | | 6 | 250 | Pilot |
| 2004 | USA—New England | New England Fixed Gear (cod, haddock) | Cod/haddock | Longline | X | X | X | | | | 4 | 50 | Pilot |
| 2007 | USA—New England | New England Herring | Herring | Small mesh trawl | X | X | X | | X | | 1 | 10 | Pilot |
| 2010 | USA—New England | New England Groundfish | Groundfish | Various | X | X | X | | X | | 10 | 800 | Pilot |
| 2002 | USA—WA/OR | WOC Midwater Trawl Shorebased Hake | Hake | Midwater trawl | X | | X | | | | 30 | 1500 | Adopted |
| 2008 | EC—Denmark | North Sea Groundfish | Groundfish | Trawl/seine/gillnet | X | | X | | | | 20 | 3000 | Adopted |
| 2010 | EC—England | North Sea Groundfish | Groundfish | Trawl/seine/gillnet | X | | X | | | | 12 | 1800 | Adopted |
| 2010 | EC—England | Irish Sea Groundfish | Groundfish | Trawl | X | | X | | | | 5 | 500 | Adopted |
| 2011 | EC—Germany | North Sea Groundfish | Groundfish | Trawl | X | | X | | | | 4 | 600 | Pilot |
| 2011 | EC—Netherlands | North Sea Groundfish | Groundfish | Gillnet | X | | X | | | | 2 | 300 | Pilot |
| 2009 | EC—Scotland | North Sea Groundfish | Groundfish | Trawl/seine/gillnet | X | | X | | | | 25 | 4000 | Adopted |

* Monitoring issues: EM = effort monitoring, CM = catch monitoring, DM = discard monitoring, CH = catch handling, PS = protected species, MP = mitigation practices.

*Continued on next page*

*Table 1 continued*

| YEAR | REGION | FISHERY | TARGET SPECIES | GEAR | MONITORING ISSUE* | | | | | | VESSELS | DAYS | STATUS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | EM | CM | DM | CH | PS | MP | | | |
| 2008 | EC—Sweden | North Sea Groundfish | Groundfish | Trawl/seine/gillnet | X | | X | | | | 2 | 250 | Pilot |
| 2005 | Australia | South Australia Shark | Shark | Gillnet | X | | | | X | | 1 | 16 | Pilot |
| 2005 | Australia | HIMI Toothfish | Toothfish | Longline | X | | | | X | | 1 | 48 | Pilot |
| 2005 | Australia | Eastern Tuna Billfish | Tuna, billfish | Longline | X | | | | | | 1 | 40 | Pilot |
| 2005 | Australia | Tasmania Small Pelagics | Redbait, mackerel | Midwater trawl | X | | | | X | | 1 | 42 | Pilot |
| 2009 | Australia | Eastern Tuna Billfish | Tuna, billfish | Pelagic longline | X | X | X | | X | | 10 | 1500 | Pilot |
| 2010 | Australia | Northern Prawn Fishery | Prawn | Trawl | X | | | | X | | 1 | 50 | Pilot |
| 2010 | Australia | Pilbara (West Australia) Trawl | Snapper | Trawl | X | | | | | | 1 | 70 | Pilot |
| 2011 | Australia | South Australia Shark | SA shark | Gillnet | X | | | | X | | 10 | 1000 | Pilot |
| 2003 | New Zealand | Inshore Groundfish Setnet | Groundfish | Gillnet | X | X | | | X | X | 5 | 82 | Pilot |
| 2003 | New Zealand | Hoki Midwater Trawl | Hoki | Midwater trawl | X | | | | X | X | 1 | 31 | Pilot |
| 2007 | New Zealand | Pelagic Longline | Tuna | Longline | X | X | X | | X | X | 2 | 60 | Pilot |
| 2007 | New Zealand | Demersal Longline | Groundfish | Longline | X | X | | | X | X | 2 | 50 | Pilot |
| 2008 | New Zealand | Inshore Trawl | Groundfish | Trawl | X | X | | | X | X | 2 | 800 | Pilot |
| 2011 | New Zealand | Inshore Snapper | Snapper | Demersal longline | X | X | | | X | X | 4 | 100 | Pilot |

* Monitoring issues: EM = effort monitoring, CM = catch monitoring, DM = discard monitoring, CH = catch handling, PS = protected species, MP = mitigation practices.

4. For a representative sample of fishing events, determine the feasibility of using the EM data to determine and, where feasible, record:
   a. Protected species retrieved from the fishing gear (assessed during haul and fish catch processing and referred to as 'protected species in the fishing gear' for the remainder of this report;
   b. Rate of occurrence and number of protected species observed around the sterns of the vessels (assessed during catch processing, and a subset of other times during fishing, and referred to as 'seabird abundance' for the remainder of this report);
   c. Number of seabird interactions with trawl warp(s) and mitigation devices, if deployed (assessed during fishing and referred to as 'warp interactions' for the remainder of this report);
   d. Lowest level of identification possible for protected species recorded in specific objectives 4a, b and c (family, morphological group or species and referred to as 'protected species identification ability' for the remainder of this report);
   e. Deployment of a mitigation device (assessed during fishing operations and referred to as 'mitigation device deployment' for the remainder of this report); and
   f. Presence/absence and quantification of offal discharge and discards (assessed during catch processing and referred to as 'assessment of discharge patterns' for the remainder of this report).
5. For the each specific objective in 4a–f where EM is feasible, develop a standard methodology that can be used on future EM datasets from inshore trawl fisheries. This will include a standard methodology for EM data analysis of variables that relate to the usefulness of the dataset (e.g. data quality, fishing gear and catch handling, crew behaviour, and other relevant information).
6. For EM-monitored fishing events where a government on-board observer was also present, provide a comparison between the two methods for each specific objective 4a–f.
7. Provide detailed recommendations on optimal storage/archiving of EM sensor and image data that would allow for secure storage and future review or audit and any other recommendations relevant to future deployment of EM systems in New Zealand fisheries.

# 2. Methods

## 2.1 PROJECT PLANNING

Project planning began in early March 2008 with a meeting at Sanford Limited in Auckland which was attended by representatives of DOC (Marine Conservation Services Programme staff), Sanford Ltd, Archipelago Marine Research Ltd, and Lat 37 Ltd. Discussion centred on identifying which inshore trawl vessels the EM systems were to be deployed on, areas of interest and tentative timelines for the installation of the equipment. Four complete EM systems were already in New Zealand, having been shipped from Canada earlier in the month.

Two inshore trawl vessels of similar tonnage were selected by vessel managers at Sanford to participate on this study. The two vessels are referred to as V1 and V2 in order to protect their identity (Fig. 1).

## 2.2 EM SYSTEM SPECIFICATIONS

Each vessel was provided with a standard EM system consisting of a control box, a suite of sensors including GPS, hydraulic pressure transducer, winch rotation sensor and up to four waterproof armoured dome closed circuit television (CCTV) cameras (Fig. 2). The control box continuously recorded sensor data, monitored system performance and controlled image capture according to pre-programmed specifications, and provided continuous feedback on system operations through a user interface. Detailed information about the EM system is provided in Appendix 1.

EM systems were installed in a similar manner on both vessels. The vessels' electrician and hydraulic engineer assisted in the installations by running wires and installing the hydraulic pressure transducers. During installations, EM control boxes, monitors, and keyboards were mounted in the vessels' wheelhouses. 240-V AC power supplies were used to run the EM system on each vessel and hydraulic lines were accessed from the engine room. The hydraulic pressure transducers were installed to indicate when the hydraulic equipment (trawl and anchor winches, etc.) was operating. The hydraulic pressure transducers were to be installed on the high-pressure side of the hydraulic system for both vessels. The EM system's GPS receivers were mounted to the mast on top of the

Figure 1. The two inshore trawl vessels that participated in the study shown alongside each other in Auckland (vessel identifiers have been removed).

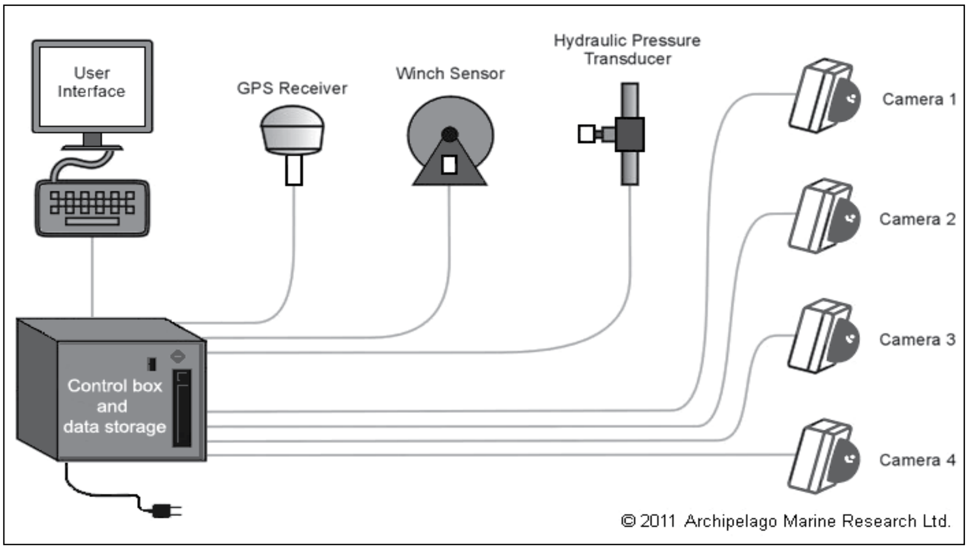


Figure 2. Schematic diagram of the electronic monitoring system.

wheelhouse, away from other electronics, and provided independent information on vessel position, speed, heading and time. The optical winch rotation sensors were mounted onto the net drum and were used to detect the shooting and hauling of the net.

Four CCTV cameras were mounted on each vessel in locations that provided views of catch and fishing operations. Both vessels had similar camera configurations, with two cameras mounted on the stern gallows and two cameras above the wheelhouse looking aft. Sensor and camera cables were run through bulkheads below the deck where hydraulic and electrical lines were already in place. The control box software was designed to boot up automatically when powered, or immediately after power interruption.

## 2.3 EM DATA CAPTURE SPECIFICATIONS

EM sensor data were recorded continuously while the EM system was powered, and the system was intended to be recording for the entire duration of each fishing trip. Sensor data were recorded every 10 seconds, resulting in a data storage requirement of 0.5 MB per day. Image capture occurred only during fishing operations, beginning when net roller winch rotations were sensed or when hydraulic pressure exceeded base threshold levels and ending 30 minutes (referred to as video run on) after either of these triggers ceased. All image data included text overlay with vessel name, date, time and position.

The EM systems received video inputs from the four CCTV cameras at selectable frame rates (i.e. images/frames per second; fps), ranging from 1 fps to 30 fps (motion picture quality). Using a frame rate of 6 fps, the data storage requirement was about 333 MB per camera per hour, equating to a required data storage capacity of 3–13 GB per day or 1.5–4 GB per tow. The data storage requirements are highly variable, as they depend on how much activity is occurring within the images, and this can be affected by bad weather and different camera configurations. Camera views facing outboard with constant motion require more storage than deck views where little activity is occurring.

## 2.4 FIELD PROGRAMME OPERATIONS

The field component began in March 2008, when the first EM system was installed on V1. The second system was installed on V2 in early May 2008. The field component continued through to November 2008 when the systems were removed from the boats. Lat 37 staff installed the EM systems on both vessels and serviced the equipment every 4–6 weeks (approximately) for the duration of the field effort. Each service period varied in length and number of trips depending on accessibility to the vessel. Camera configurations varied across the pilot project as changes to the set-up were made during the scheduled services. Communication and service schedules were organised between vessel managers at Sanford and Lat 37. Each service event included an operational check of the equipment and a cursory analysis of the data collected, adjustments to sensors as needed, and data retrieval. EM systems were aboard vessels for multiple trips and it was often difficult to assess how well camera placements would capture fishing activities during initial installation. Therefore, during each service event the EM technician inspected image data and made adjustments to camera positions, if necessary. Figures 3 and 4 show the corresponding camera views used to assess each of the project objectives for the two vessels. At the conclusion of the field effort, a Lat 37 technician removed the EM systems. All EM image data were copied to a backup hard drive and shipped to Archipelago's head office in Canada for processing.

