ELECTRONIC MONITORING IN THE NEW ZEALAND INSHORE TRAWL FISHERY: A PILOT STUDY

By

Howard McElderry[1]
Martina Beck [1]
Maria Jose Pria[1]
Simon Anderson[2]

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

[2]Lat 37 Ltd.
P O Box 3058
Ohope 3161

January 2010

Electronic Monitoring In The New Zealand Inshore Trawl Fishery: A Pilot Study

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

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

ABSTRACT

Monitoring protected species (PS) interactions with the New Zealand inshore trawl fleet has traditionally been difficult. The use of fisheries observers to perform this monitoring has been limited by the small size of inshore vessels, which may not have room to accommodate extra personnel, the less predictable fishing schedules and lack of governance structure to liaise with over placements. Electronic Monitoring (EM) is a proven and reliable technology for monitoring commercial fishing fleets worldwide. In early 2008, trials were performed to evaluate the potential use of EM in capturing PS interactions within the NZ inshore trawl fishery. EM systems consisted of four closed circuit television cameras, a GPS receiver, a hydraulic pressure sensor, winch sensor, and system control box. EM systems were deployed on two inshore vessels fishing off the NE coast of New Zealand's North Island, recording a collective total of 14 months, 65 fishing trips, over 260 vessel days at sea, and 1,022 fishing events. Overall, sensor data capture success averaged 84% with considerable variability between trips due to the EM system being manually powered off during the trip. 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 observers were also aboard. Image quality was medium to high for virtually all (98%) of the image data but usability for specific monitoring objectives varied from 0% for warp interactions and 73%-97% for the remaining five objectives. The results from this study show EM to have a range of efficacy for monitoring objectives examined and observer data were superior for most objectives. EM has tremendous potential for monitoring PS catch occurrences, providing general index of seabird abundance, and routine monitoring for mitigation practices such as offal discharge and deployment of gear avoidance devices. The use of EM for detailed observations of warp strikes, or providing a detailed census of seabirds astern of the vessel would likely be ineffective. The project results demonstrated the challenges with achieving all monitoring objectives equally well and further improvements would benefit by DOC staff prioritizing the monitoring to enable configuration of an EM system that would best meet these needs. As well, industry involvement will be critical to success of EM. Minimally, support is needed to keep the system continuously powered and operating properly. Additional industry involvement in areas such as adopting standardized catch-handling operations will significantly improve the accuracy of catch documentation. The cost savings benefits for industry could be quite significant; this pilot scale project provided monitoring at about 40% the daily cost of an at sea observer. Implementation of EM based monitoring would also require establishment of New Zealand based infrastructure for improved timeliness, coordination, and data quality.

.

TABLE OF CONTENTS

INTRODUCTION

Within the New Zealand Department of Conservation (DOC), the Marine Conservation Services (MCS) section works to examine the interactions between protected species and commercial fisheries. A key component of this work is to develop effective solutions to mitigate the adverse effects of commercial fishing on protected species (Conservation Services Programme, 2005).

Worldwide, trawl fisheries are coming under increased pressure to minimize the impact of their activities on ecosystems, including non-target species and the habitats target catch occur in. Protected species (PS) interactions with these vessels generally occur either 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 population viability and for assessing the ability of fisheries to meet sustainability requirements. At-sea observers are currently the primary method for monitoring protected species interactions in these fisheries. Data on PS interactions in inshore fisheries is limited by the small size of inshore vessels which may not have room to accommodate extra personnel, the less predictable fishing schedules and lack of governance structure to liaise with over placements; therefore alternative monitoring techniques need to be examined. For example, 250 days of observer coverage were planned during the 2007/08-observer year but only 81 days (32%) were achieved across 10 vessels (Conservation Services Annual Plan 2009/2010[1]).

Over the past decade, Archipelago Marine Research Ltd. has pioneered the development of EM technology and a number of pilot studies have been carried out to test the efficacy of this technology. Table 1 provides a listing of over 25 studies spanning diverse geographies, fisheries, fishing vessels and gear types, and fishery monitoring issues. The capabilities of EM have been reviewed in McElderry (2008).

[1] Available online at the following website:http://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. McElderry (2008).

Year	Project Location	Target Species	Gear	Monitoring Issue	Project Type*	Project Size**
2005	SA, Australia	Shark	Gillnet	Catch Monitoring	PS	1 / 16
2005	Antarctic, Australia	Toothfish	Longline	Catch Monitoring	PS	1 / 48
2005	TA, Australia	Redbait	Midwater Trawl	Protected Species	PS	1 / 42
2002	BC, Canada	Salmon	Seine	Catch Handling Discard Monitoring	PS	1 / 19
2003	BC, Canada	Halibut	Longline	Catch Monitoring	PS	19 / 459
2003	BC, Canada	Salmon	Troll	Catch	PS	4 / 60
2003	BC, Canada	Prawn	Trap	Catch/Gear	PS	1 / 60
1999-2008	BC, Canada	Crab	Trap	Gear	FI	50 / 4,000
2005-2008	BC, Canada	Groundfish	Longline	Catch	FI	230 / 12,000
2007-2008	BC, Canada	Inshore Groundfish	Trawl	Catch Monitoring	FI	9 / 840
2006-2008	BC, Canada	Hake	Trawl	Discard Monitoring	FI	34 / 2,100
2007	New Zealand	Groundfish/Pelagics	Longline	Protected Species	PS	4 / 100
2007	New Zealand	Groundfish	Gillnet	Protected Species	PS	5 / 82
2003	New Zealand	Hoki	Midwater Trawl	Protected Species	PS	1 / 31
2002	AK, USA	Halibut	Longline	Catch Monitoring	PS	2 / 120
2003	AK, USA	Groundfish	Trawl	Protected Species	PS	5 / 22
2005	AK, USA	Rockfish	Trawl	Discard Monitoring	PS	10 / 38
2006	AK, USA	Groundfish	Factory Trawl	Bin Monitoring	PS	1 / 14
2007	AK, USA	Rockfish	Trawl	Discard Monitoring	PS	1 / 14
2006	CA, USA	Swordfish	Drift Gillnet	Protected Species	PS	5 / 58
2007	CA, USA	Swordfish	Drift Gillnet	Protected Species	PS	1 / 3
2004	New England, USA	Cod/Haddock	Longline	Discard Monitoring	PS	4 / 10
2007	New England, USA	Groundfish	Longline/Gillnet	Catch Monitoring	PS	7 / 59
2007	New England, USA	Herring	Small Mesh Trawl	Catch Monitoring	PS	1 / 10
2002	West Coast, USA	Hake	Midwater Trawl	Discard Monitoring	PS	1 / 13
2004	West Coast, USA	Hake	Midwater Trawl	Discard Monitoring	FI	26 / 823
2005	West Coast, USA	Hake	Midwater Trawl	Discard Monitoring	FI	28 / 982
2006	West Coast, USA	Hake	Midwater Trawl	Discard Monitoring	FI	37/ 1,043
2007	West Coast, USA	Hake	Midwater Trawl	Discard Monitoring	FI	36 / 878

* Project Type: PS, Pilot Study; FI, Fully Implemented EM Program
** Project Size: # Vessels Monitored / # Seadays (per project or per annum)

In March 2008, Lat 37 and Archipelago began a pilot study, funded by DOC, using EM on two inshore trawl vessels to assess PS interactions in this fishery. The field study was extended from six to eight months. Given the positive outcome of the field study, DOC provided additional funding to provide a detailed analysis of the EM data collected. The analysis was initially based on a sample of the total collected data, and then later expanded to include the full EM data set. 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 the pilot project

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.

