Ministry for Primary Industries
Manatū Ahu Matua

Using Electronic Monitoring to Document Snapper Discards and Validate Catch effort Data

New Zealand Fisheries Assessment Report 2016/57

M.J. Pria,
J.P. Pierre,
H. McElderry,
M. Beck,

ISSN 1179-5352 (online)

ISBN 978-1-77665-410-9 (online)

October 2016

New Zealand Government

Growing and Protecting New Zealand

Requests for further copies should be directed to:

Publications Logistics Officer

Ministry for Primary Industries

PO Box 2526

WELLINGTON 6140

Email: brand@mpi.govt.nz

Telephone: 0800 00 83 33

Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries websites at:

http://www.mpi.govt.nz/news-resources/publications.aspx

http://fs.fish.govt.nz go to Document library/Research reports

Contents

Executive summary

Pria, M.J.; Pierre, J.P.; McElderry, H.; Beck, M. (2016). Using Electronic Monitoring to Document Snapper Discards and Validate Catch effort Data.

***New Zealand Fisheries Assessment Report 2016/57*. 38 p.**

The snapper (*Pagrus auratus*) fishery in quota management area one (SNA 1) is New Zealand's most valuable inshore finfish fishery. When the sustainability and management controls of the SNA 1 fishery were reviewed in 2013, wastage within the commercial fleet was identified by stakeholders as an area of concern. Of particular concern was the lack of information relating to how much snapper below the minimum legal size (MLS) was being returned to the sea. The Ministry for Primary Industries (MPI) contracted the services of Archipelago Marine Research Ltd. to examine the feasibility of electronic monitoring (EM) technology as a viable monitoring tool for estimating the amount of snapper returned to the sea and validating the estimates on the vessel catch effort data.

EM systems were installed on five vessels. Vessel operators were asked to batch sub-MLS snapper into specific bins in camera view and discard the snapper exclusively at pre-agreed discard points. EM imagery data was reviewed for catch sorting operations and bin fullness was recorded to estimate total undersize snapper discard weight per tow. Vessel operators were also required to record an estimate of snapper discard weight in their catch effort returns for comparison with EM estimates.

EM data were collected for a total of 101 trips and 1187 tows across all five vessels, of which 392 were randomly selected for review to estimate sub-MLS snapper discards. Overall, sub-MLS snapper discards were observed in 59% of the reviewed tows. Snapper discards were less than 15% of the total snapper captured in 68% of the 162 tows.

Catch effort estimates of snapper discards at the individual tow level were strongly correlated with EM estimates for all vessels (*r* ranged from 0.78 to 0.96) but underestimated discards. Underestimation varied by vessel, with Vessels 2, 3, 4, and 5 underestimating by 20% to 30% and Vessel 1 underestimating by 70%, relative to EM estimates.

EM sensor data was captured for 90% of the reported tows as compared with catch effort return data. Missed tows were caused by technical issues and skippers forgetting to power on the EM system. Imagery data were successfully collected for 70% of the 392 tows randomly selected for review. Imagery collection success was affected by implementation challenges early in the trial and, to a lesser degree, technical issues.

This trial was successful at developing a basic methodology for equipment set-up and catch-handling requirements, while helping to establish data review protocols for estimating snapper discards. It also provided initial verification that catch effort data tend to match EM snapper discards in situations where sub-MLS snapper are binned before being returned to the sea. More broadly, this project builds on the past decade of pilot studies of EM in New Zealand inshore fisheries, demonstrating the efficacy and potential of EM in meeting a diversity of monitoring objectives.

The results from this trial indicate that an EM programme would effectively assist MPI and SNA 1 Commercial efforts to develop accurate catch monitoring in this fishery. However, it is imperative that vessel operators follow the catch handling protocols developed in order to obtain reliable EM sub-MLS snapper discard estimates. Deviating from the protocols (e.g., discarding outside of the control points, mixing snapper with other species, etc.) contributes to imprecision and bias in the EM estimates.

Furthermore, not having a systematic way of handling catch, especially when dealing with large catch volumes, could also make it difficult for skippers to keep track of large amounts of sub-MLS snapper discards.

The key next step is to maintain effort in EM data collection and port infrastructure. Other next steps need to focus on developing a holistic EM programme design that will meet the information needs of the SNA 1 fishery, while identifying an optimal balance between data quality, data turnaround, and cost.

1.0 INTRODUCTION

The snapper (*Pagrus auratus*) fishery in quota management area one (SNA 1) is New Zealand's most valuable inshore finfish fishery and it is utilised by customary Māori, recreational, and commercial sectors (MPI, 2013). Snapper is managed under the New Zealand quota management system (QMS). Current regulations that apply to the commercial take of snapper in SNA 1 require that snapper larger than the minimum legal size (MLS) of 25 cm must be retained and landed while any undersized specimens (sub-MLS) must be discarded (MPI, 2013).

When the sustainability and management controls of the SNA 1 fishery were reviewed in 2013, wastage within the commercial fleet was identified by stakeholders as an area of concern (MPI 2013). Of particular concern were the lack of information in regarding the amount of snapper discards in the inshore trawl fleet.

To help address these issues, the commercial industry, represented by the SNA 1 Commercial group, worked with the Ministry for Primary Industries (MPI) to improve the fishery-dependent data for the inshore trawl snapper fleet fishing in SNA 1. This involved two components:

- Improving fisher-reported data by having skippers record the weight of undersized snapper discards for each tow in their catch effort returns.
- Increasing monitoring through the use of electronic monitoring technology. The intent was to support the monitoring coverage targets set for the fishery of 25% of the effort of the SNA 1 fleet by 1 December, 2013, 50% coverage by October 1, 2014, and 100% coverage by 1 October, 2015 (MPI and SNA 1 Commercial, 2013).

Electronic monitoring (EM) is being trialled or is operational in many fisheries around the world. It is implemented as an alternative and/or a complement to onboard human observers (Mangi et al. 2015; McElderry, 2008). The EM systems, developed by Archipelago Marine Research Ltd. (Archipelago), incorporate technology that has proven successful in monitoring fishing activity and collecting fisheries-related data across a range of applications for more than a decade (McElderry, 2008). Each EM system consists of a centralized computer control centre that records data on an array of sensors and cameras, and provides information on key aspects of the fishing operations such as vessel location, vessel speed, equipment activity and catch sorting and stowing.

The Ministry for Primary Industries (MPI) contracted the services of Archipelago to examine the feasibility of EM technology as a viable monitoring tool for estimating snapper discards and validating catch effort data.

1.1 Goal and Objectives

The overall goal of the project was to examine the efficacy of EM for verifying catch effort data of weight estimates of sub-MLS snapper discards[1]. Specific objectives of the project can be summarised as:

- Summarise EM equipment performance;
- Develop EM onboard methodologies specific to this fishery, including equipment set-up, catch-handling requirements, and data processing protocols to estimate snapper discard weights per tow from EM imagery; and
- Summarize results of a comparison of the EM and catch effort data.

[1] Note that discarded snapper were not verified as being sub-MLS as part of this trial. See Section 4.2 for a discussion of this topic.

1.2 Scope

The project included the development of individual vessel monitoring plans (IVMP) that specified the EM installation requirements for the vessel and involved in-season feedback to MPI and vessel owners on actions to improve data quality. Archipelago was also required to build local capacity by training local field and data technicians and provide overall project advice on all aspects of the project.

2.0 MATERIALS AND METHODS

As part of the trial, MPI nominated ten vessels for coverage with EM systems. Of these ten vessels, five were assigned to Archipelago. The remaining five vessels participated in a parallel trial led by Trident Systems (Middleton et al., 2016). The ten vessels were selected based on their catch profiles, fishing companies and geographical location. In the previous fishing year they also accounted for the majority of the trawl-effort targeting snapper in SNA 1 and over 70% of the landed SNA 1 catch. The results from the Trident trial are reported elsewhere.

Starting in January 2014, MPI and SNA 1 Commercial led a series of planning meetings that included representatives from Archipelago and Trident Systems. During these meetings, a general trial methodology was developed:

- All catch was to be brought aboard for sorting;
- All sub-MLS snapper was to be batched in specific bins before being discarded;
- All discarding was to occur in camera view from one or two discard control points, to be agreed on with the vessel owner.

A memorandum of understanding (MOU) was developed between SNA 1 Commercial and MPI to set the terms of engagement of the vessels participating in the trial (MPI and SNA 1 Commercial, 2013). The trial methodology described below was based on the terms described in the MOU. In particular, the MOU specified that:

- EM imagery data were to be encrypted;
- Imagery recording was to occur for the entire trip, (i.e., port-to-port and 24 hours a day, seven days a week);
- At least two cameras were to be deployed (general overview and detailed view of discard points);
- Fish were to be discarded from no more than two points within the unobstructed view of the camera;
- Sub MLS snapper discards were to be batched to allow quantification for each tow;
- The purpose of imagery recording was to capture all catch sorting and discarding events; and
- All discards were to be reported in kilograms (kg).