This study also used government on-board observers to provide data for comparison with the data collected by the EM systems. The observers monitored fishing operations according to standard procedures for this fishery. Observer data were compiled by New Zealand Ministry of Fisheries staff and delivered to Archipelago for comparison with EM data.

## 2.5 EM SENSOR DATA INTERPRETATION

Throughout the field trials, EM sensor data were sent to Archipelago's head office in Canada via a secure FTP site. In order to be interpreted, raw sensor data (GPS and hydraulic) were first imported to an MS SQL database and analysed to determine the completeness of each dataset by checking for time breaks in the data record, as indicated by the time interval between records exceeding the expected 10 seconds.

Sensor data were then analysed to plot the geographic positions of fishing operations and identify key vessel activities including transit, gear setting and gear retrieval. All of the sensor data collected during the project were interpreted. EM sensor data interpretation was facilitated using a relational database as well as time series and spatial plots, which are illustrated in Fig. 5. Vessel speed and hydraulic pressure often correlate uniquely with various activities such as transit, net shooting and net hauling. Net shooting and hauling events were characterised by high hydraulic pressure and relatively low speed (plus high winch counts for V1). Towing was characterised by speeds of between 2.5 and 3.5 knots, and was easily identified between two gear events (i.e. net shooting and hauling).


Figure 3. Sample images from V1. A. Overall view of the complete deck area. B. View used for assessing seabird abundance and for the detection of mitigation devices. C. and D. views were used for quantifying and identifying protected species bycatch, offal discharge and discarded bycatch.


Figure 4. Sample images from V2. A. View used for analysis of offal discharge, discarded bycatch and protected species bycatch. B. View used for assessing seabird abundance and mitigation device deployment. C. View used to detect protected species bycatch when the codend was hauled over the stern. D. View initially set up to detect warp strikes. This view was eventually used to detect deployment of the warp scarer that was clipped to the main warp.

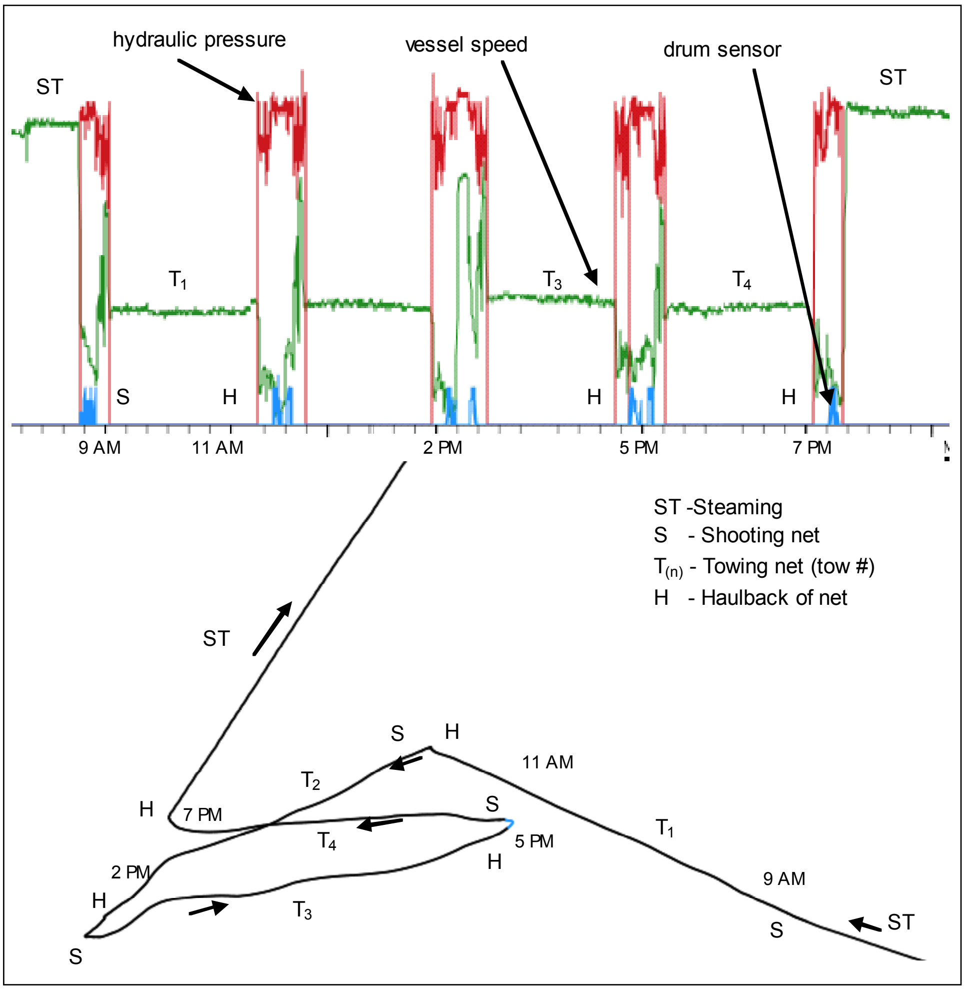


Figure 5. Example of sensor data from one of the study vessels. The time series graph (upper) shows vessel speed, winch rotations and hydraulic pressure over a 12-hour period. The spatial plot (lower) shows the vessel's cruise track for the same time interval with vessel activity denoted.

Part of the sensor data interpretation also involved the evaluation of the EM system sensors. The GPS, hydraulic pressure transducer, and winch sensor signals were evaluated for completeness throughout each trip. For each trip, each sensor's signals were rated as follows:

- Complete: the sensor performed to its full capacity.
- Incomplete: the sensor experienced intermittent failures or false readings.
- No data: the sensor did not operate during the trip.
- Not installed: the sensor was not installed for the trip.

Tow start and end times determined by sensor data interpretation provided an initial reference for accessing image data. The sensor database was sent to Lat 37 between service intervals where it was analysed along with the captured video for that service period to provide monthly reports to DOC.

## 2.6 EM IMAGE DATA INTERPRETATION AND ANALYSIS

EM image data were copied to a backup hard drive and shipped to Archipelago's head office in Canada for processing. Image data were interpreted using a custom software product that provided synchronised playback of all camera images and results were entered into an MS Excel spreadsheet. Playback speeds during image analysis varied from about 1.5 to 4 times real time depending on the project objective being assessed, image quality and camera configurations.

As part of image data analysis, every tow was rated for image quality and usability. Image data quality was assessed as an average across all four camera views, while usability was determined based on individual monitoring objectives. Image quality assessments are illustrated in Fig. 6 and described below:

- High: the image data is very clear, the viewer has a good view of catch processing and mitigation device deployment, and seabird activity is easy to assess.
- Medium: the view is acceptable, slight blurring or slightly darker conditions, there may be some difficulty assessing discards and mitigation device deployment, but assessment of seabird activity is not greatly hampered.
- Low: the image data are difficult to assess. Some camera views may not be available. Image data are somewhat blurred or lighting has significantly diminished (night time), making discharge, mitigation device deployment or seabird activity difficult to describe.

Image analysis was carried out on all the fishing events where imagery was usable, including the events where an observer was aboard. The focus of the analysis was to determine the feasibility of using EM to assess the monitoring objectives

Figure 6. Examples to illustrate EM image quality. From top to bottom: high, medium and unusable imagery for assessing discarded bycatch (left) and estimating seabird abundances (right).

4a–f. Standard methodologies were developed to suit the needs for EM analysis of these objectives and to best reflect the observer methods. The EM methods were created with the aim of optimising their use with future EM datasets from the inshore trawl fishery and to achieve optimal comparison results for this report and for other management use.

# 3. Results

## 3.1 SENSOR DATA SUMMARY

Table 2 provides an inventory of the data collected during the study by service period for both participating vessels (results for each individual trip are shown in Appendix 2). EM systems logged data across 9 months on V1 and 7 months on V2 for a total of 65 fishing trips and 1022 tows. Both vessels participating in this study generally carried the EM system for multiple trips between servicing events.

The data recording success of EM systems varied considerably between the two participating vessels, with V2 having much more complete sensor data than V1 (92% v. 78%, respectively). On an individual trip basis, sensor data capture success varied between 43% and 100% (see Appendix 2). EM system error logs indicate that the most likely reason for an incomplete data record was vessel operators manually turning off the EM system when the vessel was not fishing. Gaps in the sensor data record occurred at the start, end and during fishing trips, causing some tows to be captured only partially (i.e. either the shooting or hauling was missed) and it is likely that some tows were missed completely. Trip durations for 18 trips for V1 and four trips for V2 had to be estimated as the EM system was powered off during transit either at the beginning or end of the trips. Estimates used have been based on the vessel's distance from port. Overall image data collected during all trips amounted to over 1700 hours. An observer was present onboard V2 during four trips for a total of 60 tows between September and October.

Table 3 summarises sensor performance, and shows that the GPS performed without problems for the duration of the project. The net rotation sensors worked very well, but were susceptible to damage. Both vessels had failures with either the reflector or optical sensor becoming dislodged, likely due to gear overruns on the net drum. Two trips for V1 were affected by this problem before the EM technician serviced the equipment, identifying and solving the problem. Image data recording was unaffected for these trips, as the hydraulic pressure sensor triggered video recording. Eight trips on V2 were affected by the same problem, as there was no opportunity for the EM service technician to inspect the equipment and solve the problem. No image data were recorded for these trips, as the hydraulic pressure sensor had been incorrectly installed (see below) and did not trigger image recording.

The hydraulic pressure sensor on V1 was not installed during the vessel's first few trips, but was installed and performed without problems for the remainder of the study. The V2 hydraulic engineer incorrectly installed the hydraulic pressure sensor on the low- rather than the high-pressure side of the system, resulting in

TABLE 2. SUMMARY OF DATA COLLECTED DURING THE STUDY BY SERVICE PERIOD FOR BOTH PARTICIPATING VESSELS. FISHING EVENTS WHERE AN OBSERVER WAS PRESENT ARE DENOTED AS 'OBSERVED TOWS'.

| VESSEL ID | SERVICE PERIOD | TRIPS | SENSOR DATA EXPECTED (DAYS) | SENSOR DATA CAPTURED (DAYS) | SENSOR DATA COMPLETE-NESS (%) | IMAGE DATA COLLECTED (HOURS) | TOWS CAPTURED | TOWS VIEWED | OBSERVED TOWS |
|---|---|---|---|---|---|---|---|---|---|
| V1 | Mar-19 to Apr-30 | 9 | 34.59* | 32.53 | 94 | 171.34 | 103 | 99 | 0 |
| | Apr-30 to May-20 | 2 | 5.02* | 4.87 | 97 | 24.43 | 16 | 15 | 0 |
| | May-20 to Jun-24 | 4 | 32.66* | 23.61 | 72 | 125.54 | 50 | 46 | 0 |
| | Jun-24 to Aug-08 | 6 | 31.64* | 25.72 | 81 | 143.76 | 86 | 77 | 0 |
| | Aug-08 to Sep-12 | 5 | 20.91* | 13.16 | 63 | 70.42 | 48 | 44 | 0 |
| | Sep-12 to Sep-25 | 1 | 2.31* | 1.76 | 76 | 12.96 | 8 | 8 | 0 |
| | Sep-25 to Oct-22 | 3 | 13.29* | 10.75 | 81 | 69.60 | 42 | 41 | 0 |
| | Oct-22 to Nov-26 | 3 | 14.23* | 11.01 | 77 | 69.30 | 44 | 41 | 0 |
| **Vessel total** | | **33** | **154.65** | **123.41** | **78** | **687.35** | **397** | **371** | **0** |
| V2 | May-20 to Jun-24 | 4 | 17.41 | 18.29 | 93 | 100.36 | 60 | 57 | 0 |
| | Jun-24 to Aug-13 | 11 | 39.58* | 32.17 | 86 | 40.30 | 194 | 68 | 0 |
| | Aug-13 to Sep-02 | 3 | 16.51 | 16.51 | 100 | 138.24 | 77 | 77 | 0 |
| | Sep-02 to Sep-26 | 4 | 13.31 | 13.27 | 100 | 93.27 | 71 | 71 | 39 |
| | Sep-26 to Oct-10 | 5 | 16.28 | 13.70 | 84 | 328.12 | 83 | 80 | 21 |
| | Oct-10 to Nov-25 | 5 | 27.36 | 26.06 | 95 | 223.94 | 140 | 138 | 0 |
| **Vessel total** | | **32** | **130.45** | **120.00** | **92** | **924.23** | **625** | **491** | **60** |
| **Overall total** | | **65** | **285.10** | **243.41** | **84** | **1611.58** | **1022** | **862** | **60** |

* Denotes durations estimated when the EM system was off for the start or end of the trip.