4. For a representative sample of fishing events, determine the feasibility of using the EM data to determine and, where feasible, record the:
    a) Protected species retrieved from the fishing gear (assessed during haul and fish catch processing and referred to as “PS in the Fishing Gear” for the remainder of this report); and
    b) Rate of occurrence and number of protected species around the stern of the vessel (assessed during fishing catch processing, and a subset of other times during fishing, and referred to as “Seabird Abundance” for the remainder of this report); and
    c) Number of seabird interactions with warp(s) (assessed during fishing and referred to as “Warp Interactions” for the remainder of this report); and
    d) Lowest level of identification possible for protected species recorded in specific objectives 4.a, 4.b and 4.c (family, morphological group or species and referred to as “PS Identification Ability” for the remainder of this report); and
    e) Deployment of 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 4a-f where EM is feasible, develop a standard methodology that can be used on future EM data sets from inshore trawl fisheries. This will include a standard methodology for EM data analysis of variables that relate to the usefulness of the data set (e.g. data quality, fishing gear and catch handling, crew behaviour, and other relevant information).

6. For EM-monitored fishing events where a government observer was 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.

METHODS

EM SYSTEM SPECIFICATIONS

The two vessels that participated in this study are referred to as V1 and V2 in order to protect their identity. 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 (Figure 1). 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 I.

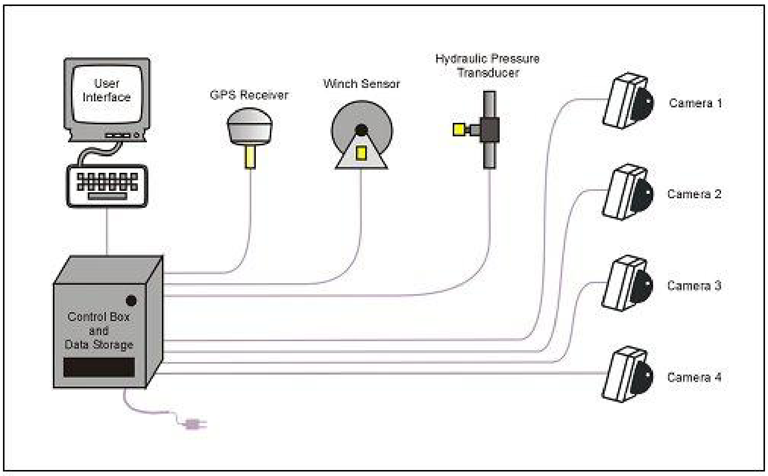

Figure 1. Schematic diagram of the electronic monitoring system.

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 transducer respectively. During installations, EM control boxes, monitors, and keyboards were mounted in the wheelhouse of each of the vessels. 240v AC power supply was used to power the EM system on both vessels and hydraulic lines were accessed from the engine room. The hydraulic pressure transducers were installed to provide an indication of when the hydraulic equipment (trawl and anchor winches, etc.) was operating. The hydraulic pressure transducers were to be installed on the high-pressure side for both vessels. The EM system's GPS receivers were mounted to the mast on top of the 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.

EM Data Capture Specifications

EM sensor data were recorded continuously while the EM system was powered, and was intended to be recording for the entire duration of the fishing trip. Sensor data were recorded every 10 seconds with 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 four CCTV cameras at selectable frame rates (i.e., images per second), ranging from 1 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 system capacity of between 3-13 GB of storage required per day or 1.5-4 GB per tow. The data storage requirements are highly variable depending on how much activity is occurring within the images, 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.

Field Programme Operations

Project planning began in early March 2008 with a meeting at Sanford Limited in Auckland attended by representatives of DOC MCS, Sanford Limited, Archipelago Marine Research Ltd., and Lat 37 Limited. Discussion centered on identifying which inshore trawl vessels the EM systems were to be deployed, 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.

Figure 2. The two inshore trawl vessels that participated in the study shown alongside in Auckland (vessel identifiers have been removed).

Two inshore trawl vessels of similar tonnage were selected by vessel managers at Sanford to participate on this study. The field component began in March 2008 with the first EM system installed on V1 and the second system installed on V2 in early May 2008 and continued through to November 2008 when the systems were removed. Lat 37 staff installed the EM systems on both vessels and serviced the EM equipment roughly every four to six weeks 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 often during initial

installation it was difficult to assess how well camera placements would capture fishing activities. 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 as part of phase II of the project.

This study involved the use of at-sea observers for comparison with data collected by an EM system. New Zealand government 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.

Figure 3. Sample images from V1; the top left camera view gives an overall view of the complete deck area, the top right was used for assessing seabird abundance and for the detection of mitigation devices. The views from the bottom left and right cameras were reviewed for quantifying and identifying PS bycatch and discharge patterns.

Figure 4. Sample images from V2; the top right shows the camera view used for assessing seabird abundance and mitigation device deployment; the top left camera view was reviewed for analysis of discharge patterns & PS bycatch. The bottom left camera was used to detect PS bycatch when the codend was hauled over the stern, and the camera view on the bottom right was initially setup to view warp strikes but was eventually used to detect deployment of the Warp Scarer that was clipped to the main warp.

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 data set by checking for time breaks in the data record, as indicated by the duration between records exceeding the expected 10-second time interval.

Sensor data were then analysed to interpret the geographic position of fishing operations and distinguish 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 Figure 5. Vessel speed and hydraulic pressure often correlate uniquely for various activities such as transit, net shooting, and net hauling. Net shooting and hauling events were characterized by high hydraulic pressure, relatively low speed, and, high winch counts (V1 only). Towing was characterized by speeds of between 2.5 to 3.5 knots and was easily identified between two gear events (i.e. net shooting and hauling).

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. 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 data database was then sent back to Lat 37 between service intervals where it was further analyzed along with the captured video (for that service period) and used for the monthly reporting requirements to DOC.

