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Using Electronic Monitoring to Document Inshore Set Net Captures of Hector's Dolphins

Electronic Monitoring Trial: Timaru Set Net
(For Advisory Group Use Only)

Submitted by
Archipelago Marine Research Ltd.

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CONFIDENTIAL

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Document History

Version	Date	Author	Distribution/Notes
1	July 26, 213	s 9(2)(a)	Initial Draft for Client review.

Abstract

The New Zealand inshore Set Net fishery operating in statistical area 022 is a commercial fishery of approximately 12 vessels that targets rig shark, elephant fish and school sharks. The Ministry for Primary Industries (MPI) has tested the use of electronic monitoring (EM) to document captures of Hector's dolphins and other protected species and fishing location within the fishery.

The project objectives were to evaluate EM and methods of implementing automatic data collection of at-sea fisheries data; to compare data collected by EM reviewers and at-sea observers; and to evaluate the needs of an operational program for the use of EM within the inshore Set Net fishery.

A total of 160 fishing trips and 162 hauls were monitored using EM on six vessels. EM data were reviewed by Archipelago Marine Research Ltd. (Archipelago) to verify data completeness, identify all fishing events within each trip, and detect protected species captures.

EM data collection was complete for 87% of the hauls but only 26% of the trips. Data loss was mainly the result of skippers not turning on the EM system for the entire fishing trip. Image data quality was usable for 94% of the trips. Overall there were approximately 207,075 meters of net monitored for hauls with complete and usable data. One Hector's dolphin capture and two seabird captures were detected by EM. In addition, three instances of unusual or unexplained behaviour by the skippers and/or crew may have resulted in catch or bycatch not being recorded on EM video data.

In order to quantify detection of catch by EM compared to observer detection, shark captures were used as proxy for dolphin captures. Nine hauls were analyzed resulting in 300 sharks recorded by EM reviewer and 294 by observer. After catch items were paired, 93% of records matched between the two methods, 14 records were missed by the observer and 8 were missed by the EM reviewer. The number of sharks missed by both methods was negligible according to Chapman's total population estimates. These results corresponded to a 97% detection rate by EM reviewer and 95% detection rate by observer.

While further work in motivating the skippers to demonstrate that all fishing activity was properly monitored and improvements to certain camera set-ups are required, EM has proven to be a reliable source of some data types such as fishing location, time, and protected species detection, provided data is complete and onboard catch handling methods are followed.

Suggested citation

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Contents

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1.0 Introduction

1.1 Background

Electronic monitoring (EM) systems are being used in some fisheries as an alternative and/or a complement to human observers onboard (McElderry, 2008). Archipelago Marine Research Ltd. (Archipelago) has developed an EM system that has been used in a wide variety of applications for monitoring fishing and collecting fisheries related data (McElderry, 2008). The EM systems consist of a centralized computer combined with several sensors and cameras that record the key aspects of the fishing operations such as vessel location, vessel speed, and equipment activity.

Since October 2008, commercial set net fishing within four nautical miles of the East Cost of the South Island has been banned in an effort to mitigate the risk of accidental mortality of Hector's dolphin. Observers have been placed onboard commercial set net vessels that operate outside the four nautical mile limit of the East Coast of the South Island to monitor mortality of Hector's dolphins. In general, observer coverage targets have not been met for a number of reasons, including maritime safety implications and fishers' reluctance to carry observers.

The Ministry for Primary Industries (MPI) requested the services of Archipelago to examine the feasibility of EM technology as a viable alternative to observers to monitor Hector's dolphin's mortality on set net fisheries. During the 2012/2013 season, observer coverage was planned for statistical area 022 (Canterbury Bight/Timaru). MPI wanted to explore the use of EM as a tool to allow sufficient coverage of fishing activity in this area. This project built upon the lessons learnt from the 2003 project Archipelago completed with this particular fishery (McElderry, *et al*., 2004).

1.2 Objectives

The overall goal of the project was to examine the feasibility of using EM technology to monitor this small boat fishing fleet. Specific objectives were as follows:

- To gather information to estimate overall mortality/mortality rate of Hector's dolphins, and other protected species, in set net fisheries on the East Coast of the South Island.
- To test the feasibility and quantify the effectiveness of electronic monitoring in gathering this information.
- To test protocols, frameworks, and the infrastructure necessary for the delivery of electronic monitoring.

In order to meet these objectives the project included provision, installation and maintenance of EM equipment as well as development of a Vessel Monitoring Plan that specified the EM installation requirements for the vessel. Archipelago was to build local capacity by training a local EM equipment technician and data reviewers and provide analysis software to enable MPI access to the EM data collected. Finally, Archipelago was to provide overall project advice on all aspects of the project.

1.3 Set Net Fishery

The inshore commercial set net fishery operating in statistical area 022, on the East Coast of the South Island, is composed of vessels fishing out of Timaru and Moeraki. Roughly 12 vessels participate in the fishery, targeting mainly rig sharks, elephant fish and school sharks. The vessels are small, ranging from 9.5 to 20.7 meters and a median length of 12.0 meters. Fishing may take place year round, but in recent years the majority of the activity is concentrated between October and February. The fishery is managed by transferable quotas.

Fishers are encouraged by fishing companies, who lease them quota, to use acoustic pingers to minimize cetacean interactions with the set net gear and are required to report all Hector's dolphin entanglements.

1.4 Project Partners and Roles

As the project sponsor, MPI was responsible for overall program direction and was the main contact with vessel captains. This work included securing volunteer vessels to participate in the program, ensuring vessels were able to carry EM, and outreach with industry.

Archipelago was responsible for the day-to-day coordination of the project, providing advice on the program design based on Archipelago's experience with fisheries monitoring programs, training the local field technician, analyzing the data collected and reporting on it.

Ongoing maintenance of the EM systems in the port areas was provided by a local field technician subcontracted by Archipelago. The local field technician was responsible for providing service to the vessels when required, including data retrievals, troubleshooting, and moving or replacing sensors or cameras.

2.0 Materials and Methods

2.1 Data Collection

2.1.1 Survey Plan

In preparation for installing EM systems, Archipelago worked with MPI to gather information on the vessels using questionnaires and vessel photographs. The information gathered included deck layout, power systems available, fishing behaviour, catch handling, and structures that could support camera installations. Not all vessel skippers could be reached ahead of installations to gather this information.

Archipelago and the local field technician installed the EM systems between October 31st and November 9th, 2012. Technicians met with vessel captains and owners to discuss the installation and use of the EM system.

Skippers were asked to operate the EM systems for the six-month study period during all fishing operations. Systems were to be powered on at departure from port and powered off upon return to port.

With the exception of two vessels that were not set netting in November, when the EM system functionality was checked within a few days of the installations to ensure that everything was working well. After the initial check, vessel visits were scheduled on a monthly basis to retrieve data and check the system's functionality. Additional services were planned as needed if there were issues with the equipment functionality or if a dolphin capture was reported.

2.1.2 Vessel Details

EM systems were installed on six vessels in Timaru and Moeraki. These vessels are referred to as vessels "A" to "F" to protect their privacy. Although the initial plan was to install eight EM systems, it was not possible to find additional volunteers to participate in the EM program. The participating vessels were representative of the fleet in terms of size (approximate vessel sizes from 12 to 21 meters) and hauling layout (both stern and bow hauling layouts included).

Four of the participating vessels also carried observers onboard for a portion of their fishing trips.

2.1.3 Electronic Monitoring System

The EM systems used for this project were manufactured by Archipelago in Victoria, Canada and are designed for the collection of fisheries data. EM systems have been installed on a variety of fishing gear types and boats around the world, and have been in use as a key source of fishery data in the British Columbia Groundfish Fishery since 2006 (McElderry 2008; Stanley *et al*. 2011).

The EM system consisted of an EM Observe™ v4.5 control centre with an array of digital and/or analog closed circuit television cameras, a GPS receiver, a hydraulic pressure sensor, and a rotational sensor (Figure 1). The EM Record™ operating software, installed on the control centre, collects high-frequency sensor data throughout the entire trip and records imagery.

Imagery and sensor data are stored digitally on a removable hard drive that can be exchanged by captains or an EM technician prior to reaching its storage capacity.

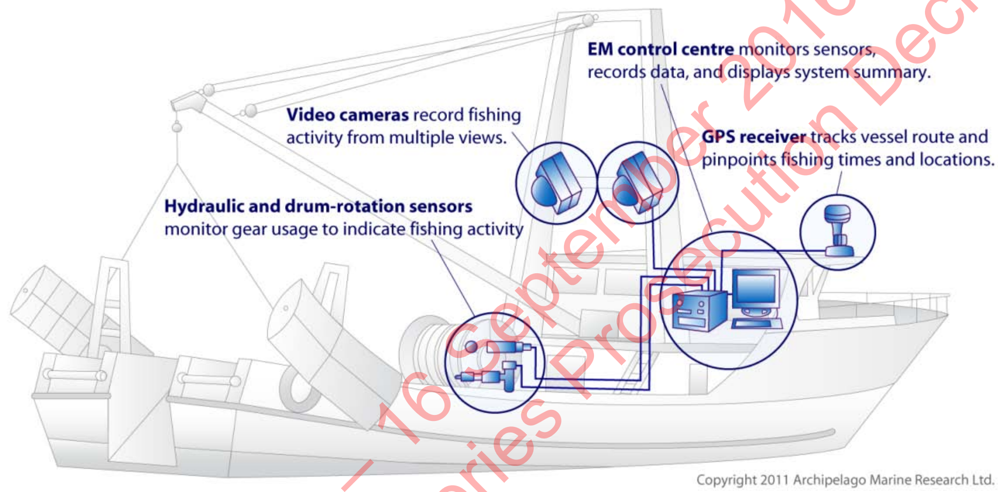

Figure 1: Schematic of a standard EM Observe v4.5 system used during this study

The EM systems operated independently, and were set to record imagery only when there was hydraulic activity or rotations on the net drum (typically associated with fishing activity), and continue to record for 30 minutes after hydraulic activity and net drum rotation had stopped.

On all but one vessel, EM systems were powered with DC power using a transformer to bring the 24V power from the vessel's battery bank to 12V power, the voltage accepted by the EM system. The EM system on the remaining vessel was powered with AC power via the vessel's inverter.

2.1.4 Onboard Methodologies and Camera Views

On all vessels, catch was brought onboard over the roller on to the deck where it was picked and sorted. Two cameras were used to monitor all catch (Figure 2).