2.1 Project Partners and Roles

The project sponsor (MPI) was responsible for overall programme direction, and served as the main contact with vessel owners. This work included securing vessels to participate in the programme, ensuring vessels were able to carry EM equipment, and leading outreach with industry.

SNA 1 Commercial, a working group of commercial fishers, quota owners, and Licensed Fish Receivers (LFRs) in SNA 1, provided advice and support on programme direction.

Archipelago was responsible for the day-to-day coordination of the project, providing advice on the programme design, training the local field and data technicians, overall data analysis and reporting.

Ongoing maintenance of the EM systems in the port areas was provided by local field technicians 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.

Archipelago subcontracted Johanna Pierre Environmental Consulting Ltd. to provide programme advice, and to complete a portion of the data processing locally in New Zealand.

2.2 Field Operations

Archipelago staff and the local field technicians installed the EM systems in late February, 2014. Technicians met with each vessel representative (i.e., vessel owner or fleet manager depending on the vessel) to discuss the installation and use of the EM system.

Data collection began in late March or early April, 2014, depending on when each vessel representative signed the MOU. Data collection was planned for six months and ended at the end of August 2014. EM systems were removed in October 2014.

Vessels ranged in length from 15.4 to 18.2 meters.

EM systems were installed on five vessels; two in Auckland and three in Whangarei. Subsequently, vessels were serviced in these ports as well as in Totara North because one vessel relocated partway through the trial.

EM technicians visited the vessel within one week of each vessel's first EM trip to verify the EM system setup. EM technicians then visited the vessels on a regular basis to retrieve data and check the EM system's functionality. Additional services were provided as needed to address any issues or concerns about the monitoring equipment.

Data retrieval schedules varied by vessel depending on the amount of data collected. The original plan was to visit the vessels monthly and collect data on 500 GB hard drives, both measures intended to reduce programme costs. However, initial data collection showed that the hard drives could be filled in less than a month. Hard drives were then changed to 1 TB capacity and data retrievals were scheduled on a biweekly basis for vessels with particularly high levels of fishing activity. This ensured data collection continuity.

To protect their privacy, participating vessels were identified using a vessel ID in this report, rather than the vessel name.

2.2.1 Individual Vessel Monitoring Plans

Meeting the data requirements relied on understanding the combination of catch-handling protocols and EM system configurations. The primary data needs that drove the standards for catch handling and equipment installation were the need to verify that discarding had occurred within the designated control points, and the requirement to estimate the amount of sub-MLS snapper by observing what was in the bins being discarded and assessing how full they were. EM reviewers did not estimate the length of snapper being discarded but assumed they were sub-MLS snapper.

Catch-handling and equipment installation standards were documented in the IVMP. The IVMP is a communications tool designed to help vessel representatives/skippers, EM field technicians, EM data reviewers, and project coordination staff to understand their roles for a successful implementation.

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

- General vessel information;
- Skipper responsibilities;
- EM system configuration:
  - General description of the type of data being recorded, and
  - Location and objective of each EM system component (including camera views);
- Catch-handling protocols:
  - Catch sorting, and
  - Discard control points;
- Diagram of the vessel; and
- Software configuration specifications (for EM technician reference).

2.2.2 Electronic Monitoring System

The EM systems were designed and manufactured by Archipelago in Victoria, BC, Canada, specifically for the purpose of monitoring and collecting fishing-activity data at sea.

The EM system consisted of an EM Observe™ v4.5 control centre with an array of digital 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, collected high-frequency sensor data every ten seconds throughout the entire trip, and recorded imagery data.

Skippers were to power EM systems on at departure from port and only power them off upon return to port. The EM systems operated independently and were set to record imagery using a geo-fencing feature in the EM Record software. At the time of installation, the EM technician configured the EM system to record imagery whenever the vessel was inside of the SNA 1 quota management area (QMA). Imagery data recording was triggered by geo-fencing, and began immediately inside the SNA 1 QMA, and would stop ten minutes after the vessel went into a different QMA or entered the port area.

Imagery and sensor data were encrypted and stored digitally on a removable hard drive.

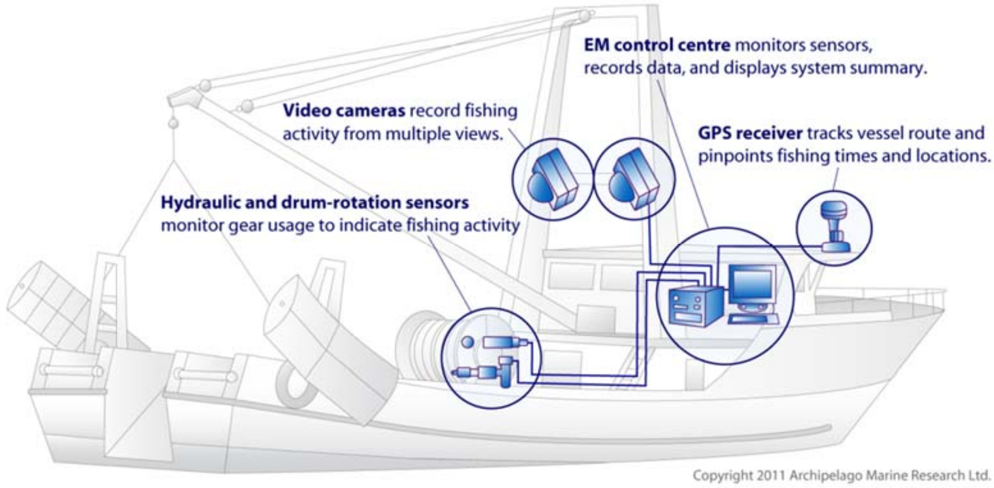


Figure 1: Schematic of a standard EM Observe v4.5 system used during this study.

2.2.3 Onboard Methodologies and Camera Views

Catch Handling

Vessels had slightly different methods for how the catch was brought on board, sorted and discarded or stowed. However, crews generally sorted catch on deck. Retained catch was batched into bins and stowed in the hold or in containers on the deck and sub-MLS snapper was batched in bins and discarded over the side rails or stern usually once all catch was sorted. Other discarded catch such as porcupine fish (*Allomycterus jaculiferus*), skates and rays, and kingfish (*Seriola lalandi*) was generally discarded individually during sorting.

The main exception to the catch handling protocol described above was Vessel 1, on which the codend was sometimes emptied down the central hatch into the hold. In this situation, catch sorting took place below deck out of camera view. Discards, including sub-MLS snapper, were batched in bins, brought up through the centre hatch, and discarded over the rails.

Camera Views

Camera placement varied by vessel depending on the vessel configuration and catch-handling practices. Three cameras were used per vessel, with the exception of one vessel for which vessel size and layout required four cameras.

There were two general camera configurations. The first consisted of a general deck overview, and close up views of the catch sorting areas and discard control points (Figure 2). This configuration was used on Vessels 1, 3 and 5.

Figure 2: Example of the first general camera configuration used. Clockwise from top left: view of the trawl net coming in on the stern; deck overview; starboard catch sorting and discard control point area; and port catch sorting and discard control point areas. The fourth camera was used to provide a close up view of the port slurry bin in case it was used to sort catch.

The second general configuration, for Vessels 2 and 4, did not have a deck overview but instead had a camera view covering the area off the stern of the vessel to observe the trawl net coming onboard as well as two cameras covering the deck where catch was sorted, discarded and stowed (Figure 3).

Figure 3: Example of the second general camera configuration used. Clockwise from top left: port side catch stowage area; starboard catch sorting and discard control point areas; and view of the trawl net coming in on the stern.

All cameras were mounted to existing superstructure on the fishing vessels. Vessel representatives provided guidance as to where the cameras could be mounted and were least likely to be damaged or have views obscured during regular vessel operation.

2.3 EM Data Review and Analysis

2.3.1 Sensor and Image Data Interpretation

After the EM data were retrieved from a vessel they were passed to a group of EM reviewers, who were responsible for data review and analysis.

The EM data sets were reviewed using the Archipelago EM Interpret^{TM} Pro software, a specialized software package designed to help the reviewer quickly process, evaluate, and report on fishing activity. The EM Interpret™ Pro software integrates thousands of imagery, sensor, and GPS records into a single synchronized profile, and presents it along a common timeline. This allows reviewers to quickly follow cruise tracks, review fishing events times and locations, and verify catch handling. 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 secondary processing.