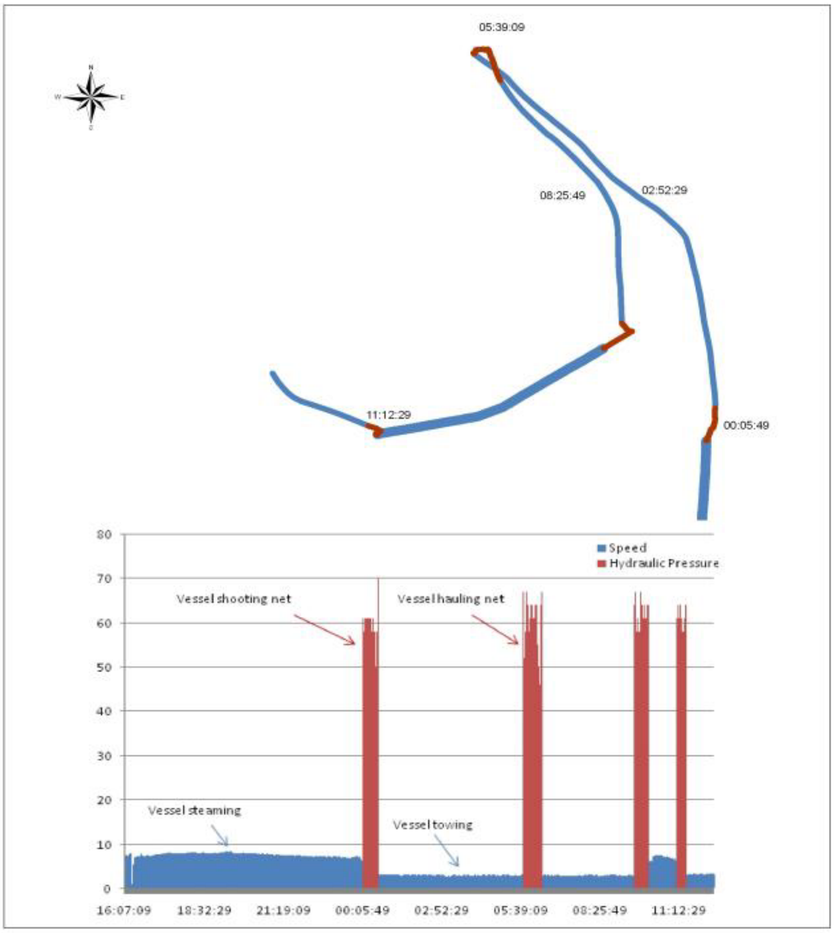

Figure 5. Example of sensor data from one of the study vessels. The time series graphs (lower) show vessel speed (knots) and hydraulic pressure (psi). Net shooting and retrieval was associated with high hydraulic pressure and relatively low speed. The spatial plot (upper) shows the vessel's cruise track for the second and third tows, with net shooting (Doors Out) and hauling (Doors In) highlighted in red.

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 in a 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 Figure 6 and described below:

- High. The image data is very clear, the viewer has a good view of catch processing, mitigation device deployment and seabird activity was 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 was not greatly hampered.

- Low. The image data is difficult to assess. Some camera views may not be available. Image data is 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 EM to assess for the monitoring objectives 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 for optimal application to future EM data sets from the inshore trawl fishery and to achieve optimal comparison results for this report and for other management use.

Figure 6. Example imagery to illustrate image quality. On the left from top to bottom: high, medium and unusable imagery for assessing discarded bycatch. On the right from top to bottom: high, medium, and unusable imagery for estimating seabird abundances.

RESULTS

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 II). EM systems logged data across nine months on V1 and seven months on V2 for a total of 65 fishing trips and 1,022 tows. Both vessels participating in this study generally carried an 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% versus 78% respectively). On an individual trip basis, sensor data capture success varied from 43% to 100% (see Appendix II). EM system error logs indicate that the most likely reason for the incomplete data record was due to vessel operators manually turning off the EM system when not fishing. Gaps in the sensor data record occurred at the start, end and during the fishing trip causing some tows to only be captured partially (i.e. either the shooting or hauling was missed) and it is likely that some tows were missed completely. Detecting tows for partial data was more complicated as sensor data patterns were not as obvious. Trip durations for 18 trips for V1 and 4 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 1,700 hours. An observer was present on board V2 during four trips for a total of 60 tows between the months of September and October.

Table 2. Inventory 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'. * - denotes durations estimated as the EM system was off for the start or end of the trip.

Vessel ID	Service Period	Trips	Sensor Data Expected (Days)	Sensor Data Captured (Days)	Sensor Data Completeness (%)	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	
	Apr-30 to May-20	2	5.02*	4.87	97%	24.43	16	15	
	May-20 to Jun-24	4	32.66*	23.61	72%	125.54	50	46	
	Jun-24 to Aug-08	6	31.64*	25.72	81%	143.76	86	77	
	Aug-08 to Sep-12	5	20.91*	13.16	63%	70.42	48	44	
	Sep-12 to Sep-25	1	2.31*	1.76	76%	12.96	8	8	
	Sep-25 to Oct-22	3	13.29*	10.75	81%	69.60	42	41	
	Oct-22 to Nov-26	3	14.23*	11.01	77%	69.30	44	41	
Vessel Totals		**33**	**154.65**	**123.40**	**78%**	**687.34**	**397**	**371**	**0**
V2	May-20 to Jun-24	4	17.41	18.29	93%	100.36	60	57	
	Jun-24 to Aug-13	11	39.58*	32.17	86%	40.30	194	68	
	Aug-13 to Sep-02	3	16.51	16.51	100%	138.24	77	77	
	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	
Vessel Totals		**32**	**130.44**	**120**	**92%**	**924**	**625**	**491**	**60**
Overall Totals		**65**	**285.09**	**243.40**	**84%**	**1611.56**	**1022**	**862**	**60**

A summary of sensor performance is shown in Table 3, and the results indicate that the GPS performed without problems for the duration of the project. The net rotation sensors worked very well but they were susceptible to damage. Both participating 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 recorded 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 initially installed on the 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 no usable hydraulic pressure data for all 32 V2 trips completed. The ability to detect fishing events and record imagery was still possible from GPS and winch rotation sensor data.

Table 3. Summary of sensor performance for all trips throughout the pilot study for both participating vessels

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**	

IMAGE DATA SUMMARY

Table 4 provides an inventory of all the EM image data captured during the pilot project and a summary of the tows selected for EM review. All 60 tows with 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 was 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

	Total Tows	Complete Tows	Tows Viewed
Observed	60	60	60
Unobserved	962	802	802
Total	**1022**	**862**	**862**

IMAGE DATA QUALITY AND USABILITY

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 may be due to a number of different reasons such as the sunshield obstructing the view, poor image resolution, bad sun glare or moisture in the lens. Different camera views were used to assess for each of the project objectives (see Figures 3 and 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 deemed usable or unusable for project objectives 4a-f for both participating vessels. Four of the six objectives being assessed during EM analysis had approximately 80% or more usable tows (i.e. 60% of total tows). Seabird identification had 73% usable tows, and seabird warp interactions could not be assessed during EM review as the observer sampling periods could not be aligned with EM data and appropriate camera views were not available for the duration of the trip. The EM viewer was able to assess for seabird abundance and identification for all daylight tows (81%) but night-time tows were deemed unusable (19%). EM analysis was able to assess for mitigation device deployment for 97% of the tows and 3% were deemed unusable due to poor image resolution. EM assessment 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% were considered unusable.

Table 5. Summary of the usable and unusable tows for EM analysis, where (+) and (-) represent usable and unusable tows.

	PS in Fishing Gear		Seabird Abundance		Seabird Warp Interactions		Seabird Identification		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**

Table 6 provides a summary of image quality for all tows reviewed during EM analysis. The results show that image quality for both the 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 quality for 29%, and low for 3%. Image quality for V2 during EM review was very similar to V1. The majority of the medium quality tows typically occurred in low lighting conditions during night tows or during daylight tows when bad sun glare was encountered (see Figure 6 for example images). Lower quality image data typically resulted from poor image resolution or obstruction of the field of view (e.g. sunshield blocking camera view). Poor image quality affected the methods used by EM viewer for assessing seabird abundance and identification, and therefore general grouping codes were established for EM analysis.

Table 6. Summary of image quality for all tows reviewed during EM analysis.

	High	Medium	Low	Total Tows Viewed
V1	68%	29%	3%	**371**
V2	75%	23%	2%	**491**
Total %	**72%**	**26%**	**2%**	**862**

Throughout the duration of the pilot, changes were made to different camera's field 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 subsequent processing, which made camera placement difficult. V1 had a stern ramp where every haul was winched up the stern ramp, onto the aft deck, catch spilled from the codend with the catch sorted and processed in this area. In contrast V2 did not have a stern ramp with the codend usually being lifted over the starboard side. 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 come 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. Subsequently, in order to improve the capture of certain events of interest, the changes to the camera configurations diminished the ability to monitor for other objectives. The rotation of camera views in effort to capture all events made subsequent analysis of the image data for this project difficult for the EM viewer.