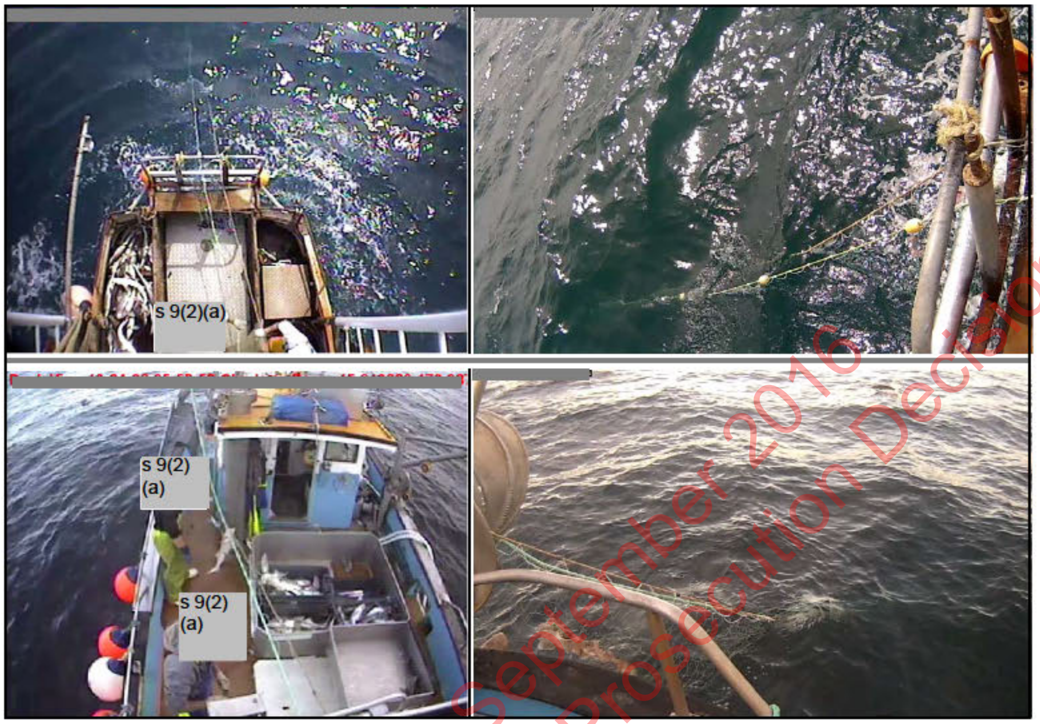

Figure 2: Camera views for the two cameras used on a vertical stern hauler vessel (upper) and bow hauler (lower). Images on the left show wide angle deck views and images on the right show close-up roller views.

A digital camera provided a close-up view of the hauling area to capture imagery of the net as it came out of the water and onto the roller. This view assisted in the identification of catch as well as the detection of any catch that may have dropped out of the gear before being landed on the deck. An analog camera provided a wide-angle view of the deck where catch was picked and sorted and protected species may be released. This view assisted in confirming fishing activity, detecting catch when landed on the deck of the boat, observing life status of catch, and observing if protected species were released. This view also acted as a back-up if the gear went out of view of the roller camera.

On four of the vessels, temporary camera mounts were fabricated from aluminium piping, and positioned so as to provide a good view of the net and catch before it came over the roller. On one vessel there was no need to fabricate a mount as the trawl net bar on the vessel provided an adequate mounting structure. On another vessels, the skipper was concerned with having a structure outboard from the stern and so the camera was instead placed on the vessel's existing structures as best as possible.

2.1.5 Vessel Monitoring Plans

The Vessel Monitoring Plan (VMP) is a communications tool designed to help vessel captains, EM field technicians, EM data reviewers, and project coordination staff to understand their roles for a successful implementation.

Each VMP used a combination of text and images to document the key points related to vessel-specific EM installation and operation:

- General vessel information
- EM system configuration being used to meet the project objectives:
  - General description of the type of data being recorded
  - Location and objective of each EM system component (including camera views)
- Catch handling protocols:
  - Setting and hauling
  - Fish sorting
  - Protected species discarding
- Diagram of the vessel
- Software configuration specifications (for EM technician reference)

2.2 EM Data Review Methods

2.2.1 Identifying Events and Documenting Catch

The data sets collected using EM were reviewed using the Archipelago EM Interpret™ Pro software.

EM Interpret™ Pro is a specialized software package designed to help the reviewer quickly process, evaluate, and report on fishing activity. The EM Interpret™ Pro software integrates thousands of video, sensor, and GPS records into a single synchronized profile, and presents it along a common timeline (Figure 3), so reviewers can quickly follow cruise tracks, review gear deployment and retrieval times and locations, and verify "retained and discarded" catch records. Key events, comments and observations can be saved as annotations, created by the reviewer and saved along with the data set for future reference. All information is then stored in a standard database format for easy reference, analysis, or downstream processing.

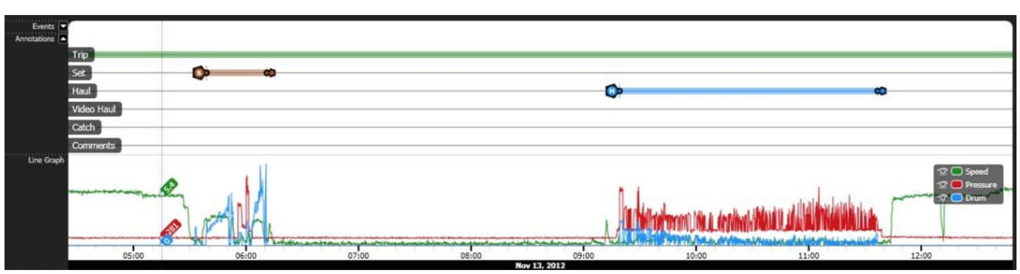

Figure 3: Example of typical sensor data (speed, drum rotation, and hydraulic pressure) for a set and haul using set net gear.

The EM data were reviewed by Archipelago staff after each data retrieval. EM data review included examining the data to check that is was complete, identifying all gear setting and hauling activity time and location, and reviewing the video for protected species captures or proxy species counts. MPI provided Archipelago with a shape file of the four nautical mile closure so the reviewer could confirm that fishing had occurred outside of the four nautical mile limit. All catch entries included metadata on time and location. The reviewer was able to watch the imagery from half of real time speed to up to 16 times speed. The protected or proxy species were documented to the species or species group as appropriate (see Appendix B: Species and Species Groups).

EM data completeness was measured at the trip and the haul levels. At the trip level, each trip was examined to assess if the EM systems were powered on for the entire duration of each fishing trip to allow a complete reconstruction of what occurred during the fishing trip including:

- **Trip start and trip end:** Time that the vessel departed from and arrived to port
- **Set:** Monitoring time and location of gear setting
- **Haul:** Monitoring time and location of gear hauling as well as protected species captures
- **Transit and gear soak periods:** Confirming that all fishing events between trip start and end were monitored

Each haul was examined to assess if there was complete video from the start to the end of the haul, and to determine whether the video was of good enough quality to allow detection of protected-species captures. Hauls were rated for image quality according to the following guidelines (see Figure 4 for examples):

- **High Quality:** camera lenses properly focused, viewing areas clearly visible, and gear retrieval and catch processing easy to assess
- **Medium Quality:** gear rarely out of view; or some loss of resolution from pixilation, sunlight glare, or moisture; poor camera positioning, or minor obstruction of view; but gear retrieval and catch processing still assessable
- **Low Quality:** reduced light, increased pixilation, water spots on cameras obscure most of the view, poor focus or major obstruction of view; gear out of view; fishing activity generally difficult to resolve
- **Unusable Data:** video quality extremely poor, or camera views totally obstructed, or no imagery available and therefore analysis not possible

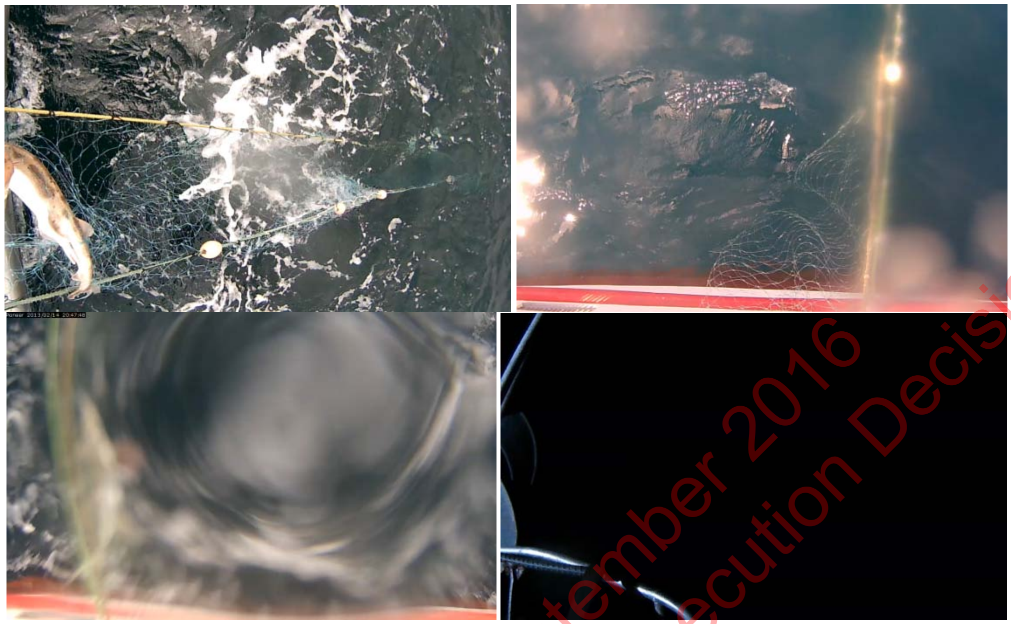

Figure 4: Examples of data quality. Top left high quality, top right medium quality due to dirty camera, bottom left low quality due to water on the camera, bottom right unusable due to inadequate lighting

Using the skipper fishing log data provided by MPI we estimated the total length of net monitored. For trips that were not present in the fishing log data we used the most common net length reported for that vessel. Net length monitored was not calculated for incomplete hauls since it was not possible to know how much of the haul was missed (i.e. the amount of time or net length hauled when the EM system was powered off).

All hauls recorded by EM were reviewed for captures of Hector's dolphins and other protected species regardless of image quality or completeness. The reviewer flagged situations where a dolphin capture may have not been able to be detected due to what could have been an intentional action by the skipper to prevent catch items from being seen on the video (referred to as unexplained behaviour).

Results were provided to MPI via a summary report once per month. These summaries included an update on field operations, system performance, data collection and completeness, protected-species captures, and recommendations to increase data quality. Additional incident reports were provided for fishing inside the four nautical mile limit, and unexplained behaviour.

2.3 Proxy Species Comparisons

2.3.1 Proxy Species Data Collection

To satisfy the objective of quantifying detection of dolphins in EM data, there was a need to compare EM reviewer detections to observer detections. However, since a dolphin capture is a rare event, we could not expect enough observations in EM and observer data records to allow for a meaningful comparison. Instead we used sharks as proxy species similar in size to a dolphin to compare observer and EM reviewer catch detection rates. The shark species used as proxies ("proxy species") were:

- Rig shark (*Mustelus lenticulatus*),
- Spiny dogfish (*Squalus acanthias)*,
- Northern spiny dogfish (*Squalus griffin*),
- School shark (*Galeorhinus galeus*),
- Porbeagle shark (*Lamna nasus*),
- Broadnose sevengill shark (*Notorynchus cepedianus*),
- Thresher shark (*Alopias vulpinus*), and
- Carpet shark (*Cephaloscyllium isabellum*)

Spiny dogfish, northern spiny dogfish and rig sharks were compared under a single catch group due to their physical similarities and the difficulties distinguishing species codes in data sheets.