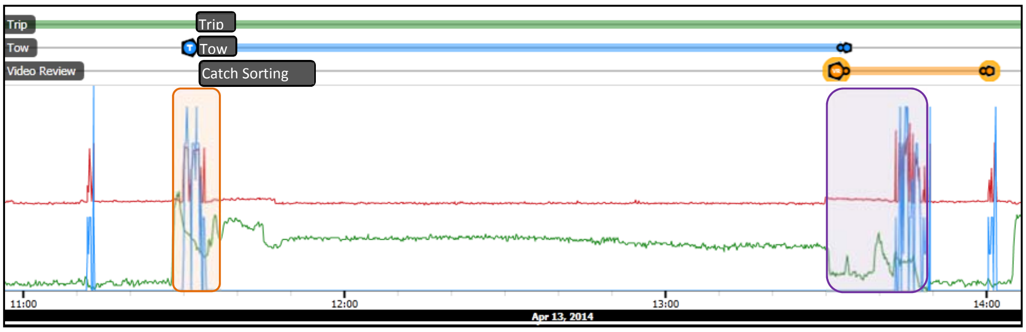


Figure 4: Example of typical sensor data signature for a tow. Sensor information is shown on a timeline with speed in green, winch rotation in blue, and hydraulic pressure in red. A typical trawl shot signature (highlighted in orange) consisted of high winch rotation counts and hydraulic pressure. Vessel speed and hydraulic pressure would remain relatively constant while the trawl was towed. During gear haul-back (highlighted in purple) the vessel would slow down followed by high winch rotation counts and hydraulic pressure.

Reviewers examined all EM data to check that sensor and imagery data recording was complete, to identify individual fishing trips, and to identify the time and location of all fishing events. Each fishing event was comprised of four time periods: trawl shot; towing; gear haul back; and catch sorting (Figure 4). For selected tows, imagery data were reviewed from the end of the tow to the end of catch stowage. For the purpose of this report we use the term "tow" to refer to the entire fishing event, as opposed to only the period when the trawl net was towed.

Reviewers randomly selected thirty percent of the tows identified in the sensor data per trip, with a minimum of one tow per trip for imagery review. If the selected tows were unusable or had no imagery data (see below for definitions), replacement tows were randomly selected from the pool of remaining usable tows in the trip.

Three EM reviewers were assigned to process the imagery data for this trial. Imagery review consisted of watching catch sorting operations which were defined as the time from the end of the tow (to observe if all catch was brought on deck), until all catch on deck was seen stowed above or below deck and discarding seemed to be complete. In cases where catch was sorted out of camera view (below deck), the imagery reviewer would watch until either the fish were brought into camera view for release or until the trawl doors came up at the end of the following tow (note that reviewers did not watch video collected between catch sorting events).

To estimate sub-MLS snapper discards, reviewers documented the type and number of discarded snapper bins as well as the fullness of each. Three types of bins were observed (Table 1).

Table 1: Snapper discard bins types, dimensions and estimated weight when full.

Bin Type	Estimated Weight (kg)	Dimensions (L x W x D in cm)
Standard Iki	20	59.7 × 36.2 × 20.5
Sanford Standard	30	67 × 39 × 27
Non-standard	Unknown	Unknown

To estimate the snapper weight discarded, reviewers visually estimated fullness of each bin to the nearest 25% increment. A trace category was reserved for bins that were less than 10% full to avoid inflating very small discard amounts but was never required because snapper were discarded individually whenever there were only a few in a tow.

If the fish was not discarded using a bin, snapper discards were recorded as individual piece counts. These were converted to weight using a mean piece weight of 0.3 kg.

Estimated weights for standard bins and snapper discards were obtained from commonly assumed weights used by industry and approved by MPI for the purposes of this trial.

For snapper discards in non-standard bins, the snapper discarded weight was visually estimated.

Nine of a total of 291 bins observed were noted to contain a proportion of other species. These were flagged as "mixed species bins" but treated in the analysis as if the composition was 100% snapper (see Section 3.3.3 for a discussion of the potential bias).

The imagery reviewer also recorded discards of other species using the same methodology as snapper discards (i.e., bin counts with estimated fullness or piece counts of individual fish discards).

Incidents where discarding was seen to occur outside the control points documented in the IVMP were noted.

No attempts were made to obtain length measurements for discarded snapper or estimate retained weights for any species.

2.3.2 Imagery data quality

The quality of the imagery was assessed for tows selected for review based on whether the imagery data were complete and whether reviewers were able to reliably detect snapper discards, not only due to the clarity of the images but also based on catch handling being conducive to meaningful observations. Imagery quality for each reviewed tow was averaged across all cameras according to the following guidelines (see Figure 5 for examples):

- **High:** Imagery was very clear and the viewer had a good view of fishing activities. Focus was good, light levels are high and all discard activity was easily seen.

- **Medium:** Imagery was acceptable, but there may be some difficulty assessing discards. Slight blurring or slightly darker conditions hamper, but did not impede analysis.

- **Low:** Imagery was difficult to assess. Some camera views may not have been available. Imagery was somewhat blurred or lighting was inadequate. Some factors such as crew standing between the catch and the camera for extended period of time may have also occurred.

- **Unusable:** Imagery was available but poorly resolved or obstructed such that snapper discards and fishing activity could not be reliably discerned. There was no imagery from one or more cameras (but not all) and those camera views were critical to record snapper discards.

- **No Data:** No imagery available from any camera for the entire tow.

Figure 5: Examples of image data quality. Top left high quality, top right medium quality due to water on camera, bottom left medium quality due to low light, bottom right unusable quality due to colour saturation on the camera.

2.3.3 Imagery Data Review Time and Analysis Ratio

Reviewers were able to adjust the imagery playback speed from frame-by-frame to up to 16 times real-time speed as well as stop and go back at specific frames as necessary depending on the activity on deck. For example, imagery of crew sorting catch was generally reviewed at two to four times real-time speed but slowed down and reviewed frame-by-frame at specific times to confirm discards.

The time required to review the catch sorting for each tow was recorded to calculate the amount of imagery review effort for estimating snapper discards. An analysis ratio was calculated by dividing the hours of real-time imagery by the time taken to review it.

2.4 Reporting

Throughout the trial, results for each vessel were provided to the vessel owners and to MPI via a monthly summary report within six weeks after month-end. The monthly summaries included an update on system performance, trips and tows reviewed, data collection and completeness, observed snapper discards in bins and as individuals, observations that did not meet the IVMP, and recommendations to increase data quality.

Catch effort data were not available in a timely manner in-season so EM vs. catch effort comparisons were not included in the monthly in-season reports.

2.5 Catch effort Comparisons

Skipper reporting requirements were modified starting March 1, 2014, such that skippers were to report a "greenweight" estimate of the sub-MLS snapper that was caught and returned to the sea under the species code SNX (to differentiate it from retained snapper, recorded under the code SNA). Skippers did not record sub-MLS snapper previous to this.

The catch effort estimates of sub-MLS discards (SNX) were compared with EM estimates for the same tows. For the purpose of this trial, the EM data were considered the standard.

Skipper catch effort data were provided by MPI for all vessels participating in this trial up to the end of the data collection period (August 31, 2014).

EM and catch effort trips and tows were paired using date and times. This allowed identification of trips and tows that were not captured by the EM system due to the system being powered off and, conversely, verification that all trips and tows captured by EM were reported in the catch effort data.

3.0 RESULTS

3.1 Data Collection Performance

During this trial, EM data were collected from 101 trips and 1187 tows (Table 2). Fishing activity levels varied by vessel. Vessel 3 represented 45% of the total tows captured. The mean number of tows per trip ranged from 8 (Vessel 5) to 19 (Vessel 3).

The catch effort returns recorded 105 trips and 1313 tows for the same time period. Overall, 90% of the tows reported by the catch effort were identified in the EM data and the tow data collection was 95% or higher for three vessels. Catch effort records were complete to the extent that no additional trips or tows were identified in the EM data.

Table 2: Summary of data collected. Trips and tows identified in the EM sensor data and reported in the catch effort returns. Percent of tows reported in the catch effort returns and captured in the EM sensor data.

Vessel ID	EM Trips	EM Tows	Catch effort Trips	Catch effort Tows	Tows with EM Sensor Data
1	15	146	19	208	70%
2	18	187	18	188	99%
3	28	533	28	559	95%
4	24	198	24	230	86%
5	16	123	16	128	96%
Totals	101	1 187	105	1 313	90%

Technical issues and having the EM system powered off resulted in 10% of the tows not being captured by EM sensor data (Table 3). Technical issues included problems with the control centre on two occasions on Vessel 1, and the EM system was powered off on Vessels 1 and 3 for most of one trip each when they were experiencing camera connectivity issues.

Vessels 4 and 5, but in particular Vessel 4, would often power the EM system off overnight or when the engine was off for extended periods and would sometimes forget to turn it on when they resumed fishing operations. Vessel 3 had vessel power issues that caused them to keep the EM system off, missing six tows, which was resolved when the vessel installed a battery dedicated to the EM system.