TABLE 3. SUMMARY OF SENSOR PERFORMANCE FOR ALL TRIPS ON BOTH VESSELS THROUGHOUT THE PILOT STUDY.

| SENSOR PERFORMANCE | GPS RECEIVER | | HYDRAULIC PRESSURE TRANSDUCER | | NET ROTATION SENSOR | |
|---|---|---|---|---|---|---|
| | V1 | V2 | V1 | V2 | V1 | V2 |
| Complete | 33 | 32 | 32 | 0 | 31 | 24 |
| Incomplete | 0 | 0 | 0 | 32 | 1 | 1 |
| No data | 0 | 0 | 0 | 0 | 1 | 7 |
| Not installed | 0 | 0 | 1 | 0 | 0 | 0 |
| **Total number of trips** | **65** | | **65** | | **65** | |

no usable hydraulic pressure data for all 32 trips completed by V2. However, the system could still detect fishing events and record imagery by using GPS and winch rotation sensor data.

## 3.2 IMAGE DATA SUMMARY

Table 4 summarises the total EM image data captured for tows during the pilot project and shows the proportion then selected for EM review. All of the 60 tows that had an observer present on board were reviewed during EM analysis. Of the remaining 962 unobserved tows, 802 (83%) had complete image data. Incomplete tows occurred when image data for a tow were only partially captured due to either net rotation sensor problems (145 tows) or when EM systems were manually turned off (15 tows).

TABLE 4. SUMMARY OF EM IMAGE DATA CAPTURED DURING THE PILOT STUDY AND DATA SELECTED FOR EM ANALYSIS, INCLUDING DETAILS OF TOWS THAT WERE ALSO OBSERVED BY ONBOARD OBSERVERS.

| | TOTAL NO. OF TOWS | NO. TOWS THAT HAD COMPLETE IMAGE DATA | NO. TOWS VIEWED |
|---|---|---|---|
| Observed | 60 | 60 | 60 |
| Unobserved | 962 | 802 | 802 |
| **Total** | **1022** | **862** | **862** |

## 3.3 IMAGE DATA QUALITY AND USABILITY

Recorded tows were determined to be usable for a specific monitoring objective when image resolution was sufficient to reliably observe the events of interest for the monitoring objectives. Unusable image data resulted from a variety of problems, such as the sunshield obstructing the view, poor image resolution, bad sun glare or moisture in the lens. Different camera views were used to address each of the project objectives (see Figs 3 & 4); therefore, when image data from one camera angle was deemed unusable it may have only affected EM analysis for one monitoring objective.

Table 5 shows the number of tows found usable or unusable for project objectives 4a–f for both participating vessels. Four of the six objectives being assessed by EM analysis had approximately 80% or more usable tows (i.e. 60% of total tows) and seabird identification had 73% usable tows. Seabird warp interactions could not be assessed because imagery was recorded during a small period when gear was towed and this recorded period did not correspond with the observer sampling period. Hence, there was no ability to compare EM and observer results. In addition, camera views generally were insufficient to resolve seabird strikes on trawl warps. EM imagery was usable for assessing seabird abundance and identification for all daylight tows (81%) but sampling during night-time tows (19%) was not carried out by the observer and, therefore, was not included in the EM analysis. EM analysis was able to assess whether the mitigation device had been deployed in 97% of the recorded tows and 3% were deemed unusable due to poor image resolution. EM records of catch processing and discards was incomplete for 15% of tows because catch processing took longer than the 30-minute video run on time set previously. During EM analysis, all fishing events were reviewed for protected species in the fishing gear; however, 6% of recorded tows were considered unusable.

Table 6 provides a summary of image quality for all tows reviewed during EM analysis. The results show that image quality for both participating vessels was assessed as high- or medium-quality for 98% of the tows reviewed. The EM image viewer assessed the overall image quality for V1 as high for 68% of the tows, medium for 29% and low for 3%. Image quality for V2 during EM review was very similar to that for V1. Medium-quality tows typically occurred in low-light conditions during night tows or during daylight tows when bad sun glare was encountered (see Fig. 6 for example images). Lower quality image data typically resulted from poor image resolution or obstruction of the field of view

TABLE 5. SUMMARY OF EM ANALYSIS FOR SPECIFIC RESEARCH OBJECTIVES (4A–F), SHOWING THE NUMBER OF TOWS FOR WHICH IMAGERY WAS USABLE OR UNUSABLE FOR THE SPECIFIC OBJECTIVE EXAMINED.
+ = USABLE TOW IMAGERY; – = UNUSABLE TOW IMAGERY.

| | PS* IN FISHING GEAR | | SEABIRD ABUNDANCE | | SEABIRD WARP INTERACTIONS | | SEABIRD IDENTI-FICATION | | MITIGATION DEVICE | | DISCARDING CATCH | | TOTAL TOWS VIEWED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | + | – | + | – | + | – | + | – | + | – | + | – | |
| V1 | 362 | 9 | 275 | 96 | 0 | 371 | 248 | 123 | 364 | 7 | 339 | 32 | 371 |
| V2 | 444 | 47 | 423 | 68 | 0 | 491 | 384 | 107 | 474 | 17 | 398 | 93 | 491 |
| Total % | 94 | 6 | 81 | 19 | 0 | 100 | 73 | 27 | 97 | 3 | 85 | 15 | 862 |

* PS = protected species.

TABLE 6. SUMMARY OF IMAGE QUALITY FOR ALL TOWS VIEWED DURING EM ANALYSIS.

| | TOTAL TOWS VIEWED | PROPORTION OF IMAGERY BY QUALITY (%) | | |
|---|---|---|---|---|
| | | HIGH | MEDIUM | LOW |
| V1 | 371 | 68 | 29 | 3 |
| V2 | 491 | 75 | 23 | 2 |
| **Total** | **862** | **72** | **26** | **2** |

(e.g. sunshield blocking camera view). Poor image quality affected the methods used by the EM viewer to identify seabirds and assess their abundance. To address this problem, general grouping codes were established for EM analysis.

Throughout this pilot study, changes were made to the cameras' fields of view in order to experiment with capturing different events on the two participating vessels. Each vessel had quite distinct methods for hauling the catch and its subsequent processing, which made camera placement difficult. On V1, every haul was winched over a stern ramp onto the aft deck. Catch spilled from the codend into this area, and was sorted and processed here. In contrast, V2 did not have a stern ramp, and the codend was usually lifted onto the deck over the starboard side of the vessel. On occasion, when the catch was small, the codend would be brought directly over the transom; and where the catch was too large to bring over the starboard side in one lift, the excess catch would be lifted over the port side.

Changes were made to the camera angles throughout the duration of the project in an effort to better capture all the events of interest (see Fig. 7 for examples). Sometimes these changes to camera configurations diminished the system's ability to monitor for other objectives. The changes in camera views made in an effort to capture all events made subsequent analysis of the image data for this project difficult for the EM reviewer.

Figure 7. Port stern camera views that were changed. V2 (top) was changed from showing the stern quarter (left) to capturing catch processing that sometimes occurred on the port side (right). This camera view on V1 (bottom) was changed from describing the catch on deck (left) to capturing action (seabirds, warp) off the stern quarter (right).

## 3.4 MONITORING OBJECTIVES

The activities defined below were used during EM analysis to ensure optimal alignment with standard observer sampling methods. During EM analysis for the monitoring objectives, a tow with high-quality imagery took approximately 15–30 minutes to review. Viewing times varied depending on image quality and the amount of catch being processed (high volumes of catch took longer to sort and therefore increased the viewing time). The EM and observer methods used to assess the monitoring objectives are compared and discussed below. The following terminology defines the intervals during which the observer and EM reviewer recorded data for the events of interest:

**Shooting:** Time between the start of net out and the trawl doors going below the surface

**Hauling:** Time between the trawl doors reaching the surface and the net hitting the stern ramp (or being lifted from the water)

**Catch processing:** Time from net on deck to when all fish have been processed from the sorting area. V1 used the stern ramp, while V2 lifted its catch either over the port or starboard side.

## 3.5 PROTECTED SPECIES BYCATCH IN FISHING GEAR

### 3.5.1 Observer methods

The observer recorded any protected species bycatch that was seen in the fishing gear during hauling and processing of catch for each of the tows.

### 3.5.2 EM methods

The EM reviewer assessed the image data for any protected species in the fishing gear following the time periods defined above for hauling and catch processing to ensure optimal alignment with the observer methods. Fishing gear would sometimes drift in and out of the field of view, with certain camera angles making EM analysis more difficult. Images recorded in low-light conditions during night-time tows were also difficult to interpret for protected species within the fishing gear.

The EM and observer data were compared across all 60 observer tows for any incidents of protected species caught in the fishing gear. Results from the observer data indicated that there was one protected species caught; a bottlenose dolphin (*Tursiops truncates*), which was recorded as dead and then discarded. EM detected this event (Fig. 8A) and was able to identify the dolphin to the species level. However, image data did not show the dolphin being discarded, as it occurred out of camera view. When the dolphin was brought on board the vessel, it appeared motionless and lifeless and was considered to be dead by the EM reviewer.

EM data for the non-observed tows were also reviewed for any incidents of protected species caught in the fishing gear. One Australasian gannet (*Morus serrator*) was observed entangled in the belly of the net while the net was being hauled on board V2 (see Fig. 8B). The seabird was identified to species level and appeared lively in the net when handled by the crew. Another small seabird was also detected landing on the vessel at night, but identification to species level was not possible.