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

Monitoring Objectives

The time periods 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 the 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 for the monitoring objectives are compared and discussed below. The following terminology defines the standard time periods during which the observer and EM viewer 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 before the net hits the stern ramp (or is lifted from the water)

Catch processing: Time of 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.

PS in Fishing Gear

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.

EM Methods
The EM viewer 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. Low lighting 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*) recorded as dead and having been discarded. EM detected this event (Figure 8 left) and was able to identify the dolphin to the species level. However, image data did not show the dolphin being discarded as it was taken out of camera view. When the dolphin was brought on board the vessel it appeared motionless and lifeless and was considered dead by the EM viewer.

EM data for the non-observed tows were also reviewed for any incidents of protected species caught in the fishing gear. The results indicate that EM analysis detected the presence of an Australasian gannet (*Morus serrator*) entangled in the belly of the net while the net was being hauled on board V2 (see Figure 8 right). The seabird was identified to the 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.

Figure 8. Example images of the protected species interactions recorded during EM analysis. One interaction was seen in the observed data set when a bottlenose dolphin was brought up in the net codend (image on the left). The image on the right shows a Gannet caught in the net that was detected during EM analysis of the non-observed data set.

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 activity but this was occurring out of the camera field of view. The seabird captures were not initially detected in the EM imagery, or in a subsequent analysis of imagery specifically looking for the seabirds in the catch. In this instance it was determined that the seabirds were too small to be discernable in the catch.

SEABIRD ABUNDANCE

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. Actual counts were given when possible; however under certain circumstances estimates were assessed in relative orders of magnitude (i.e., 10's, 100's or 1000's). Observers also specified whether the protected species were counted within or beyond the ~100m radius of the set/haul location out the stern of the vessel.

EM Methods

During EM review appropriate camera angles (see Figures 3 and 4) were used to assess for protected species abundances around the stern of the vessel. All observed daylight tows were reviewed during EM analysis and abundance estimates were taken during shooting and hauling activity. Seabirds were the main protected species regularly detected during the EM review process, although dolphins were also seen. Imagery was typically viewed around 1-2 times speed to assess for seabird abundances. The EM viewer's estimates were always less than 100m from the vessel, more likely within 25 metres of the vessel. This range limitation likely explains some of the differences seen when comparing with observer data. An overall estimate was recorded of the number of seabirds seen within the field of view for the duration of the hauling and shooting sample period. Separate abundance estimates were made during shooting and hauling periods and a total abundance estimate for the defined time period was made. 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 shows EM and observer data comparisons for abundance estimates of seabirds around the stern of the vessel. Example images showing a range of seabird abundance are shown in Appendix III. Seabird abundance comparisons indicate that EM and observer estimates fell within the same category for 23 of the 46 observed tows. The EM viewer underestimated seabird abundances for 17 tows, and overestimated it for 6 tows. Observer estimates were sometimes made at a distance greater than 100m from the vessel for a total of 29 tows, and 12 of those tows were underestimated by EM analysis. The differences in the methods used by the observer and EM viewer for estimating seabird abundances may have led to some of the variability shown.

Table 7. EM to observer data comparison of seabird abundance estimates which are grouped according to the abundance categories used during EM analysis. Estimates were made during hauling or shooting to match the observer data.

EM Abundance categories	**Observer Abundances**					
	0	**1-10**	**10-15**	**15-25**	**25-50**	**>50**
0	**8**	9	0	0	0	0
1-10	1	**12**	3	1	0	0
10-15	0	4	**2**	2	1	0
15-25	0	0	1	**1**	1	0
25-50	0	0	0	0	**0**	0
>50	0	0	0	0	0	**0**

Seabird abundance estimates across all tows reviewed by the EM imagery viewer are summarized in Table 8 and the results indicate that seabird abundances were generally higher during hauling of the fishing gear. 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 while V2 was 17%.

Table 8. Summary of EM data across all tows for both vessels of seabird abundance estimates (unless otherwise indicated) grouped according to abundance categories used during EM analysis. Estimates were made during both shooting (S) and hauling (H) of fishing gear.

EM Abundance Categories	**V1**		**V2**	
	s	h	s	h
0	29	16	139	81
1-10	75	55	96	98
10-15	38	32	51	68
15-25	35	50	50	62
25-50	15	33	28	43
>50	13	20	11	21
Total	**205**	**206**	**375**	**373**

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

WARP INTERACTIONS

Observer Method

Observers counted seabird strikes on the warp and mitigation device (if deployed) during daylight tows for periods of 15minutes. The sampling periods started on the hour (or half hour) and multiple pairs of 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 with the trawl warp or mitigation device. Heavy contacts were defined as when the bird’s path of movement is deviated when it comes into contact with the trawl warp or when the part of the wings or head touches the warp. Small birds included all petrels, shearwaters, prions, storm petrels, gulls and shags, while large birds included all albatrosses and giant petrels.

EM Method

If warps were deployed image data would be reviewed for any seabird strikes with the device. The EM image data captured for the time period from when the trawl doors go below the surface during shooting to when the doors reach the surface during hauling of daylight tows would be reviewed. Following the same definitions used by the observer for heavy contacts and small or large seabirds, the EM viewer would record counts of any interactions of seabirds with the mitigation device.

The time periods during which the observer was recording for seabird warp strikes could not be properly matched with EM because image data was only recorded up to the 30 minute run on time during shooting and hauling. Throughout the duration of the project appropriate camera views for detecting seabird warp strikes were only available for a limited number of trips. Therefore due to 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.

Figure 9. Shows the camera view from V2 that was set-up for assessing seabird interactions with the warp.

PS IDENTIFICATION

OBSERVER METHODS

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

EM METHODS

The EM viewer 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.

During EM analysis for seabird abundances, the EM viewer identified the seabirds to a general grouping level based on size. The ability of the EM viewer to detect and identify seabirds was a function of both the distance from the vessel and field of camera view. Generally, seabirds could not be identified other than to general category, based on size. It should be noted that the EM viewer 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. Example images of seabirds around the stern of V1 during hauling operations.

During review of the non-observed tows EM was able to detect dolphins around the stern of the vessel, and rough abundance estimates were made (see Figure 11). The EM viewer was able to identify marine mammals to a general species level such as dolphins *(Delphinus spp.)* Additional full resolution images are shown in Appendix III.

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

Seabirds were the only protected species seen occurring around the stern of the vessel during EM review of the observed tows. Out of the 33 tows where the observer identified seagulls the EM viewer identified the presence of seagulls in 22 of them (Table 9). The EM viewer could only detect the presence of petrels, prions and shearwaters on half of the tows compared to the observer detection, and gannets only on 2 out of 12. The observer data only contained the presence of albatross on one tow, which was not detected during EM analysis.

Table 9. Summary of the positive and negative matches for tows in which both the EM viewer and observer identified seabirds under the same general species groupings, for the V2 observer data set.

Seabird species groupings	Totals		Matches
	EM	Obs	
Seagulls (general)	23	33	22
Petrels, prions, shearwaters	15	24	11
Gannets	2	12	2
Albatross (general)	0	1	0

Table 10 provides a summary of the seabird species occurrences across all tows, 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. There where 139 instances with V2 where this seabird category was observed both during hauling and setting. Occurrences of Gannets and Albatross were quite low compared to the other two species groupings for both vessels.