Table 3: Summary of tows without EM sensor data by issue.

Issue Category	Number of Tows Affected	Percentage of Tows not Reviewed	Percentage of Total Tows
Technical Issue			
Control centre	45	36%	3%
Camera connectivity- EM off	37	29%	3%
Subtotal	**82**	**65%**	**6%**
Other Issues			
No Power	44	35%	3%
Total	**126**		**10%**

A total of 392 (33% of the captured tows) were randomly selected for imagery review from the tows captured by EM sensor data. Of those, 274 (70%) were successfully reviewed while 118 could not be reviewed either because no imagery data were collected or the imagery was unusable (Table 4). Of the tows selected that could not be reviewed, 27 were replaced by randomly reselecting other tows from the same trip.

Table 4: Summary of imagery data usability for tows selected for review.

Vessel ID	Tows Selected for Review	Tows Reviewed	Tows Not Reviewed
1	56	46	10
2	58	55	3
3	170	77	93
4	65	59	6
5	43	37	6
Totals	**392**	**274**	**118**
Percent total		**70%**	**30%**

Table 5 provides a summary of the reasons why some of the selected tows could not be reviewed. EM deployments always involve a "bedding-in" period when systems and processes are being established, personnel are being trained, and stakeholders are becoming familiar with the technology and the specific objectives of the trial. Such issues are typically resolved as deployments progress, especially in the medium or longer term. In this project, implementation issues resulted in 20% of the selected tows not being reviewed.

Technical issues, mainly problems with camera connectivity, resulted in 10% of the selected tows not being reviewed. Camera connectivity issues occurred on three vessels and caused one or more cameras to not record imagery for a period of time (Table 5).

Table 5: Reasons for not being able to review the 118 tows.

Implementation	Number of Tows Affected	Percentage of Tows not Reviewed	Percentage of Selected tows
Recording Configuration	47	40%	12%
Camera Positioning	22	19%	6%
Power disruption	6	5%	2%
Disc Space	3	3%	1%
Subtotal	***78***	***66%***	**20%**
Technical Issue			
Camera connectivity	37	31%	9%
Camera colour saturation	3	3%	1%
Subtotal	***40***	***34%***	**10%**
Total	**118**		

Imagery data quality was high for 53% and medium for 46% of the reviewed tows (Table 6). The most common reason for medium quality was dark images during night tows. In these instances, the images still allowed identification of snapper discards. Most hauls occurred during the night. Assuming night time to be between 19:00 and 06:00 hours, approximately 56% of the total EM tows (1187) would be considered night hauls and only 5% of the tows would be considered to have occurred within full daylight hours (Figure 6).

There were only three tows with low quality imagery. Snapper discards were difficult to observe in these tows due to 1) extremely low light levels combined with crew positioning, 2) the catch being sorted in an area partly obstructed from camera view, and 3) missing one camera view but with the remaining cameras providing a view of the catch sorting and discarding.

Table 6: Imagery quality ratings for reviewed tows.

Vessel ID	High	Medium	Low
1	35	11	
2	21	34	
3	41	35	1
4	30	27	2
5	18	19	
Totals	**145**	**126**	**3**
Percentage	**53%**	**46%**	**1%**

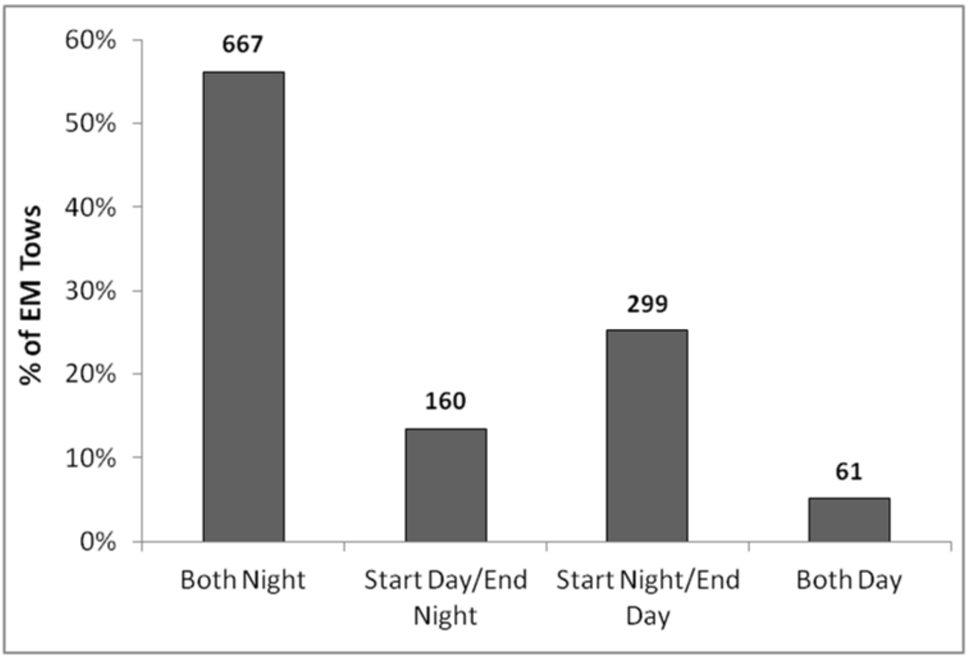


Figure 6: Percent of EM tows with both start and end times occurring at night (56%), tows with only the end occurring at night (25%), tows with only the start occurring at night (13%), and tows with both start and end times occurring during the day (5%). Label values represent the number of tows. Night time was assumed to be between 19:00 and 06:00 hours.

3.2 Fishing Location and Snapper Catch

During the trial, the participating vessels fished exclusively in SNA 1 (Figure 7).

Fishing activity was observed mostly in the north Hauraki Gulf area (Statistical Areas 005 and 006) by the vessels fishing out of Auckland. The vessels operating out of Whangarei and Totara North fished mostly along the coastal regions of Northland (Statistical Areas 002 and 003).

Figure 7 shows a spatial summary of snapper fishing effort, reported as the number of tows by start location. Retained snapper catch is shown by tow start location in Figure 8.

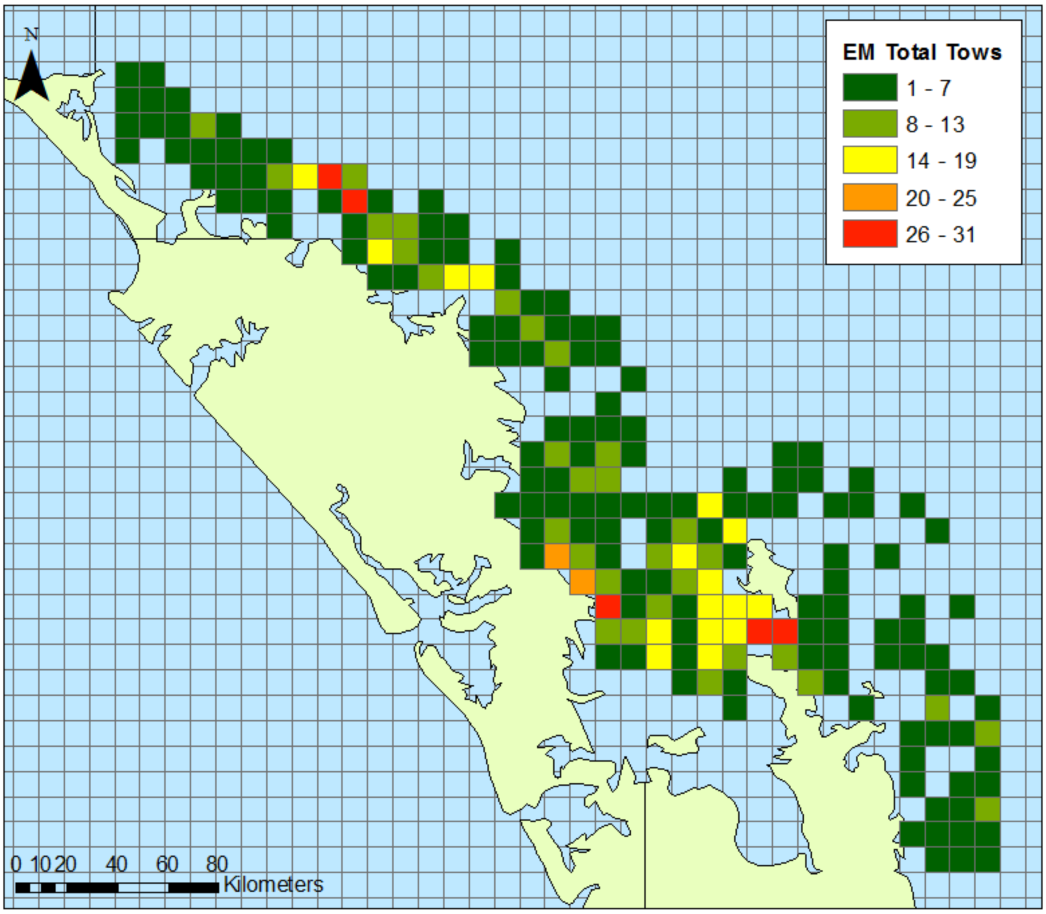


Figure 7: Chart of New Zealand's northeast North Island showing EM fishing activity by total number of tows within 10×10 km grids for all five participating vessels combined. Tows were assigned to grids according to their start location.