Proxy species data collection took place on December 2012 and January 2013 on two vessels, referred to as "Vessel 1" and "Vessel 2" to protect their privacy. Observers and EM reviewers methods were designed to ensure that the data from each method could be aligned. Observers were given specific instructions on how to collect data and provided with a custom data collection form to ensure that individual catch records could be lined up with those of the EM reviewer (see Appendix A: Proxy Species Observer Instructions and Logbooks EM reviewing methods were designed to mimic observer methods. A summary of the methodology for each data collection source is shown in Table 1.

Table 1: Overview of observer and EM reviewer methods for proxy species data collection

Observer Methods	EM Reviewer Methods
Consecutively count sharks, writing down species codes and whether they were retained, discarded or fell out of the net (drop off).	Same as observer.
First hour of hauling for the first fishing event of the day. Arm signal to camera for start and end of data collection.	Start at the beginning of the haul and end at the time indicated in the observer data. Look for arm signals as confirmation.
Note whether the animals are alive or dead.	Note whether the animals are moving or not moving as proxy for life status.
Estimate the animal length in 50 cm intervals (0-49; 50-99; 100-149; 150-199; and >200)	Same as observer.

2.3.2 Proxy Species Data Analysis

Proxy species catch record paring method

Since the main goal of the proxy species comparison was to determine if there were differences in detection, length estimation and life status observations between observer and EM reviewer methods at the catch-item level, it was important to appropriately pair the two data sets.

Analysis of individual shark data required a catch record pairing process since the observer and reviewer data sets sometimes did not match up item to item. These mismatches were caused when either the reviewer or the observers did not record a shark that was seen by the other data source.

During the catch record pairing process, we used primarily species identification to recognize where there could have been missing records from either data source and blank records were added to each data source to create maximum alignment with the least amount of changes (Figure 5).

Record	EM Reviewer Records	Observer Records		
1	Unspecified Shark Species	Dogfish/Rig Shark Combo	N	Detected- Species No Match
2	Dogfish/Rig Shark Combo	Dogfish/Rig Shark Combo	M	
3	Carpet Shark	Carpet Shark	M	
4	Dogfish/Rig Shark Combo	Dogfish/Rig Shark Combo	M	Detected- Species Match
5	Carpet Shark	Carpet Shark	M	
6	Dogfish/Rig Shark Combo	Dogfish/Rig Shark Combo	M	
7	Carpet Shark	Dogfish/Rig Shark Combo	M	Order Switched
8	Dogfish/Rig Shark Combo	Carpet Shark	M	
9	Dogfish/Rig Shark Combo	Dogfish/Rig Shark Combo	M	
10	Dogfish/Rig Shark Combo	Dogfish/Rig Shark Combo	M	
11	Dogfish/Rig Shark Combo	Dogfish/Rig Shark Combo	M	
12	Dogfish/Rig Shark Combo		EM+OBS-	Missing on Observer Data
13	Carpet Shark	Carpet Shark	M	
14	Dogfish/Rig Shark Combo	Dogfish/Rig Shark Combo	M	
15	Dogfish/Rig Shark Combo	Dogfish/Rig Shark Combo	M	
16	Dogfish/Rig Shark Combo	Dogfish/Rig Shark Combo	M	
17	Dogfish/Rig Shark Combo	Dogfish/Rig Shark Combo	M	
18		Dogfish/Rig Shark Combo	EM-OBS+	Missing on EM Reviewer Data
19	School shark	School Shark	M	
20	Dogfish/Rig Shark Combo	Dogfish/Rig Shark Combo	M	

Figure 5: Example data illustrating the shark data pairing method. Species records are colour-coded to highlight the most plausible alignment with the least number of changes to each data source.

Although to a lesser degree than species identification, the catch record pairing method also incorporated utilization (i.e.retained or discarded), life status, and estimated length data to find the best alignment. In a few occasions shark records were reversed between the two data sources when sharks were seen to have come onboard seconds apart from each other in the EM imagery.

Detection Rate Comparison

From the paired data, we were able to estimate which proxy species were detected by both methods as well as which were only detected by the EM reviewer or only by the observer. We assumed independence between all hauls and estimated the detection for each method as the ratio between the total number of sharks recorded and the estimated total sharks captured.

We calculated total number of sharks captured using a mark and recapture model for small sample sizes, the Chapman estimator (Chapman, 1951),

$$\hat{N} = \frac{(M+1)(C+1)}{R+1} - 1$$

Where,

$\hat{N}$= Estimate of total number of sharks captured

M= Total sharks recorded by the observer

C= Total sharks recorded by the EM reviewer

R= Total sharks recorded by both

The variance of $\widehat{N}$, or var$\widehat{N}$, was estimated as

$$var(\widehat{N}) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)(R+1)(R+2)}$$

Lastly, we examined the catch utilization and estimated length of catch items missed by the EM reviewer and missed by the observer to understand if these factors could have affected detection by EM reviewers. We also compared EM catch item movement entries with observer life status to evaluate movement as a proxy for life status assessment when using EM data to monitor Hector's dolphin captures.

2.3.3 Video Data Review Time

The time required to review each haul was recorded in order to estimate the amount of effort needed to review video data for protected species interactions. An analysis ratio was calculated by dividing the amount of video reviewed by the time it took to review it.

3.0 Results

3.1 EM Data Collection

3.1.1 Monitored Trips

During this project, a total of 160 trips, 162 hauls, and 129 sets were monitored during 1,457 hours of data collection between November 2012 and April 2013 (Table 2).

Table 2: EM data collected for each vessel including trips, hauls, data collected, and data completeness

Vessel Name	Sensor Data Collected (hours)	Trips	Sets	Hauls	First Data Collected	Last Data Collected
Vessel A	311	23	24	24	2-Nov-2012	7-Feb-2013
Vessel B	395	41	41	40	5-Nov-2012	31-Jan-2013
Vessel C	245	40	20	43	8-Nov-2012	8-Apr-2013
Vessel D	223	33	24	33	5-Nov-2012	18-Feb-2013
Vessel E	27	3	2	3	17-Dec-2012	25-Feb-2013
Vessel F	256	20	18	19	1-Nov-2012	24-Jan-2013
Total	**1,457**	**160**	**129**	**162**	**Nov, 2012**	**Apr, 2013**

Most vessels collected data from November 2012 to late January or February 2013; only one vessel continued set netting until April 2013. Trips monitored by vessel ranged from 41 to three, with a median of 28. One vessel had only three trips monitored due to the skipper not powering on the EM system for the remainder of their set net trips.

The EM systems were often powered down during parts of the trip. Table 4 illustrates the three main scenarios observed with respect to data collection: trip complete; EM turned off during soak time; and EM system off for significant periods:

- **Trip Complete:** EM system was on from the time the vessel left port to the time it returned to port. There is complete assurance that all fishing activity was collected.
- **EM turned off during soak time:** EM system was on for most of the trip except in between the set and haul, when the vessel drifts while the gear is soaking, usually three to five hours. This level of data completeness was considered relatively low risk as it was unlikely that fishing activity would have been missed during this time.
- **EM system off for significant periods:** The EM data record contained significant gaps that may have spanned fishing and non-fishing activity

including: trip start and end, gear setting , transit, and/or soak time. This level of data completeness was considered high risk as it could not be confirmed that all hauls for the trip were captured and/or the hauls were not captured in their entirety.

Table 3: Data completeness by trip by vessel categorized by risk levels depending on how much of the fishing trip could be reconstructed using EM. Green denotes complete trips that could be reconstructed in their entirety, yellow denotes low-risk trips where only the soak time was not captured, and red denotes high-risk trips where it was not possible to ensure that all fishing activity was captured and/or hauls were incomplete.

	Trip Complete	EM turned off during soak	EM turned off for significant periods			Total Trips
			Complete Haul(s)	Partial Haul(s)	No Haul Recorded	
Vessel A	1	6	13	2	1	**23**
Vessel B	39	0	1	0	1	**41**
Vessel C	0	0	36	3	0	**39**
Vessel D	0	0	16	15	3	**34**
Vessel E	0	0	3	0	0	**3**
Vessel F	2	16	1	0	1	**20**
Total	**42**	**22**	**70**	**20**	**6**	**160**
Percent Total	**26%**	**14%**	**44%**	**12%**	**4%**	

Trip data completeness varied substantially between vessels. There were 42 trips, or 26% of all trips monitored, with complete EM data records. Almost all of these corresponded to Vessel B but two other vessels had at least one complete trip.

Three vessels consistently turned off their EM system for significant periods on all trips. Overall, 60% of the trips monitored had significant gaps. The majority of these trips had one or more complete hauls captured and so it is likely that all fishing activity was monitored but this cannot be confirmed. Moreover there were six trips in which there was no haul recorded but it is not possible to know if any hauls were missed given that the vessel may have only set gear to be hauled later, or may have not engaged in fishing at all during that trip. The exceptions are one trip where the haul was not captured by EM after the vessel's inverter failed and another trip on a different vessel where the vessel experienced electrical problems unrelated to the EM system.

Table 4 shows a matrix of hauls by their image quality and completeness across all vessels (see Appendix D: Haul Data Completeness and Image Quality for vessel-specific results).

A total of 98 hauls, 58%, were completely monitored, meaning they were complete and had high or medium image quality allowing for a thorough assessment. An additional 38 hauls, 23%, could be considered monitored but to a lesser degree since drop-offs could have been missed as the gear was out of camera view for part of the haul. The 20, 12%, incomplete but usable hauls could be considered partially monitored. Nine hauls, 6%, could be considered to be not monitored because inadequate lighting made it impossible to see the gear coming out of the water for the entire haul and difficult to see the catch onboard. However even for the unusable hauls it is possible that a dolphin brought on deck could have been detected.

Table 4: Matrix of haul image quality and completeness across all vessels. Increasing levels of coverage are denoted from red for hauls with minimum or no coverage to green for hauls with full coverage.

Image quality	Complete Hauls	Incomplete Hauls	Total	Percent Total
High	61	7	**68**	**42%**
Medium	34	10	**44**	**27%**
Low	38	3	**41**	**25%**
Unusable	8	1	**9**	**6%**
Total	**141**	**21**	**162**	
Percent Total	**87%**	**13%**		

The total net length monitored was estimated at 207,075 meters across all vessels of which 156,725 meters had high or medium image quality and 50,350 meters had low image quality (Table 5). An additional 8,000 meters had unusable image quality. Net length was obtained from fishing log data for trips with matching records. Net length had to be estimated for 29 hauls because there was no corresponding record of these fishing trips in the fishing log data obtained from MPI.

Table 5: Net length monitored in meters for complete hauls by vessel and by image quality.

Vessel Name	High/Medium Quality (meters)	Low Quality (meters)	Total Net Length
Vessel A	38,000	8,000	46,000
Vessel B	21,150	29,350	50,500
Vessel C	19,000	13,000	32,000
Vessel D	29,800		29,800
Vessel E	7,800		7,800
Vessel F	40,975		40,975
Total	**156,725**	**50,350**	**207, 075**

Of the 162 hauls monitored with EM systems, 87% had complete video from float to float. Incomplete hauls were the result of skippers turning off the EM system before the haul ended or turning on the EM system after hauling had started with the exception of two hauls where there was a data gap in the middle of the haul (one likely due to electrical problems on the vessel and one due to a manual power down).