Fishing log data from V2 reported one dolphin and three seabird (petrel spp.) captures in the fishing gear that initial analysis of EM imagery did not detect. All incidents were from separate fishing events on vessel V2. In the case of the dolphin capture, the image data were reviewed again and it was evident that the crew were involved in catch handling activities, but these were occurring out of

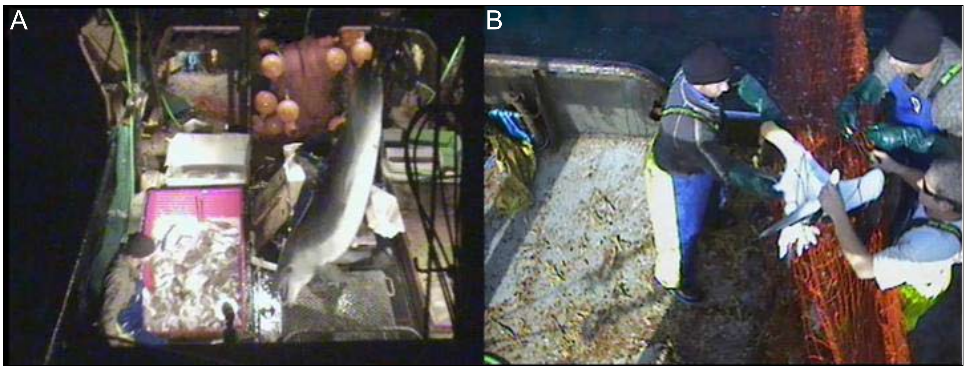


Figure 8. Examples of protected species interactions recorded by EM. A. Bottlenose dolphin (dead) brought up in the net codend; this event was also recorded by the onboard observer. B. Live gannet caught in a net that was detected during analysis of EM data recorded when no observer was present.

the camera field of view. The seabird captures were not detected in the initial review of the EM imagery, or in a subsequent analysis of imagery specifically looking for the seabirds in the catch. It was determined that the particular seabirds caught were too small to be discernable in the catch.

## 3.6 SEABIRD ABUNDANCE

### 3.6.1 Observer methods

Observers provided abundance counts for protected species occurring around the stern of the vessel for all daylight tows during shooting and/or hauling of fishing gear (see section 3.4). Actual counts were given when possible; however, under certain circumstances estimates were assessed in relative orders of magnitude (i.e. 10s, 100s or 1000s). Observers also specified whether the protected species were counted within or beyond the c.100-m radius of the set/haul location at the stern of the vessel.

### 3.6.2 EM methods

Particular camera angles (see Figs 3 & 4) were used to enable protected species abundances around the stern of the vessel to be assessed during EM review. All observed daylight tows were reviewed and abundance estimates were made for recorded gear shooting and hauling intervals. Seabirds were the main protected species regularly detected during the EM review process, although dolphins were also seen. Imagery was typically viewed at 1–2 times speed to assess seabird abundances. The EM viewer's estimates were always for distances of less than 100 m from the vessel, and more likely within 25 m of the vessel. This range limitation likely explains some of the differences seen when comparing EM-based estimates with observer data. Seabird abundance was assessed both during gear shooting and hauling. Exact seabird counts were not possible, and abundance estimates were classified into the following six abundance categories:

0 = No seabirds observed
1 = 1–10 seabirds
2 = 11–15 seabirds
3 = 16–25 seabirds
4 = 26–50 seabirds
5 = > 50 seabirds

Table 7 compares the EM reviewer's and the on-board observer's abundance estimates of seabirds around the stern of the vessel for the same events. Example images showing a range of seabird abundance are shown in Appendix 3. Seabird abundance comparisons indicate that EM and observer estimates fell within the same category for 23 of the 46 observed tows. The EM reviewer underestimated seabird abundances for 17 tows, and overestimated them for 6 tows. The observer was able to estimate abundances to a distance greater than 100 m from the vessel for a total of 29 tows, and 12 of those tows were underestimated by EM analysis. Differences in the methods used by observers and the EM reviewer for estimating seabird abundances may have led to some of the variability shown.

TABLE 7. COMPARISON BETWEEN SEABIRD ABUNDANCE CATEGORIES ESTIMATED FROM EM IMAGERY AND OBSERVER ABUNDANCE ESTIMATES FOR SHOOTING AND HAULING EVENTS.

| EM ABUNDANCE | OBSERVER ABUNDANCES | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1–10 | 11–15 | 16–25 | 26–50 | > 50 |
| 0 | 8 | 9 | 0 | 0 | 0 | 0 |
| 1–10 | 1 | 12 | 3 | 1 | 0 | 0 |
| 11–15 | 0 | 4 | 2 | 2 | 1 | 0 |
| 16–25 | 0 | 0 | 1 | 1 | 1 | 0 |
| 26–50 | 0 | 0 | 0 | 0 | 0 | 0 |
| > 50 | 0 | 0 | 0 | 0 | 0 | 0 |

Seabird abundance estimates across all tows reviewed by the EM reviewer are summarised in Table 8 and indicate that seabird abundances were generally higher during hauling of the fishing gear than they are during shooting. The incidence of no seabirds was higher during net shooting for both vessels and V2 had more instances of no seabirds than V1. Abundance estimates during hauling exceeded 25 seabirds for V1 in about 25% of cases, and in 17% of cases for V2.

Dolphins were observed around the stern of V1 during hauling for three tows. Dolphins were also seen during EM review for one tow during hauling on vessel V2.

TABLE 8. SUMMARY OF SEABIRD ABUNDANCE CATEGORIES ASSIGNED DURING EM ANALYSIS OF IMAGERY OF SHOOTING AND HAULING EVENTS FOR BOTH STUDY VESSELS.
S = SHOOTING; H = HAULING.

| EM ABUNDANCE CATEGORIES | V1 | | V2 | |
|---|---|---|---|---|
| | S | H | S | H |
| 0 | 29 | 16 | 139 | 81 |
| 1–10 | 75 | 55 | 96 | 98 |
| 11–15 | 38 | 32 | 51 | 68 |
| 16–25 | 35 | 50 | 50 | 62 |
| 26–50 | 15 | 33 | 28 | 43 |
| > 50 | 13 | 20 | 11 | 21 |
| **Total** | **205** | **206** | **375** | **373** |

## 3.7 TRAWL WARP INTERACTIONS

### 3.7.1 Observer methods

Observers counted seabird strikes on the trawl warp and on the mitigation device (if deployed—see section 3.9) for periods of 15 minutes during daylight tows. The sampling periods started on the hour (or half hour) and multiple observations were carried out for each daylight tow as conditions permitted. The observer recorded the total number of heavy contacts between small and large birds and the trawl warp or mitigation device. Heavy contact was defined as when the bird's path of movement was deviated when it came into contact with the trawl warp or when the part of its wings or head contacted the warp or mitigation device. Small birds included all petrels, shearwaters, prions, storm petrels, gulls and shags, while large birds included all albatrosses and giant petrels.

### 3.7.2 EM methods

EM imagery was recorded from the time when trawl doors were deployed to 30 minutes after gear was on the bottom fishing, and again when gear was retrieved until 30 minutes after the gear was stowed aboard the vessel. Image data could be reviewed for seabird strikes on warps or mitigation devices during these periods. Following the same definitions used by the observer for heavy contacts and light contacts, and small or large seabirds, the EM reviewer attempted to record counts of any interactions of seabirds. Figure 9 shows the camera view from V2 that was set up to assess seabird interactions with the warp.

Figure 9. Two images showing the camera view that was set up on V2 for assessing seabird interactions with the warp.

Throughout the duration of the project, appropriate camera views for detecting seabird warp strikes were only available for a limited number of trips, and none of the trips when an observer was present. Furthermore, the EM image recording duration during gear towing was limited and replicating the observer sampling periods was not possible. Therefore, because of the differences in observer and EM data alignment and the lack of appropriate camera views, it was determined that this objective could not be assessed.

## 3.8 PROTECTED SPECIES IDENTIFICATION

### 3.8.1 Observer methods

The on-board observer identified any protected species retrieved from the fishing gear to the lowest taxonomic level possible, and recorded the life status, capture method, injury and end status of the animal.

During assessment for seabird abundances, the observer identified all seabirds to the lowest taxonomic level possible, and recorded this using the appropriate observer codes. The proximity of seabirds to the vessel affected how well the observer could identify them. General codes were used in circumstances when seabirds could not be identified to species level (e.g. great albatrosses, *Diomedeidae* spp.).

### 3.8.2 EM methods

The EM reviewer was able to identify all protected species retrieved from the fishing gear to a general species level, but could not confirm the life status of the animal. Identification of marine mammals was aided by using Baker (1990), and that of seabirds by using Harper & Kinsky (1974) and Onley & Bartle (1999).

During EM analysis for seabird abundances, the EM reviewer identified the seabirds to a general grouping level based on size. The ability of the EM reviewer to detect and identify seabirds was a function of both the bird's distance from the vessel and the camera's field of view. In most cases, seabirds could not be identified other than to a general category based on size. It should be noted that the EM reviewer had limited experience with identification of New Zealand seabird species. For these reasons and for comparison purposes, EM and observer seabird identification data were grouped into the same categories: seagulls (general); petrels, prions and shearwaters; gannets (general); and albatrosses (general). Figure 10 shows example images of seabirds around the stern of V1 during hauling operations.

During review of the non-observed tows, dolphins around the vessels' sterns could be detected and rough abundance estimates made (see Fig. 11). The EM reviewer was able to identify marine mammals to a general species level such as dolphins (*Delphinus* spp.). Additional full resolution images are shown in Appendix 3.

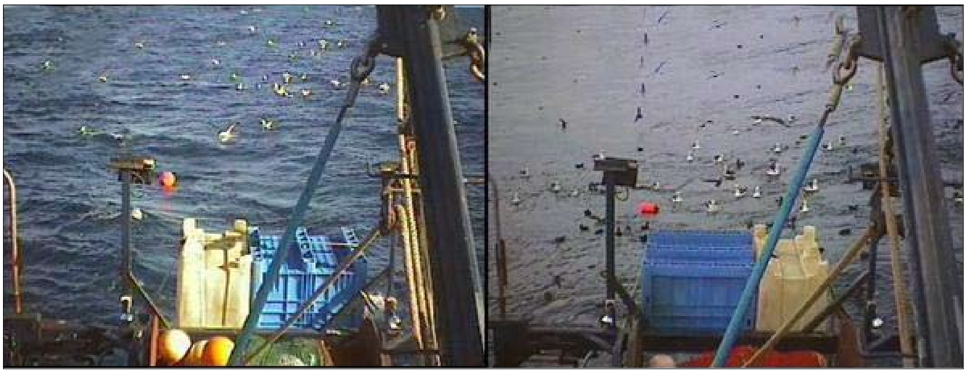

Figure 10. Example images of seabirds around the stern of V1 during hauling operations.


Figure 11. Example images of marine mammal activity from A. V2, and B. V1 during hauling operations.

Seabirds were the only protected species seen around the stern of the vessels during review of EM images of observed tows. The EM reviewer identified seagulls in 22 of the 33 tows in which they were identified by the observer (Table 9). The EM reviewer could only detect the presence of petrels, prions and shearwaters in half of the tows in which the observer recorded them, and gannets in only 2 of the 12 where they were seen by the observer. The observer recorded an albatross on one tow, which was not detected during EM analysis.

Table 10 provides a summary of the seabird species groupings identified across all tows for which usable recordings were available and, more specifically, during shooting, hauling or both. Seagulls were the most commonly occurring species grouping across both vessels, with higher occurrences during hauling of the fishing gear. Petrels, prions and shearwaters were also a commonly occurring group, particularly during hauling. For V2, this seabird category was observed during both hauling and setting in 139 instances. For both vessels, occurrences of gannets and albatrosses were quite low compared with the other two species groupings.