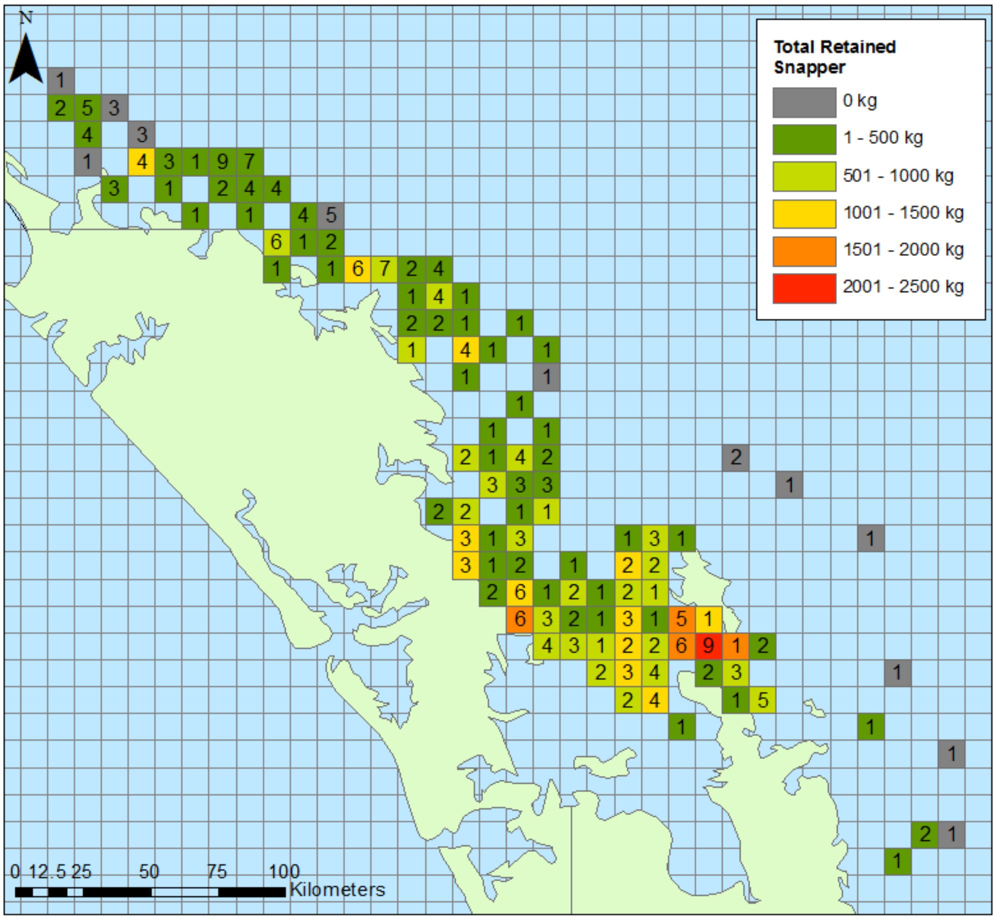


Figure 8: Total retained snapper (kg) recorded in the catch effort returns for the 274 viewed tows across all five participating vessels. Each grid represents a 10×10 km area and the values in each grid represent the number of tows.

3.3 Snapper Discards

3.3.1 Snapper discard characterization

Sub-MLS snapper discards were observed in 162 (59%) of the reviewed tows (Figure 9). Sub-MLS snapper discards were a small proportion of the total snapper captured for the reviewed tows (total snapper was calculated as the sum of retained snapper reported in the catch effort returns and discarded snapper observed in the EM data) (Figure 9). Sub-MLS snapper discards were less than 15% of the total snapper captured in 229 (84%) of the tows reviewed and exceeded 25% in 12 tows (4%). Some total snapper captured amounts per tow were very small which tended to inflate the percentages of discarded amounts.

The amount of sub-MLS snapper discards varied widely among tows as indicated by the estimates of the coefficient of variation[2] (CV) in Table 7 and Figure 10. Furthermore, the frequency and volume of sub-MLS snapper discards varied between vessels (Table 7). Maximum discard weight per vessel varied from 35 kg/tow for Vessel 2 to 270 kg/tow for Vessel 1 (Figure 10). In general, the frequency distributions of snapper discards per tow by vessel are left-skewed, (i.e., there was a large proportion

[2] We use CV (standard deviation/mean) to characterize to the variation in the raw observations (Snedecor & Cochran 1967), as opposed to the alternative usage of "CV" " in which it is used as a synonym for the relative error (RSE) of the mean.

of relatively small discard volumes per tow for each vessel and a few tows with large discard volumes) but the shape of the distribution varied widely among vessels (Figure 10).

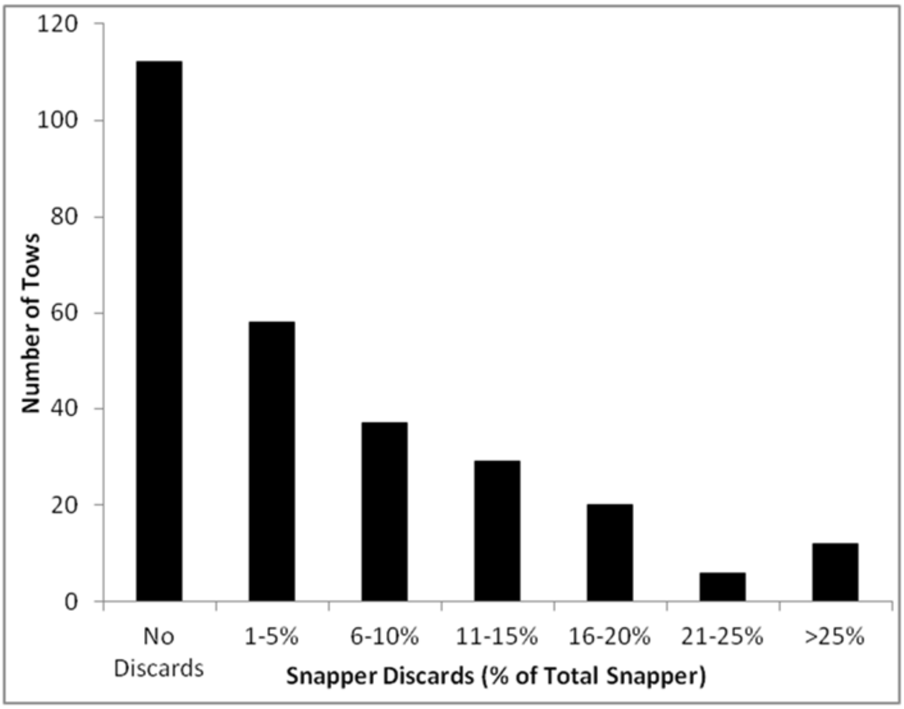


Figure 9: EM snapper discards as a percentage of total snapper (retained + discarded snapper) for all 274 reviewed tows across all five vessels.

Table 7: Characterization of snapper catches and discards for the reviewed tows, by vessel. Number of tows reviewed, number and percentage of tows with snapper discards, total snapper discarded weight (kg), mean (CV%) discarded snapper weight (kg) for tows with snapper discards, and mean (CV%) retained snapper weight (kg) (as reported in the catch effort returns) for tows with snapper discards. CV%=Coefficient of Variation (standard deviation/mean) expressed as a percentage.

Vessel ID	Tows Reviewed	Tows with Snapper Discards EM	Total Snapper Discards (kg) EM	Mean Snapper Discards/tow (CV%) (kg) EM	Mean Snapper Retained/tow (CV%) (kg) FLOG
1	46	36 (78%)	2 390.0	66.3 (105%)	362.1 (82%)
2	55	27 (49%)	144.9	5.4 (132%)	171.8 (68%)
3	77	75 (97%)	2 267.1	30.2 (88%)	270.5 (95%)
4	59	11 (19%)	114.2	10.4 (121%)	200.0 (96%)
5	37	13 (35%)	187.2	14.4 (149%)	334.6 (82%)
Total	**274**	**162 (59%)**	**5 103.4**	**31.5**[3]	**274.8**[2]

Figure 11, Figure 12, and Figure 13 respectively show the spatial distribution of total sub-MLS snapper discards, mean snapper discards per tow as reported by EM and catch effort returns, and the proportion of snapper catch discarded across all vessels. The majority of sub-MLS snapper discards occurred in the northern Hauraki Gulf area in Statistical Areas 005 and 006. Some total snapper captured amounts per tow were very small resulting in inflated percentages for discarded amounts.