The majority of hauls, 69%, were of high or medium image quality. Low image quality was predominantly the result of the net frequently drifting out of camera view in the stern camera and the inability to observe the roller on the deck view either because a tarp covering the back deck prevents a view of the roller from the deck view camera on one vessel or the deck view not covering the roller area on another vessel (Table 6).

Additionally, five hauls were categorized as having low image quality when a camera cable was accidentally severed during fishing resulting in no video from the camera at the roller. Low image quality for the two remaining hauls was caused by one instance when intense glare caused severe distortion of the colours and made it hard to resolve the images and another instance in which water spots on the camera prevented full monitoring of the gear breaking the water. The nine unusable quality hauls occurred on one vessel and were due to inadequate lighting during night hauls.

Table 6: Reasons for low and unusable image quality and the number of vessels and hauls affected by each.

Low Quality Reason	Vessels affected	Hauls Affected	Percent of Low Image Quality Hauls	Percent of Hauls
Gear Outside of Camera View	2	35	85.4%	21.6%
Camera Malfunction	1	5	12.2%	3.1%
Water spots	1	1	2.4%	0.6%
Total	**3**	**41**	**Out of 41**	**Out of 162**

3.1.2 System Performance

During the project the data from the hydraulic pressure sensor and GPS was complete for all trips. Data from the rotation sensors was complete except for eight trips on the one vessel when the data was intermittent, likely due to the sensor glass being dirty, as well as nine trips on another vessel when there was no data due to the sensor being accidentally taken out of position during fishing.

3.1.3 Field Effort

In addition to visits to install and remove equipment, the EM service technician visited the vessels 25 times throughout the project to retrieve data and two times solely to service the equipment (Table 7).

Table 7: Number of visits by the EM field technician to each participating vessel by type of visit.

Vessel Name	Data Retrievals	Equipment Services
Vessel A	6	
Vessel B	5	
Vessel C	3	1
Vessel D	5	
Vessel E	2	
Vessel F	4	1
All Trips	**25**	**2**

There were three main field effort items that affected data collection: camera view adjustments, power draw by the EM system and a severed camera wire. These are summarized below.

After initial review of EM data in November there were concerns that the gear could be hauled outside of camera view on four of the participating vessels. Action to address this issue was taken during the December data retrievals by changing the orientation of the close-up roller camera to obtain a wider field of view when the net was being brought up and minimize instances when the net would be out of view. The camera orientation adjustment resolved the issue for the three of the four vessels affected. It improved the set up for the fourth vessel but did not resolve the issue. The camera position on this vessel needed to be changed but the skipper was concerned with having the camera damaged during offload. Further outreach was planned to discuss a better camera set up with the skipper but the vessel stopped fishing before this could take place.

The EM system draws standby power, meaning that there is a small amount of power draw when the system is off. The concern was that this power draw could drain the vessel batteries when the vessel was docked. This issue was resolved in December by installing a switch on two vessels to cut DC power to the EM system when the vessel was docked. The skipper for Vessel B had no problems with power, even when leaving the EM system on while drifting at sea, but after being warned about continuous draw would disconnect the power leads to the battery to prevent drain when docked. One of the skippers never used the on/off power button on the EM system and instead would disconnect the power lead directly at the battery. This was not done on advice from EM technicians and is not advisable as it may lead to problems with the control center. Vessel D powered the system through an inverter that would be turned off when the vessel was docked preventing any battery drain issues.

In December the inverter on Vessel D stopped functioning. It is possible that the increased draw, although within the inverter limits, caused damage to the inverter and MPI replaced it. There were no problems with the new inverter installed.

The IP camera wire was severed during a fishing trip on one of the vessels resulting in low image quality for five hauls (reported in section 3.1.1).

Other minor items that were attended to during the project included attempting to install wider lenses on the roller cameras – the lenses were not successfully installed since they were extremely difficult to install.

3.2 Protected Species Detection

3.2.1 Hector's Dolphins Captures

There was one Hector's dolphin capture observed (Table 8). The capture occurred on December 4th, 2012. The dolphin first appeared in the stern camera at 10:05 NZDT. Initially the crew attempted to remove the dolphin from the net without success. The dolphin was brought on board the vessel at 10:10 NZDT. A map with the location of the capture is shown in Figure 6.

Table 8: Details on Hector's dolphin (*Cephalorhynchus hectori*) capture observed including time and location of vessel when the animal was first seen on the video as well as the animal's estimated length, utilization and its condition (observed to be moving or not)

Date and Time (NZDT)	Latitude	Longitude	Estimated Length	Utilization	Condition
04/Dec/2012 10:05 hrs	-44.22735	171.69210	100-149cm	Retained	Not Moving

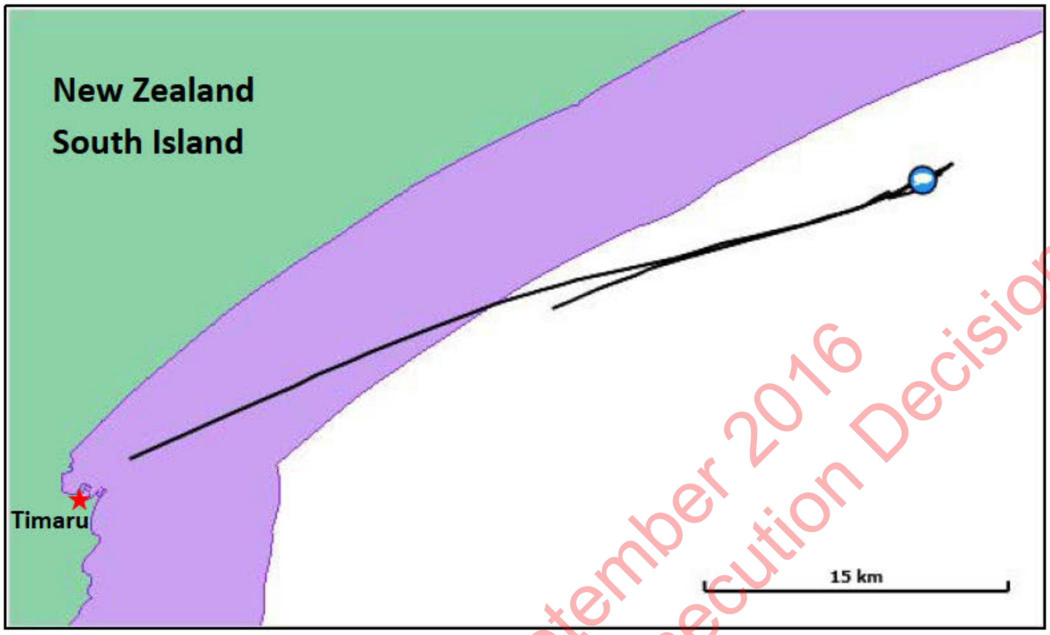

Figure 6: Chart showing vessel trip cruise track for trip on December 4th, 2012. Vessel location at the time the Hector's dolphin was brought onboard represented by blue symbol. Purple contour represents 4nm closed set net area.

3.2.2 Other Protected Species

Two seabirds, identified as belonging to the species grouping "Petrels, Prions and Shearwaters (*Hydrobatidae, Procellariidae* and *Pelecanoididae* families)" were observed to be captured and released on one vessel. The captures occurred on March 19th, 2012 (Table 9).

Table 9: Details on the two observed captured seabirds, identified as belonging to the species group "Petrel, Prion and Shearwater (*Hydrobatidae, Procellariidae* and *Pelecanoididae* families)"; including time and location of vessel when the animal was first seen on the video as well as the animal's estimated length, utilization and its condition (observed to be moving or not)

Date and Time (NZDT)	Latitude	Longitude	Estimated Length	Utilization	Condition
19/Mar/2013 22:54	-45.43389	171.33844	0-49cm	Released From Net	Moving
19/Mar/2013 22:54	-45.43387	171.33846	0-49cm	Released From Deck	Moving

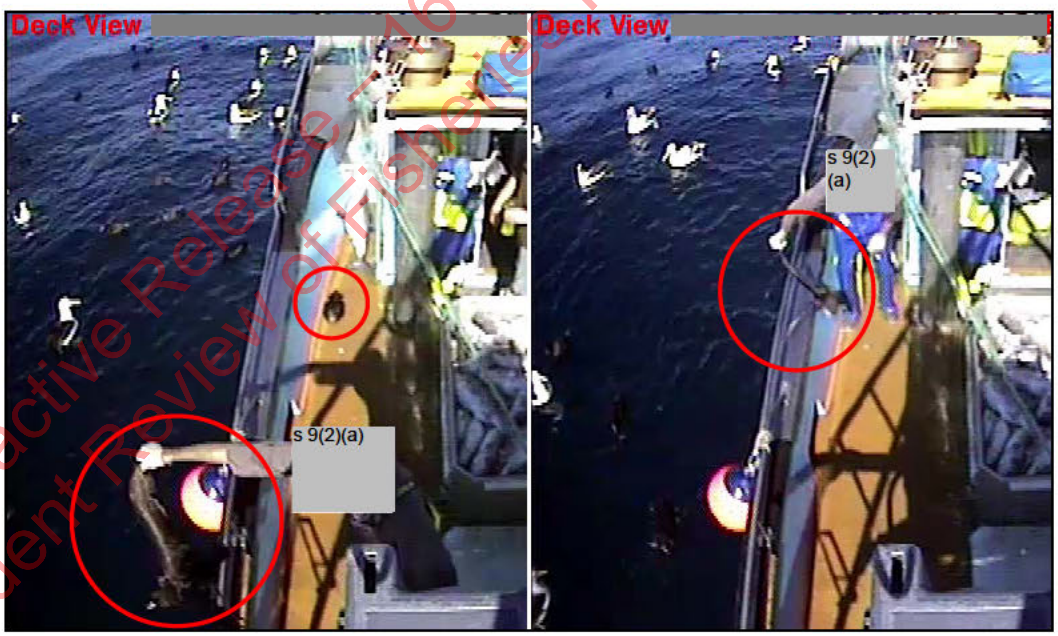

Figure 7: Images showing seabirds released. Left: Seabird released from net. The crew is observed to be releasing one bird in the lower left hand side of the camera view. The second bird is observed to have freed itself from the net. Right: Second seabird being released by the crew after freeing itself from the net. Images have been cropped from original camera views.

3.2.3 Unexplained and Unusual Activity

There were two incidents of unexplained and unusual activity during hauling where EM may have not been able to document catch in the net, including the possibility of having missed a dolphin capture.

Unexplained activity was observed an hour after the Hector's dolphin capture (December 4th, 2012 at 11:01 hrs NZDT). The skipper stoped hauling the gear and reset roughly 14 floats. The skipper and crew then processed catch for 57 minutes while net soaked, after which hauling resumed. At the time that hauling stopped the captain and crew observed an animal caught in the net but still underwater. The animal was no longer on the net when hauling resumed. It was not possible to positively identify the animal caught in the net from the EM data as it never broke the water. All that was possible to observe was that the animal was relatively large with dark and white colouring.

On another vessel it appeared that the EM system was deliberately turned off for a period of about an hour in the middle of the haul. It was not possible to see a catch item in the gear; however, prior to the EM system being turned off, the skipper and the crew member were observed looking over the stern of the vessel and then one crew member was seen entering the wheelhouse.