TABLE 9. SUMMARY OF SEABIRD IDENTIFICATIONS (TO GENERAL SPECIES GROUPINGS) MADE BY THE OBSERVER AND FROM EM FOR TOWS ON V2, SHOWING THE NUMBER OF IDENTIFICATIONS THAT MATCHED.

| SEABIRD SPECIES GROUPINGS | TOTALS | | MATCHES |
|---|---|---|---|
| | EM | OBS | |
| Seagulls (general) | 23 | 33 | 22 |
| Petrels, prions, shearwaters | 15 | 24 | 11 |
| Gannets | 2 | 12 | 2 |
| Albatrosses (general) | 0 | 1 | 0 |

TABLE 10. SUMMARY OF SEABIRD IDENTIFICATIONS (GROUPED INTO GENERAL SPECIES CATEGORIES) AROUND THE STERN OF THE VESSEL FOR DIFFERENT FISHING EVENTS IDENTIFIED FROM EM DATA FOR ALL TOWS FOR BOTH PARTICIPATING VESSELS.

| VESSEL | SEABIRD SPECIES GROUPINGS | NO. OF TOWS WITH USABLE EM IMAGERY | FISHING ACTIVITY* | | | |
|---|---|---|---|---|---|---|
| | | | S | H | B | TOTAL SETS |
| V1 | Seagulls (general) | 275 | 47 | 70 | 42 | 159 |
| | Petrels, prions, shearwaters | 275 | 40 | 49 | 67 | 156 |
| | Gannets | 275 | 3 | 21 | 5 | 29 |
| | Albatrosses (general) | 275 | 5 | 3 | 2 | 10 |
| | Unknown | 275 | 16 | 20 | 8 | 44 |
| V2 | Seagulls (general) | 423 | 50 | 104 | 114 | 268 |
| | Petrels, prions, shearwaters | 423 | 32 | 41 | 139 | 212 |
| | Gannets | 423 | 8 | 26 | 7 | 41 |
| | Albatrosses (general) | 423 | 1 | 4 | 1 | 6 |
| | Unknown | 423 | 6 | 14 | 1 | 21 |

* S = shooting, H = hauling, B = both.

## 3.9 MITIGATION DEVICE DEPLOYMENT

### 3.9.1 Observer methods

The observer recorded each type of mitigation equipment being deployed off both sides of the vessel for all the observed tows. Any mitigation-related issues were also recorded, including events such as the tori line extending less than about 10 m beyond the warp. Up to four codes for the various mitigation events observed could be entered for each tow.

### 3.9.2 EM methods

All the fishing activity captured by EM was examined by the EM reviewer to assess the deployment of mitigation devices off both sides of the vessel. The EM reviewer used the corresponding observer codes to record the type of mitigation equipment. The EM reviewer could not properly assess for any mitigation-related events, as close-up camera views of the mitigation device relative to the water were not available for the duration of the project. Image data were reviewed at 4× speed to determine whether the mitigation device was deployed.

Comparisons between EM and observer records of mitigation device deployment are shown in Table 11. EM was able to detect the deployment of mitigation devices for 51 out of the 55 usable observed tows, indicating that mitigation device deployment (or not) could be detected in 93% of the tows for which there were usable EM images. Four night-time tows and one daytime tow were found to be unusable for imagery analysis, with the EM reviewer unable to confirm mitigation device deployment. Night hauls were difficult to interpret during EM analysis, as the mitigation equipment was harder to detect. The EM reviewer's analysis of four usable recordings of tows did not match the observer's records. For three of these, the observer recorded tori lines, while EM recorded no mitigation devices. Table 12 provides a summary of the EM data for the type of mitigation devices used across all the tows reviewed for both participating vessels. For V1, the results show that warp scarers were detected for 229 tows, but no tori lines were detected. For V2, both warp scarers (179 tows) and tori lines (271 tows) were detected during EM review. During EM review there were 134 tows for V1 and 21 tows for V2 where the EM reviewer detected no mitigation devices being deployed. Image data recording was set to stop 30 minutes after hydraulic and winch activity ceased, and mitigation devices may have been deployed after the recording ended or, alternatively, no mitigation devices were deployed during these fishing events.

TABLE 11. COMPARISON BETWEEN EM AND OBSERVER DETECTIONS OF MITIGATION DEVICES FOR FISHING EVENTS WHERE BOTH EM AND OBSERVERS WERE PRESENT. SHOWN IS THE NUMBER OF FISHING EVENTS BY MITIGATION DEVICE FOR USABLE EM IMAGERY AND OBSERVERS, AND THE NUMBER OF INSTANCES WHERE EM AND OBSERVER DETECTIONS MATCHED.

| MITIGATION DEVICE | EM TOTAL | OBS TOTAL | MATCHES |
|---|---|---|---|
| Warp scarer | 23 | 23 | 23 |
| Tori line | 26 | 32 | 26 |
| Not detected | 6 | 5 | 5 |
| **Total** | **55** | **60** | **54** |

TABLE 12. SUMMARY OF EM DATA ASSESSED FOR DETECTION OF MITIGATION DEVICES ACROSS ALL TOWS FOR BOTH PARTICIPATING VESSELS.

| EM DATA ASSESSMENT OUTCOME | NO. OF TOWS | |
|---|---|---|
| | V1 | V2 |
| Warp scarer detected | 229 | 179 |
| Tori line detected | 0 | 271 |
| Mitigation device not detected | 134 | 21 |
| Imagery unusable | 8 | 20 |
| **Total** | **371** | **491** |

## 3.10 ASSESSMENT OF DISCHARGE PATTERNS

### 3.10.1 Observer methods

The observer recorded whether any fish discharge (including fish parts/offal and whole fish) occurred, and when (during shooting, hauling and/or fishing activity) for each tow. Smaller in-shore trawl vessels do not usually process their catch at sea and therefore do not discharge offal. The observer recorded only minimal amounts, so this component of the objective is not quantified further. Quantification of discards was broken down by species and the observer recorded the species, type of discard and the green weight estimate. In addition, the observer recorded where on the vessel discarding occurred, followed by the method used to estimate the green weight.

### 3.10.2 EM methods

The reviewer examined the EM records of observed tows to identify whether catch or offal discarding was occurring during catch processing operations. The EM reviewer identified any incidents to the lowest taxonomical grouping possible. When identification of discards could not be made to species level, general grouping codes or an unknown fish category were used. Quantification of the discards was broken down into general species groupings during EM analysis; however, when identification was not possible, a single weight estimate was made for the unknown fish category. The EM reviewer made rough visual weight estimates based on the available camera views and crew behaviour during catch processing. Discards data were entered using the same methods as used by the observer (described above). For V2, only discards off the starboard side of the vessel were assessed, as this was the only camera view available. Catch handling on both V1 and V2 was difficult to assess from EM imagery, as there was no systematic way in which catch was sorted and handled.

TABLE 13. SUMMARY OF WEIGHTS OF DISCARDS DISPLAYED BY GENERAL SPECIES CATEGORIES ESTIMATED BY OBSERVER AND FROM EM DATA FOR V2.

| GENERAL SPECIES | OBSERVER WEIGHT (kg) | EM WEIGHT (kg) |
|---|---|---|
| Finfish | 1471 | 420 |
| Sharks | 66 | 20 |
| Rays and skates | 727 | 465 |
| Invertebrates | 13 | 0 |
| Unidentified fish | 0 | 1015 |
| **Total weight** | **2277** | **1920*** |

* Percentage difference between total estimated weights (observer and EM) = 16%.

Table 13 provides a summary of observer and EM estimates of discard weights by general species groupings. The results show that the EM reviewer categorised 1015 kg of the discards as 'unknown fish', while the observer identified all discarded catch to species level. The observer recorded 727 kg of rays and skates, while the EM reviewer recorded 465 kg. There was a 16% difference between the observer's estimate and the EM estimate of total weight of discards.

Figure 12 plots the total weight estimates of discards per tow for EM and observer data. The average weight of discards per tow recorded by EM was 40 kg and 47 kg by the observer, with an average difference of 7 kg. When individual tows are compared, the results do show some variability. The EM reviewer underestimated weights relative to the observer for 31 of the tows, and overestimated it for 14 tows.

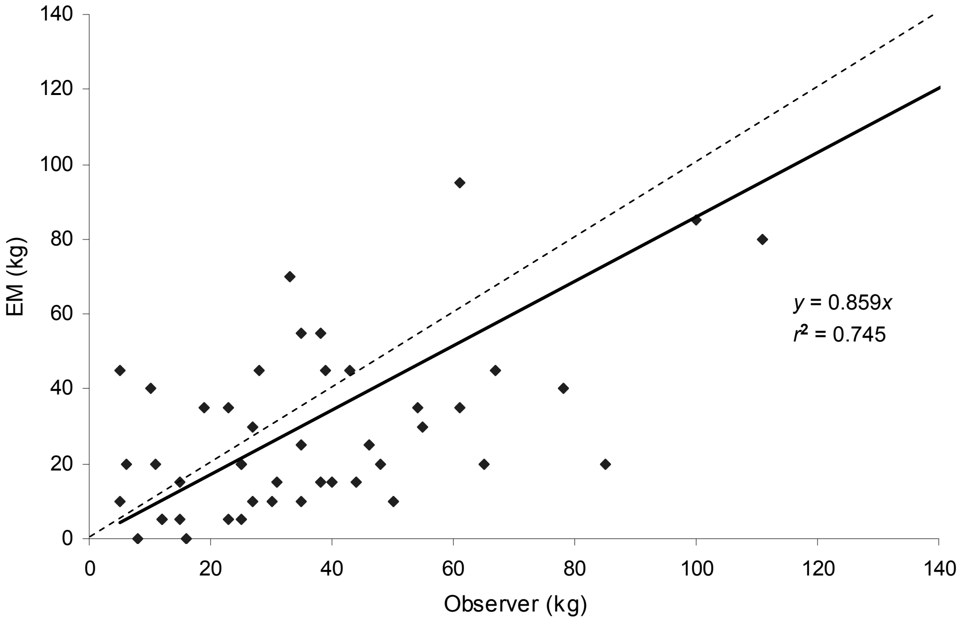


Figure 12. Comparison of EM and observer weight estimates for total discards per tow. Dashed line shows 1:1 relationship and solid line shows regression with *y*-intercept at zero.

Weights of discards estimated from the EM data and grouped into general species categories are summarised in Table 14. The estimated amount of sharks discarded by V1 was much higher than on V2 (1290 kg v. 117 kg). For both vessels combined, approximately 70% of the estimated weight of discards was categorised as unidentified fish. Invertebrates were not recorded for either vessel, as they could not be easily distinguished from fish.

TABLE 14. SUMMARY OF WEIGHTS OF DISCARDS GROUPED BY GENERAL SPECIES CATEGORIES ESTIMATED FROM EM DATA FOR ALL RECORDED TOWS AND BOTH VESSELS.

| GENERAL SPECIES GROUPINGS | EM WEIGHT (kg) | |
|---|---|---|
| | V1 | V2 |
| Finfish | 570 | 961 |
| Sharks | 1290 | 117 |
| Rays and skates | 4207 | 1707 |
| Invertebrates | – | – |
| Unidentified fish | 9688 | 10032 |
| **Total weight** | **15755** | **12817** |

# 4. Discussion

## 4.1 TECHNICAL ASSESSMENT OF THE EM SYSTEM

EM equipment was deployed on the two inshore trawl vessels for a collective total of 14 months, covering 65 fishing trips, more than 260 vessel days at sea and 1022 fishing events. Overall, sensor data capture success averaged 84%, although there was considerable variability between trips. The EM data collected did not provide a complete record of the fishing trips, however, with missing data almost entirely due to the EM system being manually powered off for various intervals at the start, during and at the end of the trips. Vessel masters likely adopted a habit of powering off the system when there was no fishing activity, such as during transit or when anchored at night. When a boat's main or auxiliary engine is not running, electrical power is supplied from batteries and the demand can be high if this has to power an EM system as well as deck lighting and other devices. Having the EM system turned off led to instances where it was not operating when fishing operations were taking place. The incomplete data resulted in problems of reliably interpreting activity when only part of an event was captured, as well as making it difficult to confirm that no fishing events were missing from the data record. A complete data record is important for confirming that fishing trips are fully documented. It is therefore recommended that more rigid guidelines be used to ensure that vessel operators keep EM systems continually powered while vessels are at sea. Because the EM systems installed for this pilot study were only temporary, power was provided to the systems from normal household AC three-point plugs located in the boats' wheelhouses. For permanent installations, we recommend that the EM system box be hardwired to the vessel's switchboard and have its own dedicated circuit breaker.