[3] Note that overall variation for the total estimate (not shown) will depend on stratification.

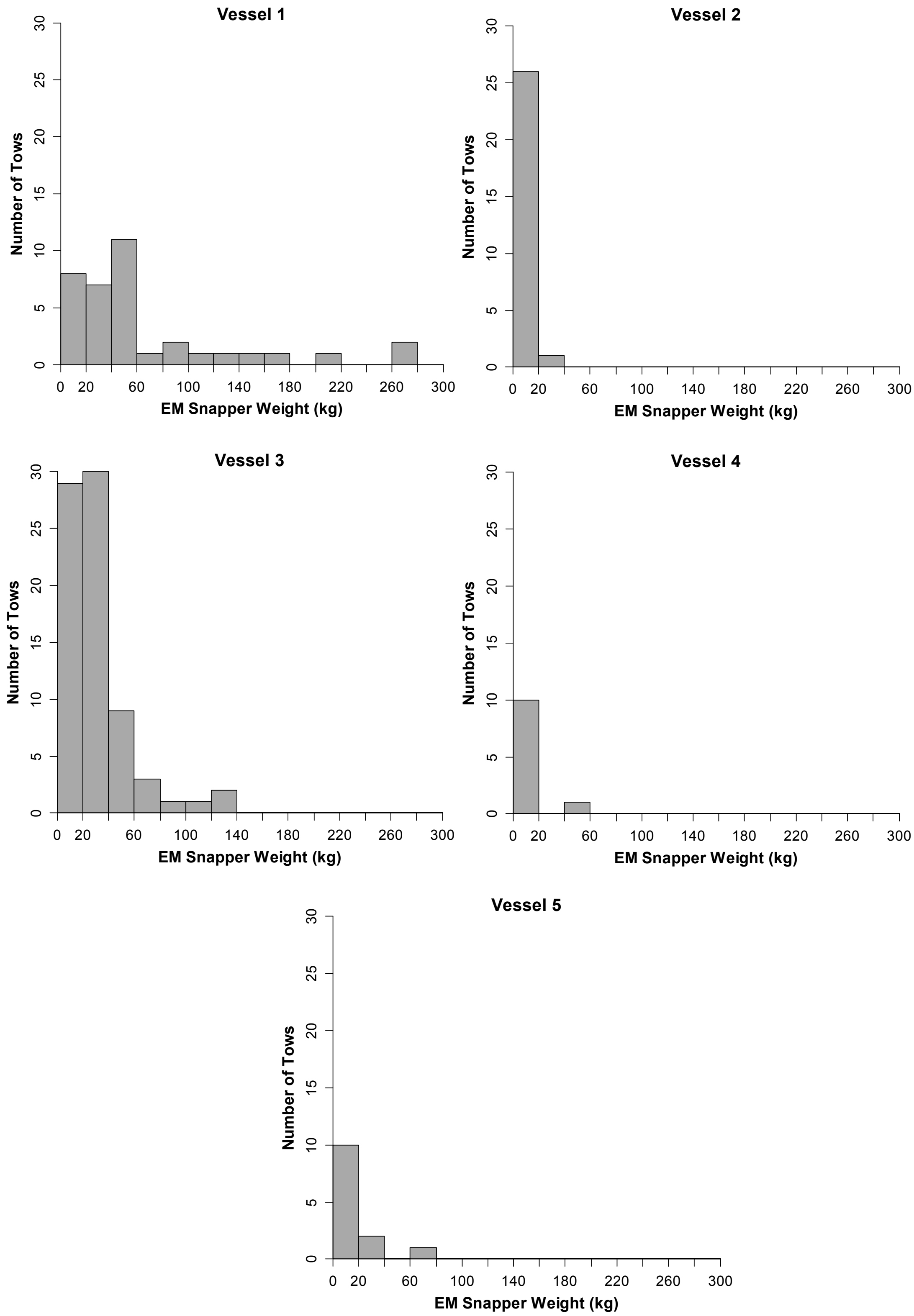


Figure 10: Histograms of EM snapper discards (kg) by individual vessel for tows with snapper discards.

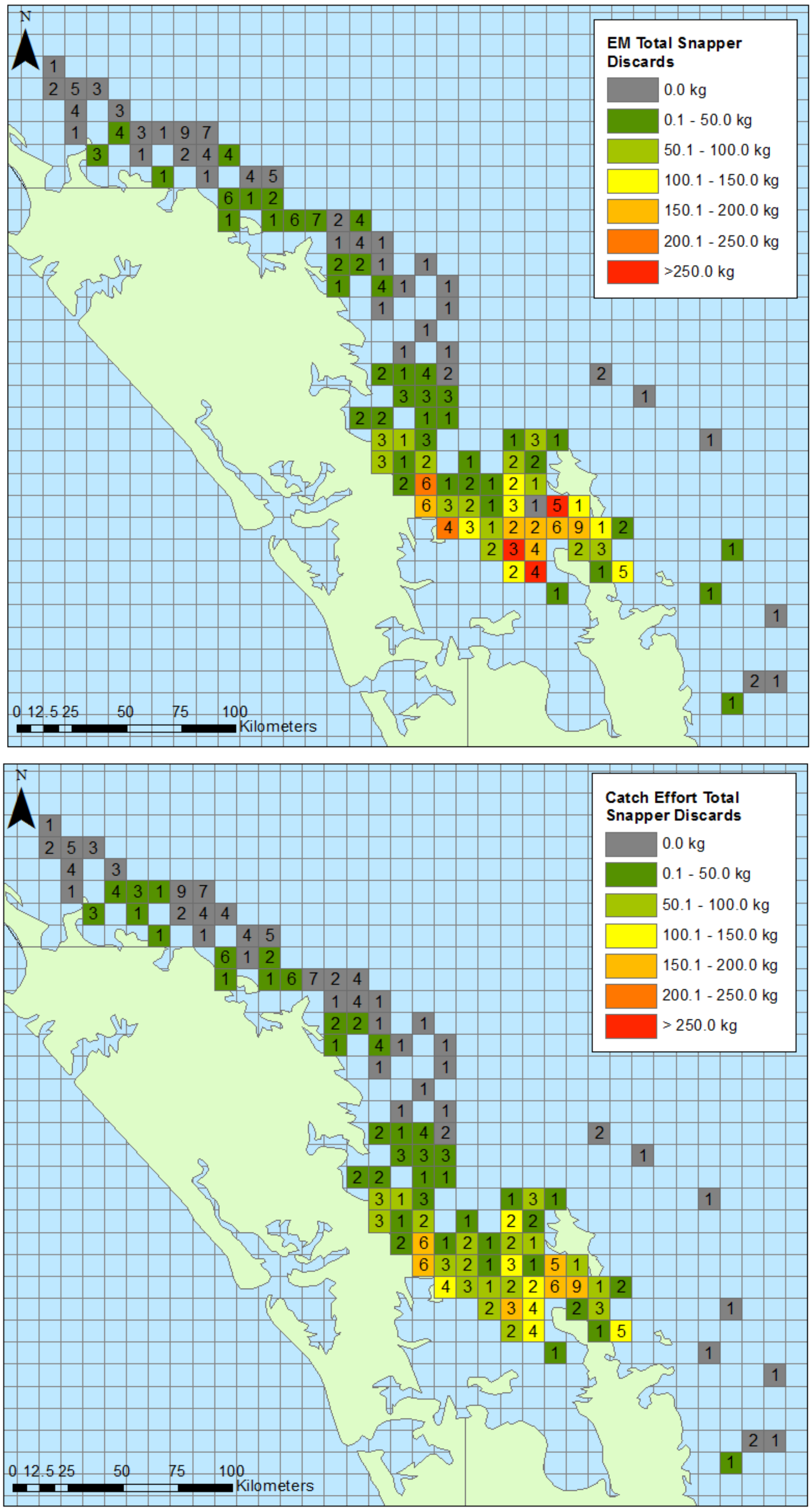
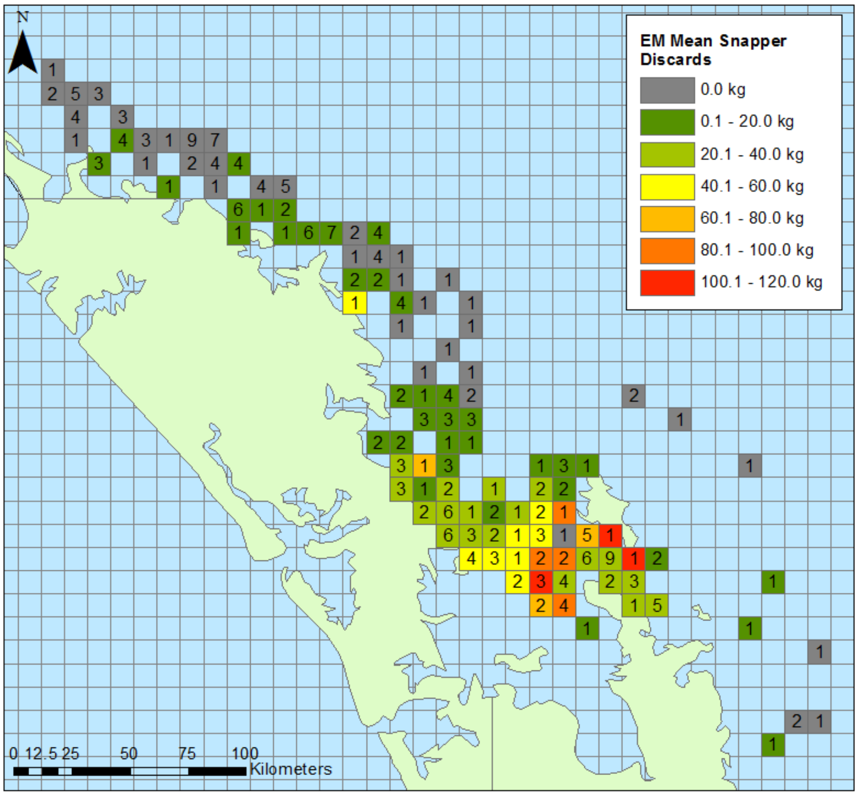