Additionally there was one haul where there appeared to be a gear tangle, which took the skipper and crew about seven minutes to resolve. This involved an anchor being tied to the net and some of the net being let out. There were no catch items visible in the net from the deck camera and there was no view available for the hauler camera since the cable had been severed during the previous trip (see section 3.1.3).

3.3 Fishing Location

During the project vessels engaged in fishing in statistical areas 022, 024, and 026 (Figure 8). Overall, 74% of hauls captured by EM occurred in statistical area 022.

All hauls occurred outside of the four nautical mile line, which is closed to commercial set net fishing. Although initially some hauls appeared to be inside the four nautical mile line, further examination of the latitude and longitude for these hauls by MPI revealed that they were outside of the closed area.

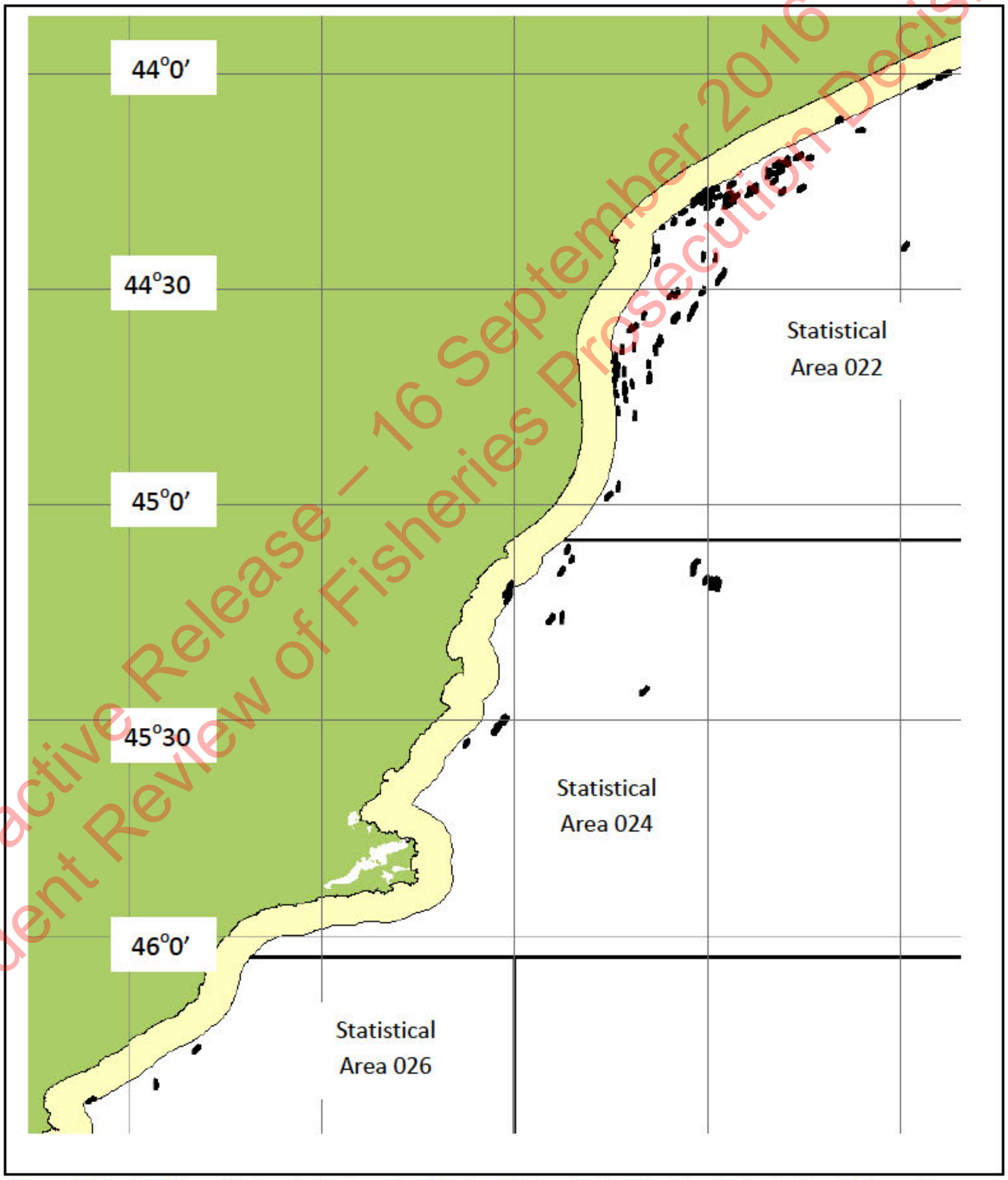

Figure 8: Chart of New Zealand's Eastern South Island showing haul cruise tracks in black. The yellow contour depicts the four nautical mile limit.

3.4 Proxy Species

3.4.1 Data Collected

Proxy species analysis was done on nine hauls, seven from Vessel 1 and two from Vessel 2 (Table 10). Observers collected proxy species data on a total of 16 hauls, of which five were usable for analysis. Of the unusable hauls, four hauls for Vessel 1 could not be used because the observer data was incomplete, and three hauls for Vessel 2 did not have EM data because the skipper did not turn on the EM system for these trips.

During EM data review for proxy species, the camera set-up on Vessel 2 was considered adequate for detecting catch while the set-up on Vessel 1 was considered challenging.

Table 10: Proxy species data collection by vessel

Vessel Name	Hauls with observer proxy species data	Usable hauls for analysis
Vessel 1	11	7
Vessel 2	5	2
Total	**16**	**9**

3.4.2 Piece Comparisons

There were seven trips from Vessel 1 and two from the Vessel 2 (Table 11) used in piece comparisons. Although Vessel 2 had fewer trips, the number of sharks recorded was much higher, approximate average of 119 pieces per haul, than on Vessel 1, approximate average of 9 pieces per haul. All but two hauls reviewed were of high quality; there was also one medium quality and one low quality.

Overall, observer and reviewer total pieces counted were within 2% with total piece differences ranging between zero and two per trip except for one trip with a difference of six pieces. This trip was very unusual in that six sharks are visible in the EM video but the observer recorded no sharks captured during this time. After following up with the observer coordinator there was no evidence that this was caused by an error in data entry by the observer; the paperwork was submitted with the correct haul information and no shark captures; however this was the first trip collecting proxy species data for this observer and it is possible that this was the reason for the error in detection.

Table 11: Comparison of total counts of proxy species by vessel by haul and EM data quality rating for each haul.

Vessel Name	EM Reviewer Count	Observer Count	Piece Count Difference	EM Image Quality Rating
Vessel 1	5	6	-1	L
	2	3	-1	H
	28	29	-1	H
	1	2	-1	H
	1	1	0	H
	18	16	2	H
	6	0	6	H
Vessel 2	72	74	-2	H
	167	163	4	M
All Trips	**300**	**294**	**6**	

3.4.3 Catch Item Pairing

Table 12 summarizes the catch item pairing analysis. The first part of the table shows the number of entries for each method as well as the total unique entries after the pairing process, these include those items that were only recorded by one method or the other. The second part of the table shows the results of the catch item pairing process including how many records were matched between the two methods as well as how many were only found in the EM reviewer data (missed by observer) and *vice versa* (missed by reviewer). We will refer to these as "missed by the observer" and "missed by the reviewer" for short form. Finally the third part summarizes the number and type of changes applied to the data to resolve the pairing.

Table 12: Catch item paring results by vessel and overall.

	Vessel 1		Vessel 2		Overall	
Entries						
EM	61		239		300	
OBS	57		237		294	
Total entries	65		243		308	
Match Summary	**Total**	**%**	**Total**	**%**	**Total**	**%**
Detection Match	53	82%	233	96%	286	93%
Missed by Observer	8	12%	6	2%	14	5%
Missed by Reviewer	4	6%	4	2%	8	3%
Total Changes	**Total**	**%**	**Total**	**%**	**Total**	**%**
Cell Addition	12	18%	10	4%	22	7%
Order Change	0	0%	5	2%	5	2%

Overall, 93% of the catch records matched between the two methods. A greater proportion of catch was matched between the two methods on Vessel 2 than on Vessel 1 data (96% *versus* 82% respectively). Overall there were 14 pieces missed by the observer and eight missed by the reviewer. Of these most were reported as retained (Figure 9).

Two catch items missed by the reviewer were recorded by the observer as having dropped off from the gear; during a second review of the video the reviewer was able to see the sharks dropping off from the gear. The EM reviewer recorded one catch item that dropped off the gear that was not recorded by the observer. Only one other catch item drop off was recorded in the data and it was detected by both observer and EM reviewer.

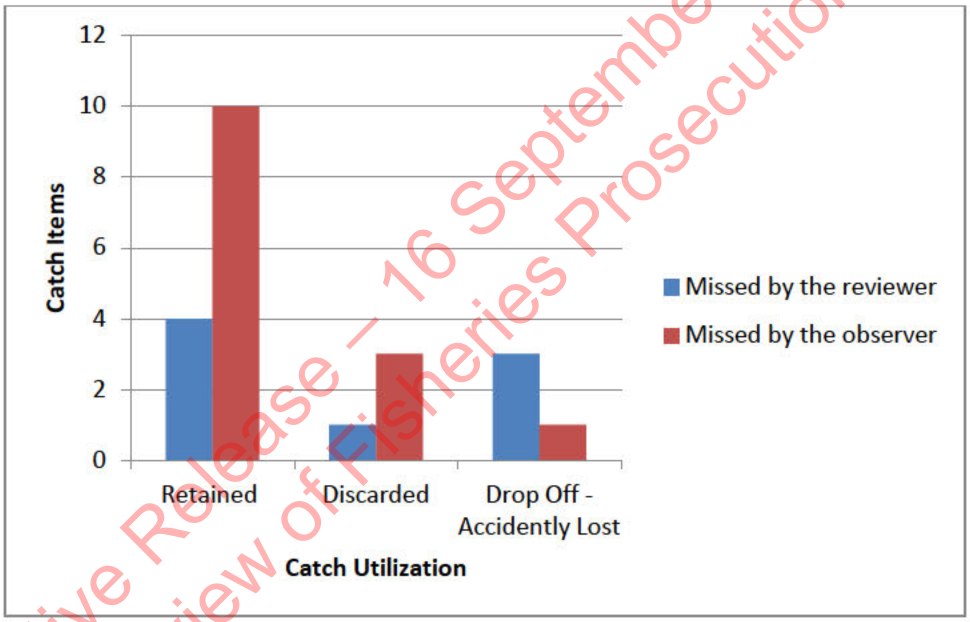

Figure 9: Utilization for catch items that were not matched between observer and EM reviewer data.

Of the catch items missed by the reviewer, 75% were estimated to be in the 50-99 cm category by the observer while the rest were evenly split between the 0-49 cm and 100-149cm length categories (Figure 10).