Table 10. Summary of EM data for the occurrence of seabird species around the stern of the vessel (grouped into general categories) during shooting (S), hauling (H) or both (B) across all tows reviewed for both participating vessels.

	Seabird Species Groupings	Usable Tows	Seabirds Present			
			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**
	Albatross (general)	275	5	3	2	**10**
	Uknown	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**
	Albatross (general)	423	1	4	1	**6**
	Uknown	423	6	14	1	**21**

MITIGATION DEVICE DEPLOYMENT

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 events were also recorded, which included events such as when the Tori Line extended less than about 10m beyond the warp. Up to four codes for the various mitigation events observed could be entered for each tow.

EM Methods

All the fishing activity captured by EM was reviewed by the EM viewer to assess for the deployment of mitigation devices off both sides of the vessel. The EM viewer used the corresponding observer codes to record the type of mitigation equipment. The EM viewer 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 was reviewed at four times speed to determine if the mitigation device was deployed.

EM and observer data comparisons for mitigation device deployment are shown in Table 11. EM was able to detect the deployment of mitigation devices for 51 out of the 55 observed tows, indicating that 93% of the usable tows matched between EM and observer for the detection of mitigation device deployment. EM deemed four night time tows and one daytime tow as unusable for imagery analysis. The EM viewer could not confirm mitigation device deployment based on the image quality. Night hauls became more difficult to interpret during EM analysis, as the mitigation equipment was harder to detect. Four usable tows did not match up between EM and the observer, three of which the observer recorded Tori Lines, while EM recorded no mitigation devices.

Table 11. EM to observer comparison of how well data matched for detection of mitigation devices across both usable and unusable EM image data for V2 observer data-set.

Mitigation Device	EM Total		Obs Total	Matches
	Usable	Unusable		
Warp scarer	23	0	**23**	23
Tori line	26	3	**32**	26
Not Detected	6	2	**5**	5
Total	**55**	**5**	**60**	**54**

Table 12 provides a summary of the EM data for the detection of mitigation devices across all the tows reviewed for both participating vessels. The results show that for V1 warp scarers were detected for 229 tows but no Tori Lines were detected being deployed during EM analysis. 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 viewer detected no mitigation devices being deployed. Image data recording was set 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 12. Summary of EM data for detection of mitigation devices across all tows reviewed for both participating vessels.

Mitigation Device	V1	V2
Warp scarer	229	179
Tori line	0	271
Not Detected	134	21
Unusable	8	20
Total	**371**	**491**

ASSESSMENT OF DISCHARGE PATTERNS

Observer Method

The observer recorded the presence of any fish discharge (including fish parts/offal and whole fish), and whether it occurred 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 large amounts of offal. Only minimal amounts were recorded so this component of the objective is not quantified in detail any 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 the location of the discard off the vessel followed by the method used to estimate the green weight.

EM Method

EM analysis did not record any offal being discharged during catch processing of the observed tows. The EM viewer identified any discards to the lowest taxonomical grouping possible. When identification of discards could not be made to the species level general grouping codes or an unknown fish category were used. Quantification of the discards was broken down by into general species groupings during EM analysis, however when identification was not possible then a single

weight estimate was made for the unknown fish category. The EM viewer made rough visual weight estimates based on the available camera views and crew behaviour of catch processing. Discards data were entered using the same methods as the observer described above. Estimates of discards for V2 only accounted for discarding off the starboard side of the vessel, as this was the only camera view available.

Table 13 provides a summary of observer and EM data for estimated weights of discards by general species groupings. The results show that the EM viewer categorized 1,015 kg of the discards as unknown fish while the observer speciated all catch. The observer recorded 727 kg of rays and skates while the EM viewer recorded 465 kg. The EM and observer data comparisons also show a 16% difference for the total estimated weight for all discards.

Table 13. Summary of observer and EM data for estimated weights of discards displayed by general species categories and total estimated weight for V2 observer data-set.

Species Name	Observer weight (kg)	EM weight (kg)	Percent Difference
Finfish	1471	420	
Sharks	66	20	
Rays and Skates	727	465	
Invertebrates	13	0	
Unidentified Fish	0	1015	
Total Weight	**2277**	**1920**	**16%**

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

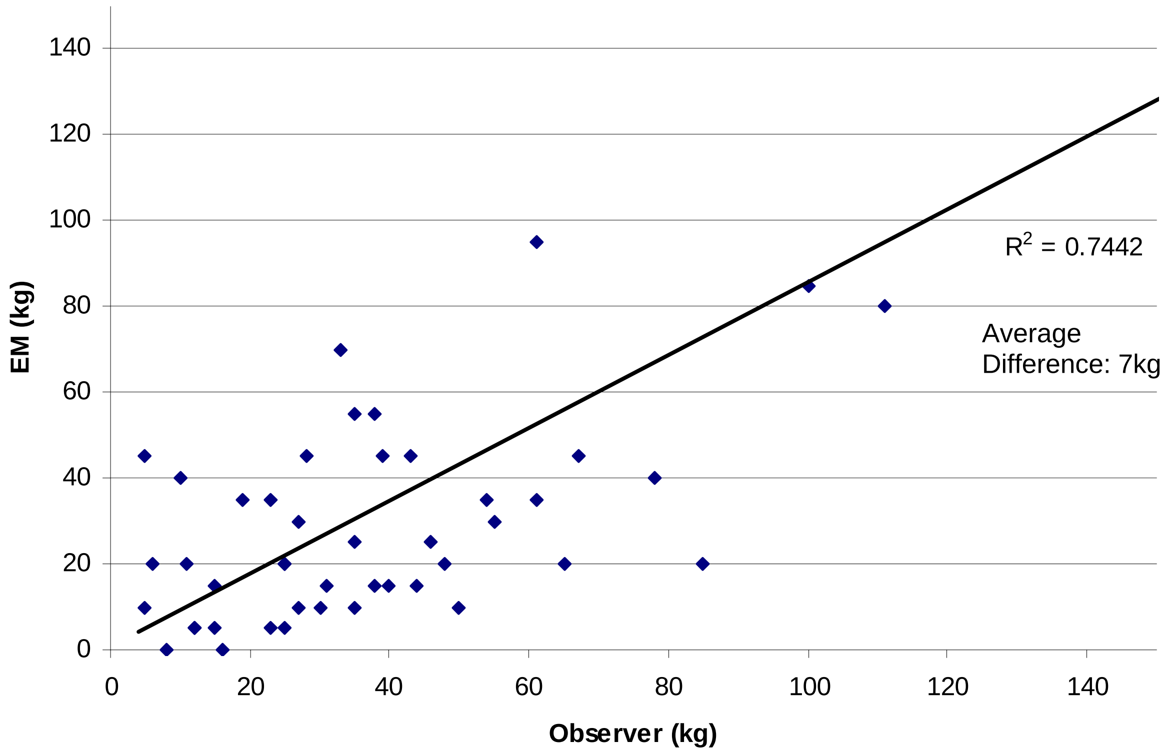

Figure 12. Comparison of EM and observer weight estimates per tow for total discards.