Sensor performance was generally high throughout the study, particularly the GPS system. The hydraulic pressure transducers also worked consistently, but one had been incorrectly installed on the low-pressure side of the hydraulic system and, as a result, was not useful for monitoring winch use and triggering image capture events. Winch motion sensors worked well, but their exposed location led to a higher susceptibility to damage, with partial or complete data loss on ten fishing trips. The combined use of both hydraulic and winch sensors for triggering image recording resulted in higher levels of recording than would result from use of a single sensor. The strategy of using two sensors should be maintained in future EM monitoring systems because of the insurance against faults that having an extra sensor provides.

Image recording was set for a 30-minute run-on following completion of the triggering event, essentially meaning that recording ended 30 minutes after gear was set and 30 minutes after the net was fully aboard. While this interval was adequate for most fishing events, catch stowage activities on about 15% of the fishing events lasted beyond the run-on interval, resulting in incomplete image data. As well, monitoring issues such as seabird abundance estimates, mitigation device usage and PS interactions with trawl warps were limited to the recording intervals, as opposed to the complete period during which fishing gear was deployed. The run-on interval should be increased, with consideration given to the requirements for each of the monitoring objectives. This change will result in greater overall data storage needs, and possibly require more frequent servicing to download data.

The existing EM technology may not be entirely suitable for the inshore trawl fishery, as the study highlighted some problems with the quality of the imagery obtained and how suitable it was for the various monitoring objectives. Image quality was medium to high for virtually all (98%) of the recorded images, but usability for specific monitoring objectives varied from 0% for warp interactions to 73%–97% for the remaining five objectives. While the usefulness of EM monitoring for each of the monitoring objectives is examined in detail below, some general comments are applicable to all the objectives. The main issues affecting image quality were lack of light during night operations, occasional sun glare and reduced clarity caused by moisture on the camera dome. The latter two issues are relatively minor, while the former can be significant. Where camera views are directed at activities on the vessel, it is relatively simple to supplement lighting and improve imagery. Where camera views are directed at areas around the vessel, providing additional lighting is more problematic.

The camera placements for the two vessels were opportunistic, with the cameras being mounted on the most suitable standing structures. Two cameras were placed amidships, covering the working deck, and two cameras were mounted on the stern gallows to cover the stern deck and water area astern of the vessel. The choice of placement and field of view for each of the four cameras was a process of attempting to optimise across all monitoring objectives. The two vessels had different operating methods, with one loading catch amidships and the other using the stern ramp. Also, how catch was handled varied between fishing events, so that some activities occurred outside the field of camera view. For example, in some cases catch would be discarded off the port side on V2 while normally this operation occurred off the starboard side. This was the case for the dolphin catch recorded by the vessel but partially missed in the EM imagery. This study demonstrated the difficulty in achieving all monitoring objectives equally well, and improvements to the usability of imagery would be a process of prioritising the specific monitoring objectives and determining camera placements that best meet these needs. As well, working with a vessel's crew to develop more standardised catch-handling operations would improve the EM system's ability to accurately document events.

The results of this study indicate that closing communication gaps and improving coordination between the various project participants (including fishing vessel operators, company management, EM service technicians and EM data analysts) could lead to considerably improved monitoring outcomes. The organisational structure involved in this project was a function of the project's small scale and it was not practical to establish infrastructure to better support the needs of the project. EM data processing took place mostly in Canada. Although the analysts were skilled, their knowledge of New Zealand fauna was limited. The EM service technicians' operational bases were remote from the vessels' ports of operation and boats were serviced monthly in order to minimise travel costs. Service scheduling was coordinated through company management at Sanford. Implementing solutions to problems identified during data analysis was slow because of the time required for analysis and the length of the time intervals between servicing. Access to the vessels was occasionally hampered because of changes at short notice to vessel operating schedules and our inability to obtain skilled tradesmen (e.g. a hydraulic engineer). Some issues took longer to correct because of the short periods of time that vessels were in port and available to us. All of these issues resulted in some lost data and delays in changing the configuration of the EM systems to improve data quality. These issues are largely related to the small scale and limited budget of the project, which meant that it was not practical to have greater support (skilled personnel and infrastructure) available. Future studies would benefit from service technicians being closer to the ports of vessel operation and basing EM data analysis in New Zealand for more timely incorporation of the results.

Recent trials using EM systems remotely monitored in real time using satellite communications have shown potential in identifying system and operational problems as they arise. Being aware that a sensor is malfunctioning or that a hard drive is nearing its capacity before the vessel reaches port will improve service response times and data quality, decrease service costs, and provide real time monitoring capability in the same fashion as VMS systems in use on many vessels. Further enhancements to the EM application software may allow two-way communications so that service technicians can reconfigure the EM systems on vessels remotely.

The level of industry cooperation and support will strongly affect the success of an EM-based monitoring programme. During this pilot project there were problems with data loss due to the EM system being manually powered off by vessel masters during periods of no fishing activity. This led to cases where EM systems were not operating when fishing activity was taking place. More timely feedback to vessel operators on the EM system performance from service technicians and data analysts would more directly address these problems. The EM systems are not tamperproof and can be interfered with, and this can have a large effect on the success of data capture. These issues indicate how critical industry support is to the success of the technology.

## 4.2 ASSESSMENT OF EM FOR THE SPECIFIC MONITORING AREAS

### 4.2.1 Protected species in fishing gear

This study shows that EM imagery has promise as a method for detecting protected species interactions with fishing gear. Most (94%) of the fishing event imagery examined was usable for this purpose and improvements to lighting for night operations would increase the amount of usable imagery. Improving camera angles so that fishing gear was within the camera’s field of view at all times would also improve the amount of usable imagery recorded by EM. Image quality was generally sufficient to provide clear images of catch, although it may be difficult to distinguish specific items when they appear within a pile of catch. However, large animals stand out clearly in piles of smaller catch and it was not surprising that both EM reviewers and observers detected a dolphin caught as bycatch during the study. Similarly, EM reviewers easily distinguished a large, actively moving seabird caught up with catch in a net. However, it was not possible for EM to identify a dolphin in the fishing gear during a night haul when the catch was brought on board out of the camera's field of view. Similarly, it is questionable whether a small, dead, water-soaked seabird would be detected in the catch unless crew used a more systematic catch sorting method. Suggested refinements to the catch sorting method are described later in section 4.2.6.

### 4.2.2 Protected species abundance

Imagery from the majority (81%) of fishing events examined was deemed usable for determining protected species abundance astern of the vessel. Dolphins were detected for several non-observed tows; however, identification by species was not possible for distances greater than about 5 m from the stern of the vessel. Compared with what observers could see, the EM resolution for assessment of seabird abundances is lower, both in terms of numbers that can be seen clearly enough to be counted and the ability to identify species. The fixed field of view from cameras limits the ability to make an overall abundance estimate, as seabirds may move in and out of camera view. The cameras are also better able to resolve seabirds when they are contrasted against the sky or are directly astern of the vessel. Larger seabirds are more easily detected than smaller seabirds, and both are more difficult to resolve on the sea surface when conditions are rough. It is doubtful that EM would reliably resolve seabirds further than 25–50 m from the vessel. However, despite these limitations, EM assessments correlated reasonably well with observer assessments when data were grouped in abundance categories, suggesting that EM could be used to provide a relative index of seabird abundance. Seabird identification issues are discussed further in section 4.2.4.

### 4.2.3 Trawl warp interactions

None of the fishing event imagery was considered suitable for assessment of seabird interactions with the trawl warp. Cameras were not directly aimed at the trawl warp and its point of water entry, so the EM images did not record sufficient detail to enable seabird strikes to be monitored. Also, image recording was limited to the 30-minute run-on period, which did not correspond to the times that observers made their observations. Previous work on this topic (McElderry et al. 2004a, b) has shown that placing cameras to record warps can be difficult, because a relatively close-up view is required and warp position behind the vessel varies according to water depth, sea conditions and other factors. Even with ideal camera placements, it is difficult and time consuming to examine imagery for strike events. Instead, previous studies (cited above) suggest measuring the risk of warp interactions by monitoring for the presence of seabirds in advance of the warp tow path. This would be easier and less time consuming approach for EM monitoring.

### 4.2.4 Protected species identification

The ability of EM to identify protected species varies for interactions where they come aboard and those where they are sighted in close proximity to the vessel. In terms of protected species as bycatch, there were two occurrences during the study where the bycaught animals were easily identifiable during EM review, and one reported event that could not be indentified during EM review. The result would likely be applicable to all marine mammal encounters and live seabirds. Small seabirds, particularly those that come aboard dead and soaked, may be difficult to detect and identify, unless procedures for catch sorting were developed (see section 4.2.6).

It is more difficult to use EM imagery for identifying protected species in close proximity to the vessel. Results from this study provided numerous instances where seabirds could be seen astern of the vessel, but in the correlation between numbers counted or estimated from EM imagery and those recorded by the observer was relatively low, even with catch grouped by general size categories. Limited EM reviewer experience with New Zealand avifauna partly explains this result. An experienced ornithologist would be able to distinguish seabirds much better, particularly if the animals are active and there are visible cues such as flight patterns and behaviour. It is likely that under these circumstances, certain distinctive species could be discerned under ideal circumstances (close to the boat, good image quality), but most would not be able to be classified beyond general taxonomic groups (i.e. albatrosses, seagulls, gannets, petrels, etc.). For marine mammals, EM recorded sightings astern of the vessel, and the quality was high enough to enable species identifications. However, ideal conditions for species identification required close proximity to the vessel, calm seas and adequate lighting. It is quite likely that marine mammal interactions would escape detection under less favourable conditions. It is therefore unlikely that EM would be a robust tool for detecting and characterising protected species in close proximity to the vessel.

### 4.2.5 Mitigation device deployment

EM imagery was very successful (97%, Table 5) in being used to observe use of mitigation devices. The EM viewer detected Tori Lines and Warp Scarers being deployed by V2 while only Warp Scarers were seen being deployed from V1. The results from this study indicate that mitigation device deployment was not detected during EM review for 36% of the tows for V1 and 4% of the tows for V2.

Agreement between EM reviewers and observers was very high overall (93%) and Tori Lines showed the lowest detection success, being missed in 3 out of 28 cases. The discrepancy may be due to the device being deployed after the EM image-recording period ceased, or the device not being distinguishable in the recorded images, particularly at night under low-light conditions. Previous studies (McElderry et al. 2004b) have found that image resolution degrades over the distance between the CCTV cameras and the point where a mitigation device enters the water, particularly in stormy wet weather where visibility is poor.

The issues affecting mitigation device detection are small and could be easily addressed and it seems likely that EM could be quite useful in monitoring the use and deployment characteristics of mitigation devices.

### 4.2.6 Assessment of discharge patterns

Most (85%) of the fishing event imagery examined in this study could be used for evaluating discharge patterns. For fishing events monitored by both an observer and EM, the level of agreement was within 16%. Keeping in mind that observer estimates also contain error, it is likely that the agreement between the two methods is mostly due to visually based weight estimates. A scatter plot showed the two methods were positively correlated ($r^2 = 0.74$) and there was no consistent bias; EM viewers overestimated about as often as they underestimated. With over half the catch recorded as ‘unknown fish’, EM reviewers made little effort to identify catch other than for the most conspicuous species.

The results of this study misrepresent the potential of EM to quantify and identify discards. The system deployed in this study was opportunistic, and had to make do with what was available. A dedicated EM system would be able to make improvements on several fronts. Camera placements need to both cover the entire area where fish come aboard and also provide a detailed view where specific catch sorting occurs. As well, catch sorting procedures by crew would need to ensure that imagery of all non-retained catch could be recorded for census and identification. Essentially, non-retained catch would need to pass across a camera-monitored chute, or similar catch choke point, where individual catch items could be distinguished. The mosaic of deck camera imagery could then be used to confirm catch coming aboard, retained catch being sorted and stowed, and non-retained catch being sorted and returned to the sea. An example of this type of configuration is presented in Fig. 13, based on a study in Alaska where discarded fish were identified, counted and measured.