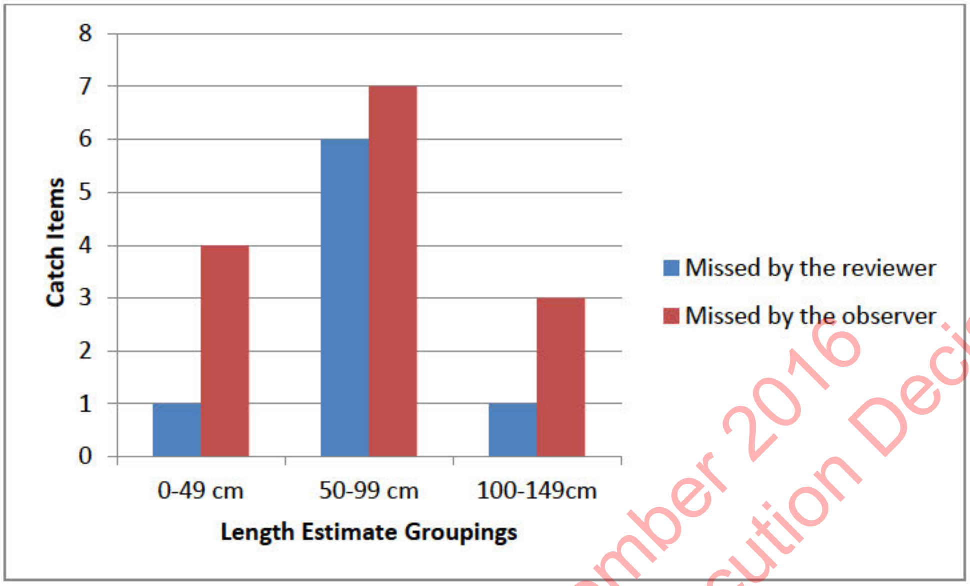

Figure 10: Estimated length groupings for catch items that could not be paired between observer and EM reviewer data.

3.4.4 Detection Estimates

Using Chapman's population size estimate all but one trip resulted in the estimated total catch being equal to the total number of catch recorded by either the observer or reviewer (Table 13). Applying the Chapman model to the total number of counts by each method, we estimated the total number of sharks captured to be 308.390 ± 0.647 (approximate 95% confidence limits) which was very close to the 308 detected when combining both methods. According to this estimate only 0.390 ±0.647 sharks were missed by both the reviewer and the observer.

Table 13: Estimated detection for EM reviewer and observer by trip

Trip#	Observer Count	EM Count	Number of Matches	Estimated total catch	Estimated Variance	Total Unique Records
1	74	72	72	74.000	0.000	74
2	163	167	161	169.074	0.077	169
3	0	6	0	6.000	0.000	6
4	6	5	5	6.000	0.000	6
5	1	1	1	1.000	0.000	1
6	3	2	2	3.000	0.000	3
7	16	18	16	18.000	0.000	18
8	29	28	28	29.000	0.000	29
9	2	1	1	2.000	0.000	2
Total	294	300	286	308.390	0.42	308

3.4.5 Life Status Comparisons

EM reviewers' assessment of shark movement as a proxy for life status matched the observer life status on 52% of the comparisons with sharks recorded as "moving-alive" accounting for 88% of the agreements (Figure 11). Of the comparisons where movement and life status did not match, 51% were recorded by the reviewer as "not moving" and 37% as "unknown."

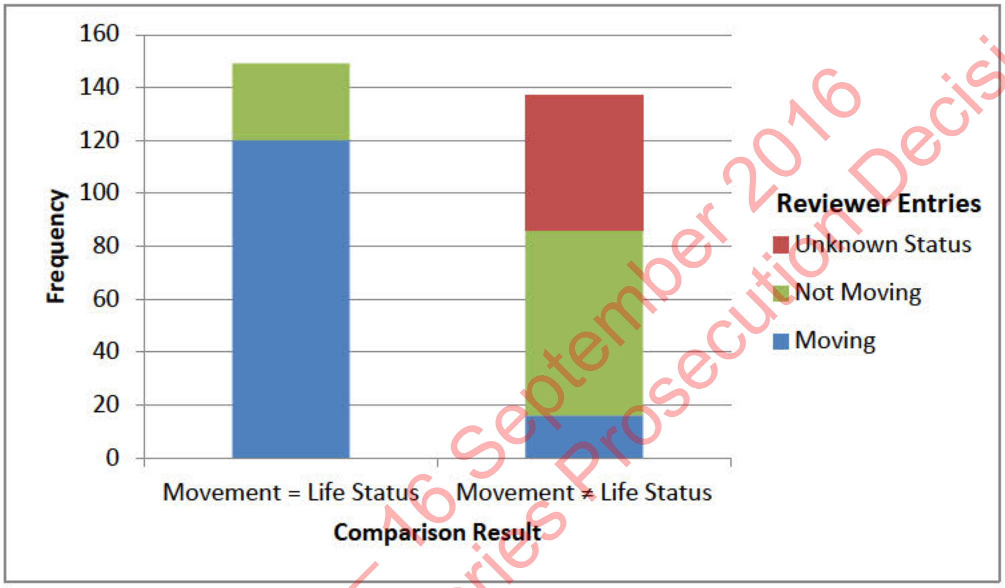

Figure 11: Comparison results for movement as a proxy for life status.

3.5 Video Review Time

A total of 155 hauls were reviewed for protected species interactions only. The review was completed in 397 hours resulting in an analysis ratio of 0.17. This means that, on average, it took 10 minutes to review one hour of hauling (Table 14).

Table 14: Number of hauls reviewed for protected species only, their duration, and associated video review time and analysis ratio.

Vessel Name	Hauls Reviewed	Haul Duration (hours)	Viewing Time (hours)	Data Analysis Ratio
Vessel A	24	72	15	0.21
Vessel B	35	75	12	0.16
Vessel C	43	112	18	0.16
Vessel D	33	85	12	0.14
Vessel E	1	3	1	0.16
Vessel F	19	50	8	0.17
Total	**155**	**397**	**66**	**0.17**

The factor that affected review time the most was gear drifting out of camera view at the roller camera. This caused difficulties tracking catch items and required the viewer to slow down to ensure that catch was accounted as best as possible. The second largest impact on reviewing time was the amount of catch in a haul. Both of these factors affected review time for protected species and proxy species although they had a greater effect when reviewing for proxy species. Finally unusable data quality on one of the vessels due to inadequate lighting resulted in reduced review time substantially as the reviewer was not able to see anything other than what was handled on the deck.

4.0 Discussion

4.1 System Performance

EM systems operated well on the participating vessels. At the beginning of the project there were some issues that resulted from not taking into account the standby power draw of the EM system and the negative effect that it could have on these vessels given that they are not connected to shore-power when docked. Once this issue was resolved there were no EM system performance issues preventing complete EM data collection. Furthermore there were no major technical issues during installs and services, which confirmed previous findings that EM is suited for inshore set net vessels (Kindt-Larsen *et al.*, 2012; McElderry *et al.*, 2007).

Camera installation was the most challenging aspect of setting up the EM systems. Lack of existing structures to install the roller view camera meant that temporary camera mounts were necessary on four vessels to achieve a high enough camera angle to monitor catch that may drop off the gear before coming onboard, while at the same time avoiding any interference with the net or offload activities. A camera mount that was higher or further out would have led to better hauling imagery, but it wasn't feasible given the net activity and the design of the boats at the stern.

Further improvements to camera views could be made on some vessels, in one vessel in particular, by extending the roller camera outboard to allow for a better angle of view of the gear coming out of the water and onto the roller. Unfortunately there was not enough time in the project, before set net fishing activity concluded for the season, to follow up with the captain with regards to improving the camera set up.

Installing cameras in an outboard manner can be challenging as there is a greater risk of damage to the system during fishing, transit, and offloading. In cases where it is not possible to get an optimal camera view where the gear will stay in view, it is possible that adding an extra camera at the roller station could help cover the gear retrieval area; however, the advantage of an outboard view is that it helps observe the gear when it is coming up vertically. Increasing the involvement of the skipper in designing the most appropriate configuration for their boat allows transferring the burden of proof to the skipper, who has a high level of control over gear retrieval and catch handling, from the EM technician or regulatory government agency, which has little or no control over these matters.

4.2 Monitoring Coverage

4.2.1 Trip level

A total of 1,457 hours of sensor data were collected encompassing 160 fishing trips. Of these, 26% had complete data for the trip. One of the participating skippers in particular provided very high data completeness throughout the project. For the other vessels, data completeness was mainly affected by skippers not turning on their EM system for the entire duration of the trip. Four skippers consistently had their system off for extended periods of time, including when transiting to and from the fishing grounds, and sometimes when setting gear. For the majority of these trips (73%) one complete haul was documented by EM and it is likely that fishing was completely accounted for given that for most of the trips in this fishery vessels only complete one fishing event. However, extensive EM data gaps during a fishing trip are problematic as they do not allow for a full reconstruction of the fishing trip, which means that it is not possible to ensure that all fishing activity was monitored. Additionally, these gaps increase the risk of extending into hauling activity either by not turning the EM system back on before the haul starts or turning it off before it ends, which was the case for 18 hauls during the project.

Given that the engine is running during transit to and from the fishing grounds there should not be any concerns with regards to providing power to the EM system as, with a proper power system onboard, the batteries on the vessel are being changed by the engine. Extended gaps during fishing trips were related to behaviour rather than technical constraints. It is often the case during pilot studies for skippers to either forget to turn on the system when leaving dock or simply not be aware of the imperative need to power the system for the entire trip (Batty, A. *et al.*, 2011; Pria M. J. *et al.*, 2011).

Even though skippers were reminded in several occasions to keep the EM system on, in our experience it often takes time for some skippers to change their behaviour, in particular when they are participating in a project on a volunteer basis. Behaviour change can be achieved with outreach to explain the need to have complete data and it is dependent on the motivation of the skippers to show their compliance to monitoring. It is imperative that a standard for 100% data collection from start to end of the fishing trip be established to ensure full monitoring of all fishing activity.

Most skippers turned off the vessel's engine while the gear was soaking. A consideration is that keeping the EM system on during this time may drain the vessel's battery. This issue has been addressed since the installation of EM systems for this project. The EM system now has the added capability to enter into a power saving mode, known as sleep mode, when the main engine is not running. An oil pressure switch installed in the vessel's engine and connected to the EM control center can automatically put the system in and out of sleep mode in concert with the main engine power cycle.

4.2.2 Haul Level

Overall, 133 hauls and 207,075 meters of net were fully monitored with varying grades of image quality. Ninety five hauls (71%) had high or medium image quality and 38 (29%) had low image quality. An additional eight hauls were reviewed but considered to be unusable due to inadequate lighting and hence not included in the total net length monitored. The criterion used to differentiate low and unusable hauls was the degree to which the gear was visible throughout the haul. In the unusable hauls the gear was never visible when breaking the water and coming onto the vessel and it was difficult to see catch items on the deck. We considered that it was possible to detect a dolphin if it was landed on the deck and so the hauls were reviewed in case a dolphin was detected.

In comparison, in the low image quality hauls the gear was often out of view or difficult to see, but not for the entire haul, and the deck view allowed for confirmation if a protected species was landed on deck. Although this distinction between low and unusable is convenient from a data analysis point of view (it is easy to distinguish and hence highly repeatable) it may not truly represent the difference between a fully monitored and partially monitored haul from the point of view of calculating monitoring coverage.