Estimated weights for discards were grouped into general species categories and are summarized in Table 14 for all tows reviewed. V1 had much higher weight estimates for discarded sharks than V2 ((1290kg versus 117kg). Approximately 70% of the estimated weight of discards was categorized as unidentified catch for both vessels combined. Invertebrates were not recorded for either vessel, as they could not be easily distinguished.

Table 14. Summary of EM data for estimated weights of discards grouped by general species categories and for total estimated weight across all tows reviewed for each of two participating vessels.

General Species Groupings	EM Weights (kg)	
	V1	V2
Finfish	570	961
Sharks	1,290	117
Rays and Skates	4,207	1,707
Invertebrates	-	-
Unidentified Fish	9,688	10,032
Total Weight	**15,755**	**12,817**

DISCUSSION

TECHNICAL ASSESSMENT OF EM SYSTEM

EM equipment was deployed on the two inshore trawl vessels for a collective total of 14 months, 65 fishing trips, over 260 vessel days at sea, and a total of 1,022 fishing events. Overall sensor data capture success averaged 84% with considerable variability between trips. The data loss was almost entirely due to the EM system being manually powered off for various intervals either at the start, during and at the end of the trip. Vessel masters likely adopted a habit of powering off the system when there was no fishing activity, such as during transit or anchoring at night. When the main or auxiliary engine was not running, electrical power is supplied from batteries and the demand can be high if powering the EM system and other devices such as deck lighting. This intervention led to instances where the EM system was not operating when fishing operations were taking place. The incomplete data resulted in problems of reliably interpreting activity when only part of the 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 to confirm full fishing trip documentation. It is therefore recommended that in the future, more rigid guidelines be used to ensure vessel operators to keep EM systems continually powered while the vessel is at sea. Due to the temporary nature of the EM installation for this pilot study, power was provided to the system from a normal household AC three point plug located in the wheelhouse. We would further recommend that for a permanent installation, the EM system box be hardwired to the vessel's switchboard with its own dedicated circuit breaker.

Sensor performance was generally high throughout the study, particularly with GPS. 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 10 fishing trips. The combined use of either hydraulic or winch sensors for triggering image recording resulted in higher levels of image recording than use of a single sensor. The strategy of using two sensors should be maintained for the added benefit of fault tolerance.

Image recording was set for a 30 minute run-on following completion of triggering event, essentially ending 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, use of mitigation device usage and PS interactions with trawl warp were limited to the recording intervals, as opposed to the complete interval when 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, possibly increasing the servicing intervals for refreshing data storage media.

Another issue concerning the technical suitability of EM technology for this fishery revolves around the quality of imagery and its utility for the various monitoring objectives. Image quality was medium to high for virtually all (98%) of the image data but usability for specific monitoring objectives varied from 0% for warp interactions and 73%-97% for the remaining five objectives. While the utility for each of the monitoring objectives is examined in detail below, some general comments are applicable to all. The main issues affecting image quality were available 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, additional lighting is more problematic.

The camera placements for the two vessels were opportunistic, mounting on the most suitable standing structures. Two cameras were placed amid ships, 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 optimize across all monitoring objectives. The operations of the vessels differed with one loading catch amidships and the other using the stern ramp. As well, circumstances varied between fishing events in terms of how catch was handled such that some activities occurred outside the field of camera view. For example, in some cases catch would be discarded off the port side while normally this operation occurs off the starboard side. This was the case for the dolphin catch recorded by the vessel but missed in the EM imagery. This study demonstrated the difficulty of achieving all monitoring issues equally well and improvements to the usability of imagery would be a process of prioritizing the specific monitoring issues and determining camera placements that best meet these needs. As well, working with the crew to develop more standardized catch-handling operations will improve the ability to accurately document events from image data.

The results from this study would improve considerably by closing communication gaps and improving coordination between the various project participants including fishing vessel operators, company management, EM service technicians and EM data analysts. The organizational structure used in this project was a function of the small scale and it was not practical to establish infrastructure to better support the needs of the program. EM data processing took place mostly in Canada using skilled analysts although their knowledge of New Zealand fauna was limited. EM service technicians were remote from the vessel ports of operation and service intervals were monthly in order to minimise travel costs. Service scheduling was coordinated through company management at Sanford. Implementation of solutions to problems identified during analysis was slow because of the time required for analysis and the duration between service intervals. Access to the vessels was occasionally hampered because of short notice vessel schedule changes and inability to access skilled trades (e.g., hydraulic engineer). Some issues took longer to correct because of the narrow time windows where vessels were in port. These issues resulted in some lost data and delays in making EM system configuration changes to improve data quality. These issues are largely related to scale. The project operated on a small scale with a limited budget where it was not practical to put in place the skilled personnel and infrastructure. 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 on remotely monitoring EM system performance real time via 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, improve data quality, decrease service costs and provide a more powerful VMS capability. Further enhancements to the EM application software may allow two way communications to enable the service technician to reconfigure the vessel system remotely.

The level of industry cooperation and support strongly affects the success of an EM-based monitoring programme. For 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 throughout the project. Therefore, industry support is critical in order to help improve the success of the technology.

Assessment of EM for the Specific Monitoring Objectives

PS In Fishing Gear

The results from this study show promise for the use of EM imagery to detect protected species occurrences in fishing gear. Most (94%) of the fishing event imagery examined was usable for this purpose and improvements to lighting for night operations would be beneficial. Improving camera angles to show the fishing gear within the field of view at all times would also help. Image quality was generally sufficient to resolve catch although it may be difficult to distinguish specific items when presented as a pile of catch. Large distinctive animals would stand out clearly and it was not surprising that both EM viewers and observers detected the marine mammal. Similarly, EM viewers easily distinguished a large, actively moving seabird. 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 if a small, water-soaked dead seabird would be detected in the catch unless crew used a more systematic catch sorting method. Refinements to the catch sorting method are described under the Assessment of Discharge Patterns Section.

PS Abundance

Imagery from the majority (81%) of fishing events examined was deemed usable for determining PS 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 five meters from the stern of the vessel. As compared with observers, the resolution for assessment of seabird abundances is lower, both in terms of absolute numbers as well as identification by 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 the camera view. The cameras are also better able to resolve seabirds contrasted against the sky or directly astern of the vessel. Larger seabirds are more easily detected than smaller seabirds, and both are more difficult to resolve on the surface when sea conditions are rough. It is doubtful that EM would reliably resolve seabirds further than 25-50m from the vessel. Despite these limitations EM assessments correlated reasonably well 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 will be discussed in a later section.

Trawl Warp Interactions

None of the fishing event imagery was considered suitable for assessment of seabird interactions with trawl warp. Camera images were not directed at the trawl warp and point of water entry in sufficient detail to monitor seabird strikes. As well, image recording was limited to the 30-minute run-on period, which did not correspond with the times when observers made their observations. Previous work on this topic (McElderry et al, 2004a, McElderry et al 2004b) has shown that camera placements 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 presence of seabirds in advance of the warp tow path. This approach would be easier and less time consuming to monitor with EM imagery.

PS IDENTIFICATION

The ability of EM to identify PS varies for interactions where they come aboard and those where PS is sighted in the proximity of the vessel. In terms of PS as catch there were two occurrences that 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.

Identification ability for proximity interactions of PS is more difficult. Results from this study provided numerous instances where seabirds could be seen astern of the vessel but in comparison with observer records; the correlation was relatively low, even with catch grouped by general size categories. Limited EM viewer 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) and most would not be classified beyond general taxonomic groups (i.e., albatross, seagulls, gannets, petrels, etc.). Among marine mammals, EM recorded sightings astern of the vessel, and the quality was high enough to enable species identifications. However, close proximity to the vessel, calm seas and adequate lighting created ideal detection conditions. It is quite likely that these interactions would escape detection under less favourable conditions. It is therefore unlikely that EM would be a robust tool for detection and characterization of PS proximity interactions.