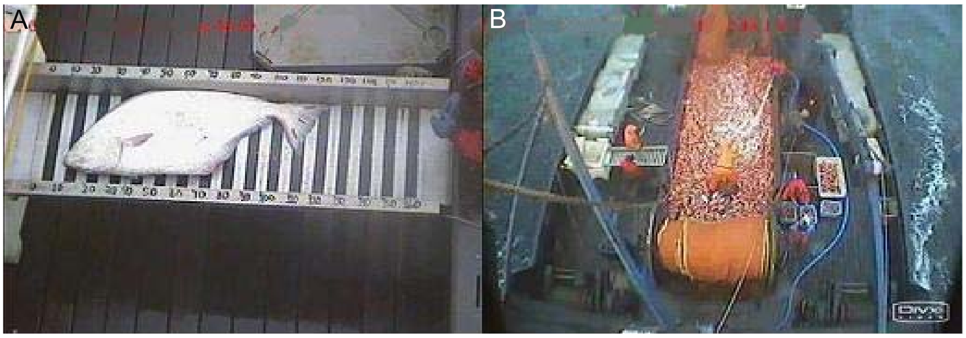


Figure 13. Example of multi-camera mosaic view of Alaskan groundfish trawl vessel showing A. Close-up view of the discard shute, and B. Full deck view. (From McElderry 2008.)

# 5. Conclusions

The results from this study show a range of efficacy for the six monitoring objectives (objectives 4a–f) examined. While observer data were superior for most of the objectives examined, we believe that EM technology shows promise for improving fishery data in the New Zealand inshore trawl fishery. In many instances, the ability of EM to address a particular monitoring objective could be improved over what was obtained in this study through either technical or organisational change. However, some prioritising of monitoring objectives would probably be required and some of those addressed in this study might not be included. EM has tremendous potential for monitoring bycatch of protected species, providing a general index of seabird abundance, and routine monitoring for mitigation practices such as offal discharge and deployment of gear avoidance devices. EM is likely to be less effective for detailed observations of warp strikes, or providing a census of seabirds astern of the vessel. The shortcomings of EM with respect to particular monitoring objectives should also be examined in relation to the potential gains of using this technology. While cost and operational efficiencies of EM as compared with on-board observers are the most common issues, McElderry (2008) provided further information on the relative merits and other practical issues for deploying this technology. A technology-based approach will be the best option if fleet monitoring levels in the fishery rise significantly. In terms of cost effectiveness, EM appears to have some financial advantages. For the total monitored vessel days achieved, the cost of this entire pilot study was about 40% of the monitoring costs using on-board observers[2].

The following issues need to be addressed if EM technology is considered for use in the New Zealand inshore trawl fishery:

1. The monitoring agency (e.g. DOC) needs to carefully examine its monitoring needs and determine if they can be met using EM technology, taking into consideration the improvements suggested in this study.
2. The quality and effectiveness of EM monitoring is highly dependent on the establishment of good working relationships with the fishing industry. Future work involving EM must build support and develop a strong relationship with industry. Improvements to data quality can only be achieved by working with industry. Feedback must be provided, and in a format that is useful to industry.
3. Communications and operational processes need to be improved to make EM more effective. EM service technicians, fishing company management and vessel skippers and crew need to be able to communicate easily. EM technicians need to be more readily available so that they can respond to vessels quickly, and able to fit in at vessels' timetables at short notice.
4. EM data analysis services should be based in New Zealand to reduce cost, improve analysis timelines, improve data quality, and better integrate the analysis results with EM programme operations. The ability to establish EM programme infrastructure will depend on the scale of monitoring activity required.

The study was able to address the majority of the seven objectives set out in section 1.1. However, objectives 2 (providing a summary of industry comments) and 7 (providing detailed recommendations on optimal storage/archiving of EM sensor and image data) require further investigation. Objectives 2 and 7 will be better understood once the operational context of an EM programme for the whole inshore trawl fishery is defined.

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[2] The comparison is based on the total study cost, 340 vessel days monitored by EM in this study and NZ$1000 per day for an at-sea observer.

# 6. Acknowledgements

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# 7. References

Baker, A.N. 1990: Whales and dolphins of New Zealand and Australia: an identification guide. Victoria University Press, Wellington, New Zealand. 107 p.

Harper, P.C.; Kinsky, F.C. 1974: Southern albatrosses and petrels: an identification guide. Victoria University Press, Wellington, New Zealand. 12 p.

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

McElderry, H.J.; Schrader, J.; Anderson, S. 2008: Electronic monitoring to assess protected species interactions in New Zealand longline fisheries: a pilot study. *New Zealand Aquatic Environment and Biodiversity Report No. 24*. Ministry of Fisheries, Wellington. 39 p.

McElderry, H.; Schrader, J.; McCullough, D.; Illingworth, J. 2004a: A pilot test of electronic monitoring for interactions between seabirds and trawl warps in the New Zealand Hoki Fishery. Unpublished Report Prepared for the Hoki Fishery Management Company Ltd., Nelson, New Zealand by Archipelago Marine Research Ltd, Victoria, BC, Canada. 35 p.

McElderry, H.; Schrader, J.; McCullough, D.; Illingworth, J.; Fitzgerald, S.; Davis, S. 2004b: Electronic monitoring of seabird interactions with trawl third-wire cables on trawl vessels—a pilot study. U.S. Department of Commerce, NOAA Technical Memorandum. NMFS-AFSC-(147). 39 p.

Onley, D.; Bartle, S. 1999: Identification of seabirds of the southern ocean: a guide for scientific observers aboard fishing vessels. Te Papa Press, Wellington, New Zealand. 81 p.

# Appendix 1

## EM TECHNICAL SPECIFICATIONS

### Overview of the EM System

The EM systems operate on the ship's power to record imagery and sensor data during each fishing trip. The software can be set to automatically activate image recording based on preset indicators (e.g. hydraulic or winch threshold levels, geographic location, time of day). The EM system automatically restarts and resumes programme functions following power interruption, or if a software lockup is detected. The system components are described in the following sections.

### Control box

The heart of the electronic monitoring system is a tamper-resistant metal control box (approx. 38 × 25 × 20 cm) that houses computer circuitry and data storage devices (Fig. A1.1). The control box receives inputs from several sensors and up to four CCTV cameras. The control box is generally mounted in the vessel cabin and powered from the vessel electrical system. The user interface provides live images of camera views as well as other information such as sensor data and EM system operational status. The interface has been designed to enable vessel personnel to monitor system performance. If the system is not functioning properly, technicians can usually troubleshoot the problem based on information presented in the screen display.

Figure A1.1. EM control box and user interface installation on V1 (ceiling mounted).

EM systems use high-capacity video hard drives for storage of video imagery and sensor data. The locked drive tray is removable for ease in replacement. Depending upon the number of cameras, data recording rates, image compression, etc., data storage capacity can range from a few weeks to several months. For example, using the standard recording rate of 5 frames per second, data storage requirements are 60–100 megabytes per hour, depending on what image compression method is employed. Using a four-camera set up and 500-gigabyte hard drive, the EM system would provide continuous recording for 52–86 days.

### EM power requirements

An EM control box should be continuously powered (24 h/day) while the vessel is at sea. The EM system can use either AC or DC electrical power; however, DC is recommended. In the case of AC power, the control box is generally fitted with a universal power supply (UPS), to ensure the power supply is continuous. The recommended circuit capacity for an EM system is 400 watts if using 240-volt AC, or 20 amps with 12-volt DC. The EM system amperage requirements vary from about 6 amps (at 12-volt DC) when all cameras are active, to less than

3 amps without cameras (sensors only), and about 20 milliamps during the 'sleep cycle'. The EM system continuously monitors the DC supply voltage and can be set to initiate a sleep cycle to save power when the vessel is idle and the engine is off, and shut off completely when vessel power drops below critical levels. During the sleep cycle the EM system box will turn on for 2 minutes every 30 minutes to check status and record sensor data. The EM system will resume functions when the engine re-starts.

## CCTV cameras

Waterproof armoured dome cameras are generally used (Fig. A1.2), as they have been proven reliable in extreme environmental conditions on long-term deployments on fishing vessels. The camera is lightweight, compact and quickly attaches to the vessel's standing structure with a universal stainless steel mount and band straps. In general, three or four cameras are required to cover fish and net handling activity and areas around the vessel. In some cases it is necessary to install a brace or davit structure in order to position cameras in the desired locations.


Figure A1.2. CCTV camera installations on vessel V2. Each camera has a mounting bracket and stainless steel mounting straps.

Colour cameras with 480 TV lines of resolution and low light capability (1.0 lux @ F2.0) are generally used. A choice of lenses is available to achieve the desired field of view and image resolution. The cameras have an electronic iris that adjusts automatically to reduce the effects of glare or low light levels on image quality. The output signal is composite video (NTSC) delivered by coaxial cable to the control box and converted to a digital image (480 x 640 pixel resolution). Electrical power (12-volt DC) is carried to the camera on conductors packaged in a single sheath with the coaxial cable.

## GPS receiver

Each EM system carries an independent GPS with an integrated receiver and antenna, which is wired directly to the control box. The GPS receiver is fixed to a mount on top of the wheelhouse away from other vessel electronics (Fig. A1.3). The GPS receiver is a 12 channel parallel receiver, meaning it can track up to 12 GPS satellites at once while using four satellites that have the best spatial geometry to calculate the highest quality positional fix. The factory stated error for this GPS is less than 15 m (Root Mean Square). This means that if the receiver is placed on a point with precisely known coordinates (a geodetic survey monument, for example), 95% of its positional fixes will fall inside a circle of 15

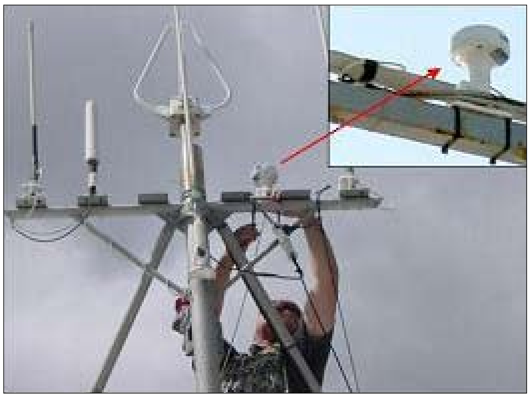

Figure A1.3. GPS receiver installed in the rigging of a vessel and a close-up photograph of the mounted GPS.

m radius centred on that point. The GPS time code delivered with the positional data is accurate to within 2 seconds of the Universal Time Code (UTC = GMT). The EM control box software uses the GPS time to chronologically stamp data records and to update and correct the real time clock on the data-logging computer.

When 12 volt DC is applied, the GPS delivers a digital data stream to the control box that provides an accurate time base as well as vessel position, speed, heading and positional error. Speed is recorded in nautical miles per hour (knots) to one decimal place and heading to the nearest degree.

## Hydraulic pressure transducer

An electronic pressure transducer is generally mounted into the vessel's hydraulic system (Fig. A1.4) to monitor the use of fishing gear (winches, line haulers, etc.). The sensor has a 0–2500 psi range, high enough for most small vessel systems, and a 15000 psi burst rating. The sensor is fitted into a ¼-inch pipe thread gauge port or tee fitting on the pressure side of the hauler circuit. An increase in system pressure signals the start of fishing operations such as longline retrieval. When pressure readings exceed a threshold that is established during system tests at dockside, the control box software turns the digital video recorder on to initiate video data collection.