An additional 20 hauls had usable data quality but were incomplete. These hauls were also reviewed for protected species captures. However it was not possible to calculate coverage percentage as the amount of net length missed was unknown. Although data from usable but incomplete hauls is useful, it is challenging to include in coverage levels. The best way to resolve this issue is to avoid incomplete data in the first place; nonetheless it is advisable to develop a way for incorporating the data gathered from incomplete hauls when they do occur.

4.3 Protected Species Detection

There was one confirmed Hector's dolphin capture. During this event the dolphin was very obvious in the camera views from the time it came out of the water. Identification was easy as these dolphins are very distinct. Through EM data analysis it was possible to obtain the date and time of capture as well as the location. Based on these results, we confirm previous findings by McElderry et.al. (2007) that EM is capable of detecting Hector's dolphin captures.

Using the estimated net length from complete hauls with usable data, the result is that one dolphin was observed over 207, 075 meters of net. Additionally two seabird captures were confirmed. Seabirds were not attempted to be identified to species but identification to species group was possible. The available metadata for these captures was the same as for the dolphin: date, time and location of capture were recorded. Furthermore it was possible to observe the manner in which the birds were released.

There were two instances in which, although a protected species capture could not be confirmed, we observed unusual or unexplained behaviour that may be considered evasive action on the part of the skipper and crew to avoid EM video recording a catch item. One additional event may have been a gear tangle but could not be confirmed from the video, likely due to the fact that the roller camera view was not functioning for that trip. The unusual and unexplained behaviour observed can be grouped into two categories: creating a gap in the data record and gear/catch handling to obscure what was caught. From a perspective of administering a monitoring program and behaviour modification, interpretation of these events can be difficult as in some cases intent has to be inferred. It is possible to remove the need to decipher intent by transferring the burden of proof to the skipper by establishing the expectation is that there must be full data completeness and that the gear and any catch items must always be in camera view.

From a perspective of wanting to quantify dolphin mortality in the fishery, the instances where a dolphin capture is suspected could be considered proxies for dolphin captures if the intent is to be conservative in the estimation of dolphin mortality.

4.4 Proxy Species Comparisons

The overlap of proxy species records from the observer and EM reviewer data sets was very high at 93%. Image quality did not seem to bias the results. Seven of the nine trips analyzed had high image quality. One of the trips analyzed had medium image quality and the other had low image quality. As expected, the medium quality did not seem to interfere with detection of catch by the EM reviewer; for this event the EM reviewer detected more catch than the observer did. Results from the low image quality haul were similar as those from other hauls with high quality image data.

Catch length also did not seem to have a strong effect on overall catch detection by EM reviewers. Of the catch items missed by the reviewer, only one was in the smallest length category (0-49 cm). Most of the pieces missed by either method fell in the 50-99 cm category— the most common length category recorded in the overall data for both methods.

It is of particular interest to understand how likely EM reviewers are to detect catch items that drop off from the net. The results show that EM reviewers are able to detect drop-offs when the gear is in view; however, the detection for these may be influenced by how many catch items are on the net at a time, in particular when they are the same species. During this project there were a total of five items that dropped off the net before coming onboard. One was detected by both the EM reviewer and observer, one was only detected by the EM reviewer, and three were only detected by the observer. During a second review, it was possible to see two drop off items originally missed by the reviewer. The third drop off was not visible and it is likely the result of the gear being hauled in at an angle and partially out of view. Size did not seem to be a strong factor as two of these items were recorded as being 50-99 cm and one as 100-149. Catch volume likely played a role in missing the two drop offs that were later confirmed on the EM video as there was a lot of catch coming up during this time and they were all the same species. Slowing down the video further during these times may help in increasing drop-off detection.

Using Chapman's population size estimate for every trip analyzed we determined that the number of catch items missed by both observer and EM reviewer are negligible (ranging from zero to 0.074). This result was further confirmed by pooling the data from all trips to calculate the total number of sharks caught (estimated sharks missed out of 308 were 0.390). We believe that this analysis, albeit somewhat crude, offers enough insight at this time on the reliability of using EM data for detecting catch items. A more rigorous analysis for estimating total sharks captured could be carried out; however, the catch pairing method is going to be the limiting factor in the accuracy of any analysis. For this project we did not have time data for observer entries resulting in the catch pairing method to be strongly based on species identification—something that was not designed to be tested directly. A data collection methodology where observer catch entries contain a time-stamp would allow a much stronger pairing method with EM reviewer data.

A total of 308.390 sharks were estimated to have been captured. Three hundred were detected by EM reviewer and 294 by the observer method. This corresponds to a detection rate of 97.1% ± 0.2% (approximate 95% confidence limits) for the EM reviewer method and 95.3% ± 0.2% (approximate 95% confidence limits) for the observer method. Removing the trip where the observer recorded no sharks captured would make the observer method detection rate the same as the EM reviewers'.

Using movement as a proxy for life status was shown to not be a very reliable method as only 52% of the records matched between EM reviewer and observer data. As expected, the results tended to match better when the EM reviewer recorded movement than when it recorded no movement. Furthermore, on 18% of the records the EM reviewer was not confident enough to make a movement assessment.

5.0 Recommendations and Conclusion

5.1 Recommendations

5.1.1 Installation Specifications

The data collection success of EM systems is highly dependent on the installation and setup of the system. The combination of camera views, sensor installation, and software settings are integral in determining when data are collected, and which variables are documented by the EM system. Based on the results of this study, and Archipelago's practical experience with similar fisheries and gear types (Pria *et al*., 2010; McElderry *et al*., 2007), we have developed recommended requirements for set net data collection.

Camera Placement

Camera placement on vessels monitored by EM is potentially the most important variable for successfully monitoring a fishery. The combination of a close-up camera view at the roller, capturing the gear coming out of the water and on to the vessel, and a wide-angle view of the deck where catch items are untangled provides a good combination for detecting and identifying catch items for most vessels.

Most vessels will have existing structures to secure deck view cameras that provide adequate views. Deck views need to provide unobstructed view of the deck and roller. If the vessel layout does not allow for this (due to a covered deck for example) additional cameras are needed to provide full coverage of the deck from the time a catch item is brought onboard.

Close-up roller views were best when the camera was slightly outboard as these views would allow reviewers to see the gear even when it was coming out close to the hull of the vessel. The ideal placement of the camera would be facing slightly inwards on a fabricated camera mounting pole mounted at a sufficient height and angle to minimize gear going out of view. The close-up roller camera should also cover any gear and catch handling by the roller in case it is necessary to untangle an animal or other catch before it is brought onboard and to allow differentiation of gear tangles and catch handling.

System Set-up Specifications

Based on the results of this study the ideal settings and conditions that should be used include:

- **Power**: system powered at all times from start of trip to end of trip with the option of system sleep. If powered by DC, the dedicated battery must be isolated from main power system;
- **Recording trigger**: hydraulics or rotation sensor activity;

- **Camera views**: (1) close-up view of the gear coming out of the water and roller, and (2) deck overview camera to confirm catch detection and make assessments on utilization, length and life status of Hector's dolphins and other protected species. Deck overview may require more than one camera if the view of the deck from above is obstructed.
- **Camera type**: digital cameras for roller views; and digital or analog cameras for deck views.
- **Recording run-on**: 30 minutes – sufficient for continuing recording during breaks in hauling due to gear problems and allowing video recording to turn off soon after hauling has ended.

Under this set up, video recording would occur during setting and hauling activity; however, only the video for hauling activity would be reviewed.

5.1.2 Captain Responsibilities

In order to obtain the best possible data, it is crucial that the skipper be responsible to providing such data. Skipper responsibilities should include:

- Keep the EM system powered for the entire fishing trip, from untying at the dock to tying up at the dock.
- Monitor the EM system performance via the monitor provided. Complete a function test of the system on each fishing trip (prior to fishing).
- Ensure that the cameras are clean and aimed properly before every haul.
- Report any problems or concerns that affect the EM system data collection to the EM technician so they can be addressed promptly.
- Provide prompt and efficient vessel access to EM technicians to remove data and service EM equipment. Provide fishing activity updates to the EM technician when requested.
- Work with program staff to develop adequate camera views and onboard catch and gear handling methods to ensure that all hauls can be properly monitored for dolphin captures: i.e. the captain is responsible for ensuring that gear is always in camera view.
- Report any unusual activity to program staff.

5.1.3 Develop EM Methodology

As an EM program is developed within the set net fishery, there are several elements that must be considered and planned in order for the program to succeed. These elements include a dedicated field services provider in the areas where vessels operate, the use of vessel monitoring plans, and a dedicated data services provider that can quickly review data and adequate feedback mechanisms between skippers, EM technicians, data reviewer and program staff to ensure full monitoring is being achieved.

5.1.3.1 *Field Services*

For this study, a technician was hired in the general region to provide support and conduct data retrievals as necessary. Future work should seek to increase the availability of trained technicians, and continue their training related to EM. This should involve developing:

- Installation and service standards; and
- Processes for giving and receiving feedback to data reviewers and fishers.

Well developed methods and standards will help to increase data collection success and enhance data quality for an EM program within the Timaru set net fishery.

5.1.3.2 *Vessel Monitoring Plans*

While operating an EM program, it is very important to develop clear communication procedures among all groups involved (i.e., field technicians, data technicians, program staff, and fishers). Vessel monitoring plans (VMPs) can be used to document the installation procedures and expected data that will be produced by a single vessel. VMPs were created during this project, but were not extensively used for communication. In future work, VMPs should be developed and contain three main components:

- Clear identification of the data needs of the monitoring program;
- Specifications about EM installation (camera views, sensors, triggers, etc); and
- Expected catch handling methods and duty of care standards that vessel personnel follow to ensure data collection success.

The use of VMPs as a communication tool can help to improve data quality by clearly defining the application of the system and the related expectations for fishers, field technicians, and data technicians.

5.1.3.3 *Data Services*

The data service provider has two main roles within an EM program, which include developing procedures, managing the overall data flow, and providing EM data output to regulators. During this study, many lessons were learned that can be applied to future work in order to assess a roadmap for developing local data analysis capacity. This work should focus on ensuring that the needs for local capacity building and ongoing data analysis are properly balanced and take into account tradeoffs between having a provider with existing capacity, like Archipelago, carry out the work versus building capacity.

During this project it was not possible to build local data services capacity due to administrative delays and a short fishing season. Instead, Archipelago staff took care of all data analysis and reporting activities. Although this resulted in no local capacity building, it allowed us to maintain a high level of control over the data review processes and reporting at a time when these were being applied for the first time in this specific environment.

Archipelago was able to take advantage of the fact that staff are already fully trained and have significant experience in EM data analysis, EM data management flow and feedback mechanisms. The effort that the local data services provider would have spent on building capacity was shifted towards better understanding the data collected, as well as dedicating more effort to supporting the EM field technician, providing project advice, and writing this report.

Now that the EM data analysis and reporting procedures have been developed, we would be in a better position to transfer that knowledge to a local service provider if needed. Future work in developing local data services provision should consider a reasonable timeframe to select an appropriate provider and slowly transfer responsibilities so that capacity building does not jeopardize attention to operational issues.