MITIGATION DEVICE DEPLOYMENT

EM imagery was very successful (97%) 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 viewers and the observer was very high overall (93%) and Tori Lines showed the lowest detection success, being missed three 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 distinctive enough. While the two vessels did provide deck lighting, the resolution of the mitigation device entry point was poor or absent due to the lowlight conditions at night and the distance from the camera. Previous studies (McElderry et al. 2003) have found that image resolution degrades over the distance between the CCTV cameras and the point where mitigation device enters the water, particularly in stormy wet weather where visibility is occluded.

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

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 observers and EM, the level of agreement was within 16%. Keeping in mind that observer estimates also contain error, the agreement between the two methods is likely mostly due to visual 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 viewers made little effort to identify catch other than conspicuous species.

The results of this study misrepresent the potential of EM to quantify and identify discards. Improvements from the opportunistic deployment in this study would be required 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, there would be a need to pass non-retained catch 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 Figure 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 full deck view (right) and a close up view of the discard chute (left). (From McElderry, 2008).

CONCLUSIONS

We believe the use of EM technology shows promise for improving fishery data in the New Zealand inshore trawl fishery. The results from this study show a range of efficacy for the six monitoring objectives examined and observer data were superior with most issues. In many instances the ability of EM to address a particular monitoring objective can be improved through either technical or organizational change however, the gains would require prioritizing the monitoring issues and perhaps not including some. EM has tremendous potential for monitoring PS catch occurrences, providing general index of seabird abundance, and routine monitoring for mitigation practices such as offal discharge and deployment of gear avoidance devices. The use of EM for detailed observations of warp strikes, or providing a census of seabirds astern of the vessel would likely be less effective. The shortcomings of EM toward particular monitoring objectives should also be examined in relation to the potential gains of using this technology. While cost and operational efficiencies are the most common issues, McElderry (2008) provides further information on the relative merits and other practical issues for deploying this technology. Technology based approach will be the best option in monitoring levels if the fishery rises significantly. As an indication of cost effectiveness, the cost of this entire pilot study in relation to total monitored vessel days achieved was about 40% of the monitoring cost by observers[2].

Future use of EM technology with the New Zealand inshore trawl fishery should consider the following:

1. The Department of Conservation needs to carefully examine its monitoring needs and determine if their needs can be met using EM technology, taking into consideration the improvements suggested in this study.

2. Future work involving EM should continue to build support and develop a strong relationship with industry. This will depend on working together with industry to improve data quality, deliver feedback in a format that is useful to industry, and add value to the program by making certain data accessible.

3. Communications and operational processes need to be improved to make EM more effective. Improving communications between EM service technicians, company management and vessels should occur. Availability of EM technicians for more timely response to vessels would also be helpful.

4. EM data analysis services should be based in New Zealand to save cost, reduce analysis timelines, improve data quality, and better integrate the results with program operations, company management, and the Department of Conservation. The ability to establish EM programme infrastructure will depend on the amount of monitoring activity acheived.

The results from this study addressed the majority of objectives set out however objectives 2 and 7 require further investigation. Objective 2 (providing a summary of industry comments) objective 7 (providing detailed recommendations on optimal storage/archiving of EM sensor and image data) will be better understood once the operational context of an EM program for the inshore trawl fishery is defined.

[2] The comparison is based on the total study cost, 340 vessel days monitored by EM in this study and NZD 1,000 per day for an at-sea observer.

References

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

Conservation Services Programme 2005. Conservation Services Programme Strategic Plan 2005-2010. Department of Conservation, Welllington, New Zealand. Available online at the following website: http://www.doc.govt.nz/publications/conservation/marine-and-coastal/marine-conservation-services/csp-plans/approved-csp-strategic-plan-2005-2010/

Harper, P.C.; Kinsky, F.C. 1974: Southern Albatrosses and Petrels: An Identification Guide. Victoria University Press, Wellington, New Zealand. 12 p.

Jones, J.B. 1992: Environmental Impact of Trawling on the Seabed-A Review. New Zealand Journal of Marine and Freshwater Research 26 (1): 59-67p.

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

McElderry, H.; Schrader, J.; McCullough, D.; Illingworth, J.; Fitzgerald, S.; Davis, S. 2004a: 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.

McElderry, H.; Schrader, J.; McCullough, D.; Illingworth, J.; 2004b: 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 Reseance Ltd., Victoria, BC, Canada. 35 p.

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. 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. 39-40 p.

ACKNOWLEDGMENTS

This project was funded by the New Zealand Department of Conservation, Marine Conservation Services Program (MCS, www.doc.govt.nz/mcs) under contracts for Electronic monitoring trial of inshore trawl vessels 2008 and Electronic monitoring analysis 2009. We are grateful for the co-operation and support from the skippers and crews of the two vessels involved in this project. Jim Fitzgerald (Sanford vessel management) was instrumental in initially identifying the two vessels in which to deploy the equipment and helped greatly in the success of the project in providing the communication link between the vessel and the service personnel. We are also appreciative of the MCS staff, in particular Johanna Pierre, Igor Debski and Stephanie Rowe who provided support and advice for the project. Lat 37 staff participating in this project included Bill Westphal and Sheryl Collins. Archipelago staff participating in this project included Alayna Siddall, Robyn Andrew and Jessica Schrader.

APPENDIX I – 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 program 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 metal tamper-resistant control box (approx. 38x25x20cm) that houses computer circuitry and data storage devices. 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.

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 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 upon the image compression method. Using a four-camera set up and 500-gigabyte hard drive, the EM system would provide continuous recording for 52-86 days.

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

EM Power Requirements

An EM control box should be continuously powered (24hr/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 continuous power supply. The recommended circuit capacity for an EM system is 400 watts if using 240-volts AC, or 20 amps with 12-volts DC. The EM system amperage requirements vary from about 6 amps (at 12-volts 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 (Figure A2), 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.

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.

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

GPS Receiver

Each EM system carries an independent GPS, 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 (Figure A4). The GPS receiver is a 12 channel parallel receiver, meaning it can track up to 12 GPS satellites at once while using 4 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 metres (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 metres radius centered 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 volts 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.

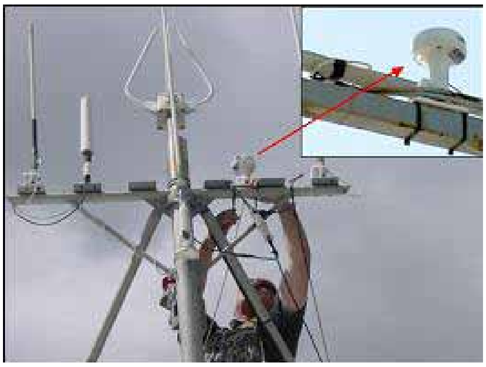

Figure I.III. GPS receiver installed in the rigging of a vessel and a close up photograph of the mounted GPS.

Hydraulic Pressure Transducer

An electronic pressure transducer is generally mounted into the vessel hydraulic system (Figure A5) to monitor the use of fishing gear (e.g., winches, line haulers, etc.). The sensor has a 0 to 2,500 psi range, high enough for most small vessel systems, and a 15,000 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. (Figure A5).