Figure 11: EM (top) and catch effort (bottom) total snapper discards (kg) for all 274 reviewed tows across all five participating vessels. Each grid represents a 10×10 km area, and the values in each grid represent the number of tows. Tows are assigned to grid cells using start location.



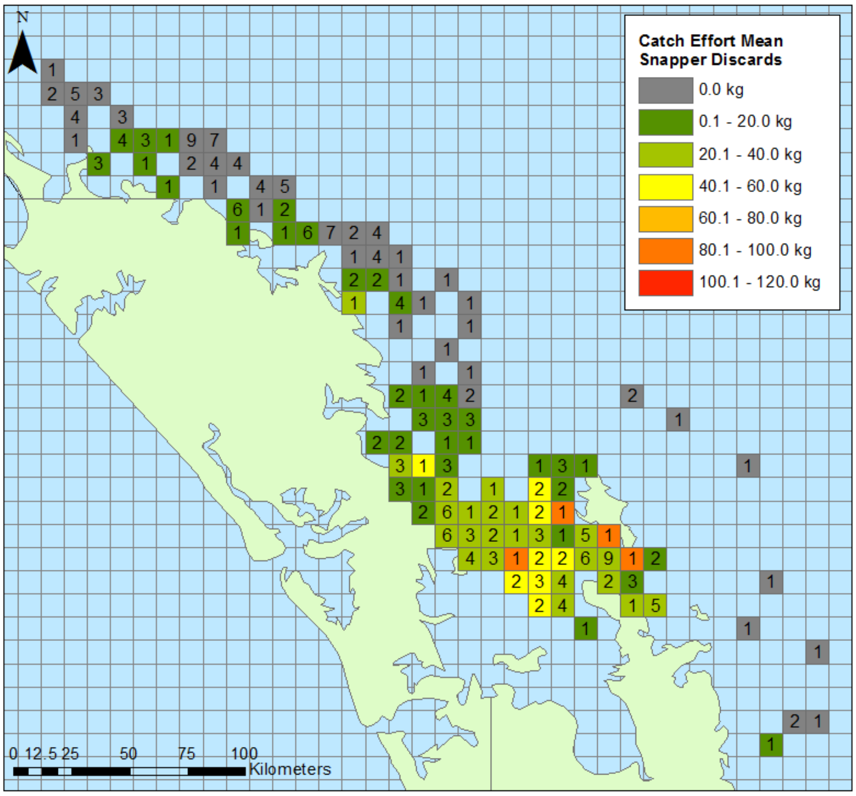
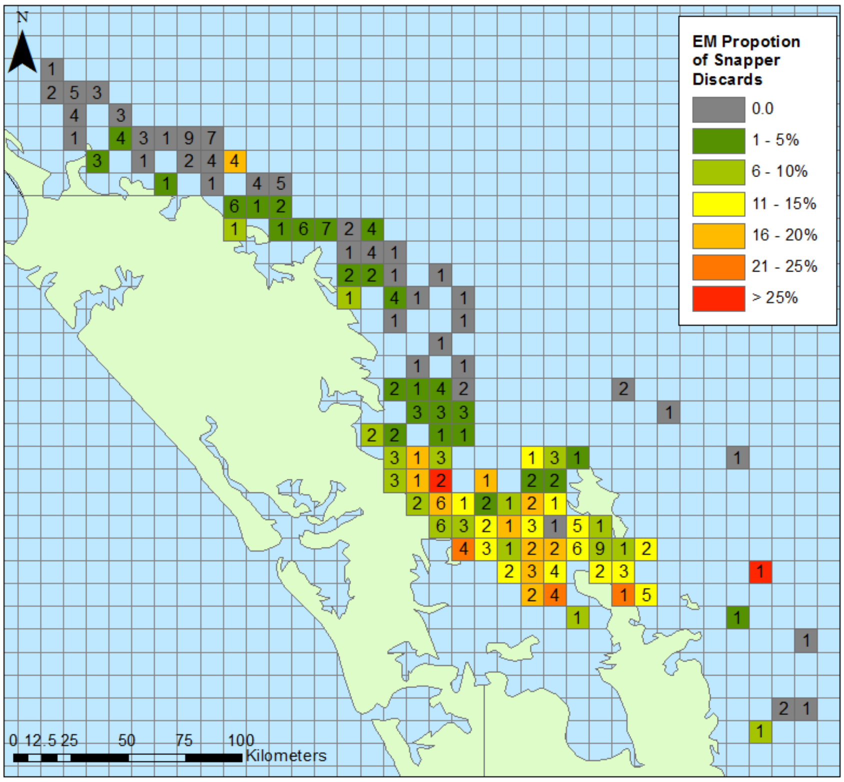


Figure 12: EM (top) and catch effort (bottom) average snapper discards (kg) for all 274 viewed tows across all five participating vessels. Each grid represents a 10×10 km area, and the values in each grid represent the number of tows. Tows are assigned to grid cells using start location.



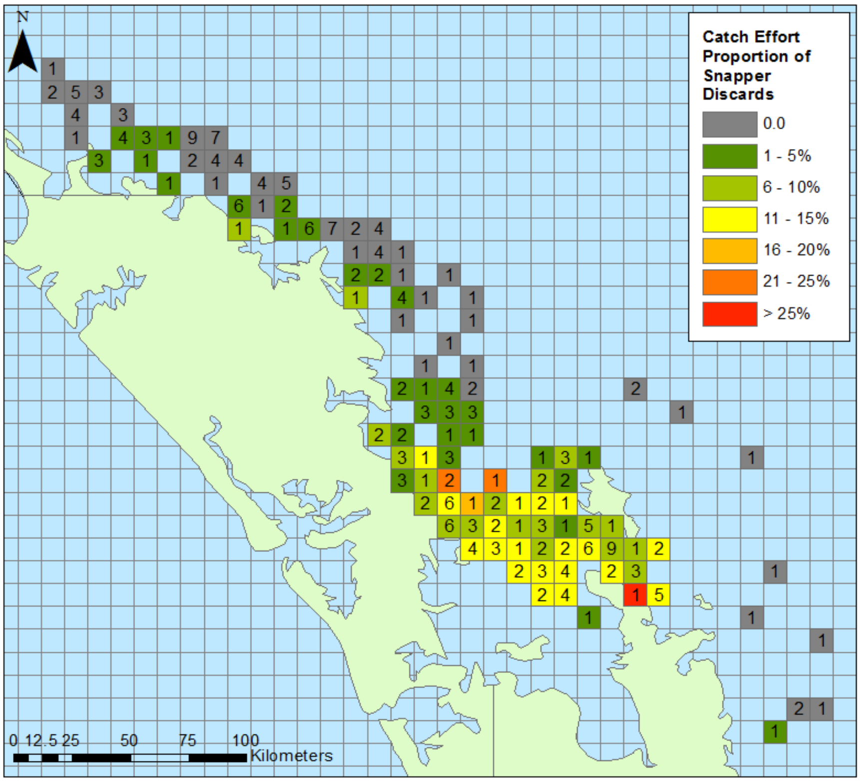


Figure 13: Sub-MLS snapper discards as a percentage of total snapper catch for all 274 reviewed tows across all five vessels for each 10×10 km area grid. EM proportions= sum of EM discards by grid / (EM discards + retained snapper). Catch effort proportions= sum of catch effort discards by grid / (catch effort discard + retained snapper).