The EM data review process used in this project highlighted the need for continuing development in order to ensure that high quality protected species mortality data is garnered from the EM data. This includes:

- Reviewing data quality categories and standards to further define what constitutes a fully monitored haul and what does not;
- Formalizing QA/QC processes;
- Formalizing reporting of incidents related to protected species captures and fishing in closed areas;
- Developing a way for reporting and using the data available from partially monitored hauls;
- Developing methods for reviewers to quickly provide feedback to field technicians and fishers using the VMP as a reference point; and
- Assess the value of increasing data collection to include use of mitigation devices or practices.

If more proxy species data collection was required we recommend reviewing observer data collection methods to include time stamps, which would greatly improve catch item data pairing.

5.2 Conclusion: Feasibility of the EM System

The primary objective of this study was to evaluate the suitability of EM to gather information to estimate overall mortality/mortality rate of Hector's dolphins and other protected species, and provide information to quantify protected-species captures in the fishery. This project demonstrated that EM could be used to document Hector's dolphin and other protected species captures in the fishery with an overall detection rate of 97%.

Results of this project also demonstrated that EM could be reliably used to document fishing effort and location. There are two main challenges: motivating skippers to keep their EM system turned on for the entire duration of every trip, and ensuring that the gear remains in camera view for all hauls. We recommend that this be approached by shifting the burden of proof for providing complete, usable data to the skippers.

Further work to develop the methods and application of EM will be required to fully take advantage of the monitoring capabilities of EM in the future.

6.0 References

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Appendices

Appendix A: Proxy Species Observer Instructions and Logbooks

The following is an example of the referenced observer instructions and form used for proxy-species data collection during this project:

If you are on a vessel with electronic monitoring, you will be required to record information about sharks to help us assess the accuracy of the electronic monitoring in detecting captures. This is necessary because capture events can sometimes only be visible for a few seconds before the animal drops into the water before coming onboard.

You will need to consecutively count the number of sharks landed on deck or that fall out of the net during the first hour of hauling for the first fishing event of the day, noting whether the animals are alive or dead and providing separate counts for each species. Label sharks from one onwards for each separate observation period.

This fishery catches rig (SPO) and schoolshark (SCH) as well as occasional mako sharks (MAK), porbeagle sharks (POS), broadnose sevengill sharks (SEV) and thresher sharks (THR). All these species will need to be recorded if and when they are caught. In addition you may add any other shark species not mentioned.

You will need to note the time you start observing (the same time as the start of the hauling event) and the time you finish observing (one hour into the haul or once the haul finishes, whichever happens first). These times also need to be notified to the deck view camera by raising one arm in the camera view while looking at the camera when observations begin. Two arms raised while looking at the camera signifies the end of observations.

For these observations a fish is defined as landed once it comes over the side of the vessel. If it is released in the water before coming over the side of the vessel it has not been landed.

The exact start and finish times need to be recorded in your diary, as well as the exact counts of rig, schoolshark and additional species. Hauling observations take place in addition to your normal marine mammal and seabird observations. Only one hauling observation is required per day.

Page ___ of ___

Setnet Hauling Observations

1. Set information

Trip number	Voyage number	Set number

2. Hauling information

Start of haul	End of obs/haul
Date	

SPO	Rig	SEV	Sevengill
SCH	School shark	POS	Porbeagle
MAK	Mako	THR	Thresher

3. Catch information

No.	Species code	Alive (A), dead (D), unknown (U)	Outcome - ACC/REM/DIS/RET	Estimated length (m)	Comment

Outcome
ACC - whole fish accidently lost from net
REM - whole fish removed from net before landing
DIS - whole fish landed then discarded
RET - whole fish or part of fish retained by vessel

Estimated length (m)
0-49cm
1 - 50cm-99cm
2 - 100cm-149cm
3 - 150cm-199cm
4- >200cm

Appendix B: Species and Species Groups

The following species and species groups were available to the EM reviewer during video review. Not all categories were used.

Table 15: Protected species list available for this project

Preferred Common Name	Scientific Name
Hector's dolphin	Cephalorhynchus hectori
Bottlenose dolphin	Tursiops truncatus
Common dolphin	Delphinus delphis
Dusky dolphin	Lagenorhynchus obscurus
New Zealand fur seal	Arctocephalus forsteri
New Zealand sea lion	Phocarctos hookeri
Albatross (Unidentified)	Diomedeidae (Family)
Shag	Phalacrocoracidae (Family)
Gulls and Terns	Laridae (family)
Petrel (Unidentified)	Procellariidae (Family)
Penguins	Spheniscidae (Family)
Storm petrels	Hydrobatidae (Family)
Boobies and Gannets	Sulidae (family)
Petrels, Prions and Shearwaters	Hydrobatidae, Procellariidae & Pelecanoididae (Families)
Yellow-eyed penguin	Megadytes antipodes

Table 16: Proxy species list available for this project

Preferred Common Name	Scientific Name
Mako shark	Isurus oxyrinchus
Porbeagle shark	Lamna nasus
School shark	Galeorhinus galeus
Broadnose sevengill shark	Notorynchus cepedianus
Spiny dogfish	Squalus acanthias
Rig	Mustelus lenticulatus
Thresher shark	Alopias vulpinus
White pointer shark	Carcharodon carcharias
Northern spiny dogfish	Squalus griffin
Carpet Shark	Cephaloscyllium isabellum
Dogfish/Rig Shark Combo*	
Shark (Unidentified)	

Appendix C: Trip Data Completeness

Details by trip on data completeness.

Table 17: Colour coding legend

	Complete Data
	Incomplete Data
	No Data
	Not Applicable
?	Event May Have Occurred on a Different Trip

Vessel A

Table 18 Inventory of data captured for trips completed by Vessel A.

	Start	Transit	Set	Soak	Haul	Transit	Set	Soak	Haul	Transit	Return
07-Nov-12											
20-Nov-12											
22-Nov-12											
26-Nov-12											
27-Nov-12											
03-Dec-12											
04-Dec-12											
06-Dec-12											
09-Dec-12											
10-Dec-12											
11-Dec-12											
12-Dec-12											
11-Jan-13											
12-Jan-13											
14-Jan-13											
16-Jan-13											
21-Jan-13											
22-Jan-13											
28-Jan-13											
29-Jan-13											
30-Jan-13											
06-Feb-13											
07-Feb-13											

Vessel B

Table 19: Inventory of data captured for trips completed by Vessel B.

	Start	Transit	Set	Soak	Haul	Transit	Return
07-Nov-12							
08-Nov-12							
09-Nov-12							
10-Nov-12							
13-Nov-12							
15-Nov-12							
16-Nov-12							
17-Nov-12							
20-Nov-12							
21-Nov-12							
22-Nov-12							
25-Nov-12							
26-Nov-12							
27-Nov-12							
03-Dec-12							
04-Dec-12							
05-Dec-12							
06-Dec-12							
09-Dec-12							
10-Dec-12							
11-Dec-12							
12-Dec-12							
13-Dec-12							
14-Dec-12							
15-Dec-12							
16-Dec-12							
17-Dec-12							
19-Dec-12							
04-Jan-13							
11-Jan-13							
12-Jan-13							
13-Jan-13							
14-Jan-13							
16-Jan-13							
21-Jan-13							
22-Jan-13							
25-Jan-13							
28-Jan-13							
29-Jan-13							
30-Jan-13							
31-Jan-13							

Vessel C

Table 20: Inventory of data captured for trips completed by Vessel C.

	Start	Transit	Set	Soak	Haul	Transit	Set	Soak	Haul	Transit	Set	Soak	Haul	Transit	Return
27-Nov-12															
05-Jan-13									?						
06-Jan-13			?						?						
07-Jan-13			?						?						
07-Jan-13			?						?						
08-Jan-13															
12-Jan-13															
14-Jan-13															
15-Jan-13															
16-Jan-13															
18-Jan-13															
20-Jan-13															
21-Jan-13			?												
22-Jan-13															
25-Jan-13															
27-Jan-13															
29-Jan-13															
07-Feb-13															
08-Feb-13															
09-Feb-13															
10-Feb-13															
16-Feb-13															
19-Feb-13															
19-Feb-13															
20-Feb-13															
23-Feb-13															
26-Feb-13															
27-Feb-13															
01-Mar-13															
07-Mar-13															
08-Mar-13															
09-Mar-13															
12-Mar-13															
14-Mar-13															
15-Mar-13															
20-Mar-13															
25-Mar-13															
05-Apr-13															
06-Apr-13															
08-Apr-13															

Vessel D

Table 21: Inventory of data captured for trips completed by Vessel D.

	Start	Transit	Set	Soak	Haul	Transit	Set	Soak	Haul	Transit	Return
07-Nov-12											
08-Nov-12											
09-Nov-12											
10-Nov-12											
15-Nov-12											
20-Nov-12											
21-Nov-12											
22-Nov-12											
25-Nov-12											
27-Nov-12											
04-Dec-12											
05-Dec-12											
06-Dec-12											
09-Dec-12											
10-Dec-12											
11-Dec-12											
12-Dec-12											
13-Dec-12											
15-Dec-12											
16-Dec-12											
04-Jan-13											
11-Jan-13											
21-Jan-13											
23-Jan-13											
25-Jan-13											
28-Jan-13											
29-Jan-13											
30-Jan-13											
31-Jan-13											
07-Feb-13											
08-Feb-13											
14-Feb-13											
15-Feb-13											

Vessel E

Table 22: Inventory of data captured for trips completed by Vessel E.

	Start	Transit	Set	Soak	Haul	Transit	Return
14-Jan-13							
16-Jan-13							
11-Feb-13							

Vessel F

Table 23 Inventory of data captured for trips completed by Vessel F.

	Start	Transit	Set	Soak	Haul	Transit	Return
08-Nov-12							
09-Nov-12							
13-Nov-12							
15-Nov-12							
16-Nov-12							
20-Nov-12							
21-Nov-12							
22-Nov-12							
25-Nov-12							
27-Nov-12							
05-Dec-12							
06-Dec-12							
08-Dec-12							
10-Dec-12							
11-Dec-12							
12-Dec-12							
13-Dec-12							
16-Dec-12							
19-Dec-12							
11-Jan-13							

Appendix D: Haul Data Completeness and Image Quality

Details by vessel on haul data completeness and image quality.

Vessel A

Image quality	Complete Hauls	Incomplete Hauls	Total
High	13	1	14
Medium	5		5
Low	4	1	5
Unusable			0
Total	22	2	

Vessel B

Image quality	Complete Hauls	Incomplete Hauls	Total
High	13		13
Medium	5		5
Low	22		22
Unusable			0
Total	40	0	

Vessel C

Image quality	Complete Hauls	Incomplete Hauls	Total
High	15	1	16
Medium	4		4
Low	13	1	14
Unusable	8	1	9
Total	40	3	

Vessel D

Image quality	Complete Hauls	Incomplete Hauls	Total
High	3	5	8
Medium	14	10	24
Low		1	1
Unusable			0
Total	17	16	

Vessel E

Image quality	Complete Hauls	Incomplete Hauls	Total
High	1		1
Medium	2		2
Low			0
Unusable			0
Total	3	0	

Vessel F

Image quality	Complete Hauls	Incomplete Hauls	Total
High	15		15
Medium	4		4
Low			0
Unusable			0
Total	19	0	