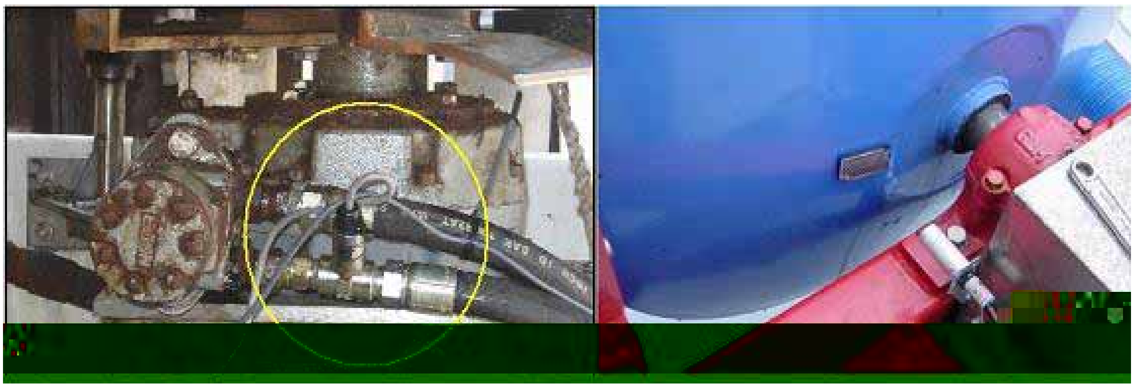

Figure I.IV. A hydraulic pressure sensor installed on the supply line of a vessel line hauler (left). Drum rotation sensor (right) mounted on pelagic longline vessel, showing optical sensor and reflective surface.

APPENDIX II – DATA CAPTURE DETAILS PER TRIP

Table II.I Sensor data capture per trip

Vessel ID	Trip Number	Departure	Return	Trip Length (Days)	Sensor Data Missing (Hours)	Sensor Data Completeness (%)	Imagery Collected (Hours)	Tows Captured	Observed Tows
1	1	18-Mar	23-Mar	5.02	0.03	100%	21.38	15	
	2	24-Mar	26-Mar	1.86	0.00	100%	12.96	8	
	3	27-Mar	31-Mar	4.05	0.00	100%	24.43	15	
	4	01-Apr	05-Apr	3.86	0.00	100%	18.44	11	
	5	06-Apr	08-Apr	2.11	0.00	100%	10.97	7	
	6	09-Apr	15-Apr	6.02	0.00	100%	31.43	15	
	7	16-Apr	21-Apr	5.21	31.93	74%	23.32	11	
	8	22-Apr	27-Apr	4.94	12.07	90%	20.93	14	
	9	29-Apr *	30-Apr	1.52	5.41	85%	7.48	7	
	10	01-May	03-May	2.17	0.00	100%	12.46	8	
	11	04-May *	07-May	2.85	3.62	95%	11.96	8	
	12	26-May	02-Jun	6.65	0.00	100%	35.92	19	
	13	03-Jun	22-Jun	19.34	168.02	64%	63.68	12	
	14	12-Jun *	13-Jun *	0.76	11.91	48%	1.00	1	
	15	16-Jun *	22-Jun *	5.91	37.33	74%	24.94	18	
	16	26-Jun	29-Jun	3.77	0.00	100%	29.64	20	
	17	06-Jul	08-Jul	2.32	2.87	95%	14.85	10	
	18	09-Jul *	15-Jul	6.35	2.01	99%	33.42	19	
	19	16-Jul	22-Jul *	5.71	10.24	93%	23.27	17	
	20	24-Jul *	03-Aug	10.38	112.38	55%	30.88	14	
	21	05-Aug *	08-Aug *	3.11	14.61	80%	11.70	6	
	22	13-Aug	15-Aug	2.24	0.00	100%	10.97	6	
	23	16-Aug	19-Aug	2.78	0.00	100%	13.96	7	
	24	20-Aug *	23-Aug *	3.41	20.26	75%	12.42	8	
	25	25-Aug *	31-Aug *	6.38	81.98	46%	15.46	12	
	26	05-Sep *	11-Sep *	6.10	83.59	43%	17.61	15	
	27	13-Sep *	15-Sep *	2.31	13.40	76%	12.96	8	
	28	04-Oct *	05-Oct *	1.13	7.73	71%	7.48	4	
	29	08-Oct *	13-Oct *	5.20	9.74	92%	33.91	19	
	30	14-Oct *	21-Oct	6.96	43.32	74%	28.21	19	
	31	23-Oct *	28-Oct *	5.64	13.24	90%	34.41	22	
	32	29-Oct	03-Nov *	4.93	33.43	72%	21.78	13	
	33	14-Nov *	17-Nov	3.67	30.67	65%	13.11	9	
	Vessel Totals			**154.64**	**749.79**	**80%**	**791.14**	**397**	**0**
2	1	03-Jun	08-Jun	5.24	32.98	74%	22.09	13	
	2	09-Jun	15-Jun	5.80	0.04	100%	33.42	22	
	3	16-Jun	19-Jun	3.11	0.00	100%	15.96	11	
	4	20-Jun	23-Jun	3.26	0.05	100%	18.45	14	
	5	24-Jun	26-Jun	2.26	0.00	100%	10.44	15	
	6	27-Jun	30-Jun *	3.43	1.20	99%	13.43	20	
	7	01-Jul *	03-Jul	2.26	0.94	98%	11.95	14	
	8	05-Jul	09-Jul	4.52	11.33	90%	14.92	22	
	9	10-Jul	16-Jul	6.47	9.08	94%	0.00	27	
	10	17-Jul	20-Jul	3.30	0.61	99%	0.00	18	
	11	21-Jul	24-Jul	3.33	0.00	100%	0.00	19	
	12	25-Jul	29-Jul	4.07	38.44	61%	0.00	9	
	13	03-Aug *	05-Aug *	2.40	24.67	57%	0.00	11	

14	06-Aug	*	10-Aug	4.24	37.43	63%	0.00	21	
15	11-Aug		14-Aug	3.31	0.00	100%	0.00	18	
16	15-Aug		20-Aug	5.18	0.00	100%	43.73	22	
17	21-Aug		26-Aug	5.32	0.00	100%	48.58	29	
18	27-Aug		02-Sep	6.01	0.00	100%	45.92	26	
19	03-Sep		07-Sep	3.31	0.00	100%	28.43	23	
20	08-Sep		10-Sep	1.92	0.00	100%	9.97	9	
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	
26	10-Oct		14-Oct	3.97	29.31	69%	65.94	18	
27	15-Oct		20-Oct	5.26	20.71	84%	105.31	30	
28	21-Oct		27-Oct	5.86	15.39	89%	42.72	26	
29	28-Oct		03-Nov	6.04	1.11	99%	46.19	33	
30	06-Nov		09-Nov	3.14	14.47	81%	22.86	14	
31	10-Nov		17-Nov	7.20	0.12	100%	62.81	42	
32	18-Nov		23-Nov	5.12	0.04	100%	49.35	25	
Vessel Totals				**130.44**	**250.70**	**92%**	**924.22**	**625**	**60**
Overall Totals				**285.09**	**1000.49**	**85%**	**1715.36**	**1022**	

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

APPENDIX III-SAMPLE IMAGES OF SEABIRD ABUNDANCE CATEGORIES

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


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

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

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