## Drum rotation sensor

A photoelectric drum rotation sensor is generally mounted on either the warp winch or net drum to detect activity, as vessels often deploy gear from these devices without hydraulics. The small waterproof sensor is aimed at a prismatic reflector mounted to the winch drum to record winch activity and act as a secondary video trigger. (Fig. A1.4).

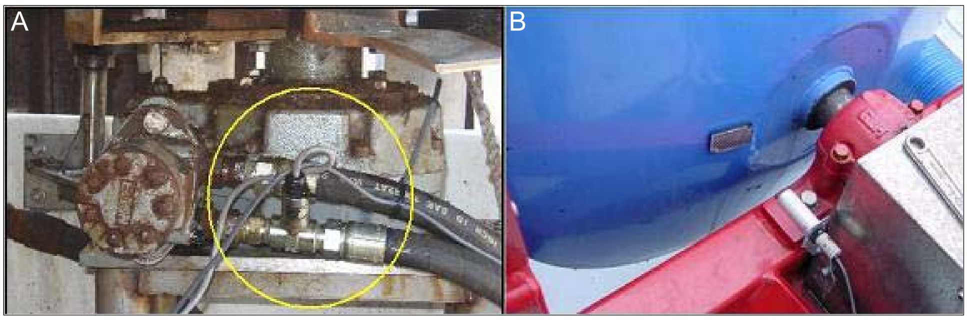


Figure A1.4. A. Hydraulic pressure sensor (within yellow circle) installed on the supply line of a vessel line hauler. B. Drum rotation sensor mounted on pelagic longline vessel, showing optical sensor and reflective surface.

# Appendix 2

## SENSOR DATA CAPTURE PER TRIP

| VESSEL ID | TRIP NO. | DEPARTURE | RETURN | TRIP LENGTH (DAYS) | SENSOR DATA MISSING (HOURS) | SENSOR DATA COMPLETENESS (%) | IMAGERY COLLECTED (HOURS) | TOWS CAPTURED | OBSERVED TOWS |
|---|---|---|---|---|---|---|---|---|---|
| V1 | 1 | 18-Mar | 23-Mar | 5.02 | 0.03 | 100 | 21.38 | 15 | 0 |
| | 2 | 24-Mar | 26-Mar | 1.86 | 0.00 | 100 | 12.96 | 8 | 0 |
| | 3 | 27-Mar | 31-Mar | 4.05 | 0.00 | 100 | 24.43 | 15 | 0 |
| | 4 | 01-Apr | 05-Apr | 3.86 | 0.00 | 100 | 18.44 | 11 | 0 |
| | 5 | 06-Apr | 08-Apr | 2.11 | 0.00 | 100 | 10.97 | 7 | 0 |
| | 6 | 09-Apr | 15-Apr | 6.02 | 0.00 | 100 | 31.43 | 15 | 0 |
| | 7 | 16-Apr | 21-Apr | 5.21 | 31.93 | 74 | 23.32 | 11 | 0 |
| | 8 | 22-Apr | 27-Apr | 4.94 | 12.07 | 90 | 20.93 | 14 | 0 |
| | 9 | 29-Apr* | 30-Apr | 1.52 | 5.41 | 85 | 7.48 | 7 | 0 |
| | 10 | 01-May | 03-May | 2.17 | 0.00 | 100 | 12.46 | 8 | 0 |
| | 11 | 04-May* | 07-May | 2.85 | 3.62 | 95 | 11.96 | 8 | 0 |
| | 12 | 26-May | 02-Jun | 6.65 | 0.00 | 100 | 35.92 | 19 | 0 |
| | 13 | 03-Jun | 22-Jun | 19.34 | 168.02 | 64 | 63.68 | 12 | 0 |
| | 14 | 12-Jun* | 13-Jun* | 0.76 | 11.91 | 48 | 1.00 | 1 | 0 |
| | 15 | 16-Jun* | 22-Jun* | 5.91 | 37.33 | 74 | 24.94 | 18 | 0 |
| | 16 | 26-Jun | 29-Jun | 3.77 | 0.00 | 100 | 29.64 | 20 | 0 |
| | 17 | 06-Jul | 08-Jul | 2.32 | 2.87 | 95 | 14.85 | 10 | 0 |
| | 18 | 09-Jul* | 15-Jul | 6.35 | 2.01 | 99 | 33.42 | 19 | 0 |
| | 19 | 16-Jul | 22-Jul* | 5.71 | 10.24 | 93 | 23.27 | 17 | 0 |
| | 20 | 24-Jul* | 03-Aug | 10.38 | 112.38 | 55 | 30.88 | 14 | 0 |
| | 21 | 05-Aug* | 08-Aug* | 3.11 | 14.61 | 80 | 11.70 | 6 | 0 |
| | 22 | 13-Aug | 15-Aug | 2.24 | 0.00 | 100 | 10.97 | 6 | 0 |
| | 23 | 16-Aug | 19-Aug | 2.78 | 0.00 | 100 | 13.96 | 7 | 0 |
| | 24 | 20-Aug* | 23-Aug* | 3.41 | 20.26 | 75 | 12.42 | 8 | 0 |
| | 25 | 25-Aug* | 31-Aug* | 6.38 | 81.98 | 46 | 15.46 | 12 | 0 |
| | 26 | 05-Sep* | 11-Sep* | 6.10 | 83.59 | 43 | 17.61 | 15 | 0 |
| | 27 | 13-Sep* | 15-Sep* | 2.31 | 13.40 | 76 | 12.96 | 8 | 0 |
| | 28 | 04-Oct* | 05-Oct* | 1.13 | 7.73 | 71 | 7.48 | 4 | 0 |
| | 29 | 08-Oct* | 13-Oct* | 5.20 | 9.74 | 92 | 33.91 | 19 | 0 |
| | 30 | 14-Oct* | 21-Oct | 6.96 | 43.32 | 74 | 28.21 | 19 | 0 |
| | 31 | 23-Oct* | 28-Oct* | 5.64 | 13.24 | 90 | 34.41 | 22 | 0 |
| | 32 | 29-Oct | 03-Nov* | 4.93 | 33.43 | 72 | 21.78 | 13 | 0 |
| | 33 | 14-Nov* | 17-Nov | 3.67 | 30.67 | 65 | 13.11 | 9 | 0 |
| **Vessel 1 totals** | | | | **154.66** | **749.79** | **80** | **687.34** | **397** | **0** |

* Departure or return estimated based on distance from port since EM system was manually powered off by vessel operator.

*Continued on the next page*

*Appendix 1 continued*

| VESSEL ID | TRIP NO. | DEPAR-TURE | RETURN | TRIP LENGTH (DAYS) | SENSOR DATA MISSING (HOURS) | SENSOR DATA COMPLETE-NESS (%) | IMAGERY COLLECTED (HOURS) | TOWS CAPTURED | OBSERVED TOWS |
|---|---|---|---|---|---|---|---|---|---|
| V2 | 1 | 03-Jun | 08-Jun | 5.24 | 32.98 | 74 | 22.09 | 13 | 0 |
| | 2 | 09-Jun | 15-Jun | 5.80 | 0.04 | 100 | 33.42 | 22 | 0 |
| | 3 | 16-Jun | 19-Jun | 3.11 | 0.00 | 100 | 15.96 | 11 | 0 |
| | 4 | 20-Jun | 23-Jun | 3.26 | 0.05 | 100 | 18.45 | 14 | 0 |
| | 5 | 24-Jun | 26-Jun | 2.26 | 0.00 | 100 | 10.44 | 15 | 0 |
| | 6 | 27-Jun | 30-Jun* | 3.43 | 1.20 | 99 | 13.43 | 20 | 0 |
| | 7 | 01-Jul* | 03-Jul | 2.26 | 0.94 | 98 | 11.95 | 14 | 0 |
| | 8 | 05-Jul | 09-Jul | 4.52 | 11.33 | 90 | 14.92 | 22 | 0 |
| | 9 | 10-Jul | 16-Jul | 6.47 | 9.08 | 94 | 0.00 | 27 | 0 |
| | 10 | 17-Jul | 20-Jul | 3.30 | 0.61 | 99 | 0.00 | 18 | 0 |
| | 11 | 21-Jul | 24-Jul | 3.33 | 0.00 | 100 | 0.00 | 19 | 0 |
| | 12 | 25-Jul | 29-Jul | 4.07 | 38.44 | 61 | 0.00 | 9 | 0 |
| | 13 | 03-Aug* | 05-Aug* | 2.40 | 24.67 | 57 | 0.00 | 11 | 0 |
| | 14 | 06-Aug* | 10-Aug | 4.24 | 37.43 | 63 | 0.00 | 21 | 0 |
| | 15 | 11-Aug | 14-Aug | 3.31 | 0.00 | 100 | 0.00 | 18 | 0 |
| | 16 | 15-Aug | 20-Aug | 5.18 | 0.00 | 100 | 43.73 | 22 | 0 |
| | 17 | 21-Aug | 26-Aug | 5.32 | 0.00 | 100 | 48.58 | 29 | 0 |
| | 18 | 27-Aug | 02-Sep | 6.01 | 0.00 | 100 | 45.92 | 26 | 0 |
| | 19 | 03-Sep | 07-Sep | 3.31 | 0.00 | 100 | 28.43 | 23 | 0 |
| | 20 | 08-Sep | 10-Sep | 1.92 | 0.00 | 100 | 9.97 | 9 | 0 |
| | 21 | 11-Sep | 15-Sep | 3.90 | 0.00 | 100 | 29.43 | 23 | 23 |
| | 22 | 16-Sep | 20-Sep | 4.17 | 0.95 | 99 | 25.44 | 16 | 16 |
| | 23 | 01-Oct | 02-Oct | 1.87 | 0.23 | 99 | 44.62 | 11 | 11 |
| | 24 | 03-Oct | 05-Oct | 2.09 | 0.04 | 100 | 50.15 | 10 | 10 |
| | 25 | 06-Oct | 09-Oct | 3.08 | 11.57 | 84 | 62.09 | 14 | 0 |
| | 26 | 10-Oct | 14-Oct | 3.97 | 29.31 | 69 | 65.94 | 18 | 0 |
| | 27 | 15-Oct | 20-Oct | 5.26 | 20.71 | 84 | 105.31 | 30 | 0 |
| | 28 | 21-Oct | 27-Oct | 5.86 | 15.39 | 89 | 42.72 | 26 | 0 |
| | 29 | 28-Oct | 03-Nov | 6.04 | 1.11 | 99 | 46.19 | 33 | 0 |
| | 30 | 06-Nov | 09-Nov | 3.14 | 14.47 | 81 | 22.86 | 14 | 0 |
| | 31 | 10-Nov | 17-Nov | 7.20 | 0.12 | 100 | 62.81 | 42 | 0 |
| | 32 | 18-Nov | 23-Nov | 5.12 | 0.04 | 100 | 49.35 | 25 | 0 |
| **Vessel 2 totals** | | | | **130.44** | **250.71** | **92** | **924.20** | **625** | **60** |
| **Overall totals** | | | | **285.10** | **1000.50** | **85** | **1715.34** | **1022** | **60** |

* Departure or return estimated based on distance from port since EM system was manually powered off by vessel operator.

# Appendix 3

## SAMPLE IMAGES OF SEABIRD ABUNDANCE CATEGORIES

Figure A3.1. Sample image from V2 during hauling of fishing gear, seabird abundance category 1 (0–10 seabirds).

Figure A3.2. Sample image from V1 during hauling of fishing gear for seabird abundance category 2 (11–15 seabirds).

Figure A3.3. Sample image from V1 during hauling of fishing gear, for seabird abundance category 3 (16–25 seabirds).

Figure A3.4. Sample image from V2 during hauling of fishing gear, for seabird abundance category 4 (26–50 seabirds).