3.3.2 Snapper discard EM and catch effort comparisons

There was agreement in presence/absence of snapper discards in EM and catch effort returns for 255 of the 274 reviewed tows (93%) (Table 8). Of these, 102 tows (37%) recorded an absence of snapper discards. For the remaining 19 tows (7%) either EM reported snapper discards and the catch effort did not, or vice versa. Estimated discarded amounts (either from EM or catch effort) for these tows were small and ranged from 0.2 to 9 kg.

Table 8: Snapper discard matrix for the number of tows when both EM and catch effort returns recorded snapper discards, when no snapper discards were recorded by either, and when only EM or catch effort returns recorded snapper discards.

	Catch effort Snapper Discards	Catch effort No Snapper Discards	Totals
EM Snapper Discards	153	10	**163**
EM No Snapper Discards	9	102	**111**
Total	**162**	**112**	**274**

The EM and catch effort estimates were correlated for each vessel, but varied in degree with *r* varying from *r*=0.78 for Vessel 1, 0.82 for Vessel 3 to over 0.94 for Vessels 2, 4, and 5 (Figure 14) Catch effort returns for all vessels tended to underestimate sub-MLS snapper discards. Catch effort estimates tended to be 70% to 80% of the EM estimates for Vessels 2, 3, 4, and 5. The underestimation bias was particularly strong in Vessel 1, where catch effort estimates tended to be 30% of the EM estimates overall and estimates were very heavily underestimated for larger values (i.e., EM estimates larger than 100 kg). Note that although the results suggest that the catch effort data for this vessel did not record discards over 100 kg, an examination of the catch effort data for the entire data collection period revealed that this was not the case. The catch effort data did include some tows (not selected for review) that reported discards over 100 kg.

A closer examination of the tows with EM estimates over 100 kg revealed that these tows had high or medium image quality, so video quality was unlikely to be a contributing factor. However, deviation from the standard catch handling protocols designed for the trial may be affecting the estimates for these tows. In two tows from Vessel 1, snapper was mixed in with other species in some of the discard bins. This deviation from the catch handling protocols may be resulting in an overestimation of EM sub-MLS snapper discard estimates or conversely the snapper discarded with other species may have not been properly accounted for in the catch effort returns. In two additional tows for Vessel 1, catch was discarded outside of the discard control points. In the remaining six tows there were no notable circumstances to explain the large discrepancies between the catch effort and the EM estimates.

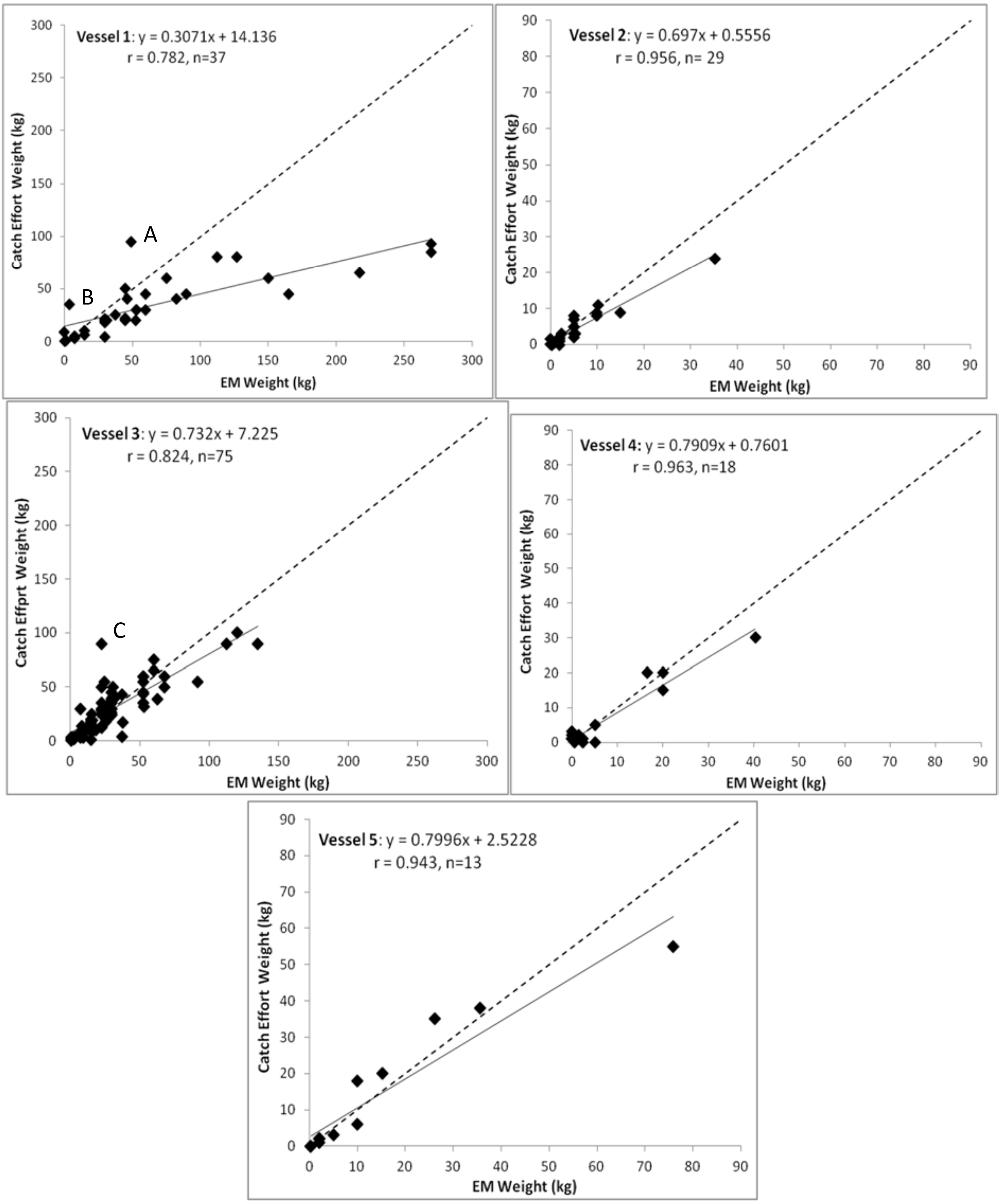


Figure 14: Catch effort vs. EM snapper discards (kg) for Vessel 1 (top left), Vessel 2 (top right), Vessel 3 (middle left), Vessel 4 (middle right), and Vessel 5 (bottom) for tows with reported sub-MLS snapper discards. The dashed line represents the zero intercept and slope of one.

Large differences where catch effort data overestimated snapper discards compared with EM were also investigated. Data points marked as A and B in Figure 14 are both tows where discards occurred outside of the control points (at the stern and through the scuppers respectively). However, we could not detect any obvious reasons for discrepancy shown as C in the vessel 3 observations.

3.3.3 Discarding methods

EM reviewers collected information on the onboard methodologies used to discard snapper and whenever discarding occurred outside of the discard control points.

The majority of snapper was binned into standard containers (either iki or Sanford bins) before being discarded (Table 9). However 158 snapper were discarded individually across 61 tows. The latter practice was mostly observed on Vessel 3. Vessel 1 was the only vessel that used non-standard containers and that discarded other species in the same bin as snapper.

As mentioned in Section 2.3.1, there were nine bins out of 291 bins observed where a proportion of other species were mixed in with snapper. These were treated as being all sub-MLS snapper because snapper appeared to dominate in most of these bins and it was not considered feasible to develop a consistent protocol for estimating bin-specific proportions among reviewers. The total estimate of sub-MLS snapper discards from these five bins was 218 kg, or 4% of the total EM sub-MLS snapper discards in the study.

Table 9: Summary of the number of tows with EM snapper discards by discard method. The tow counts do not add to the total tows as more than one discard method may have been used during catch sorting for a single tow.

Vessel ID	Tows with Snapper discards	Standard Bin	Individual Snapper	Mixed Species	Non-Standard Bin
1	36	30	8	5	2
2	27	21	10	0	0
3	75	71	30	0	0
4	11	7	7	0	0
5	13	11	6	0	0
Total	**162**	**140**	**61**	**5**	**2**

Fish were discarded outside of the control points in 5% of the reviewed tows (15 tows), (Table 10). Discards outside of control points were mainly done at the stern of the vessel whereas the discard control points were along the side of the vessel at the rails. In addition to stern discarding, crew on Vessel 1 swept fish off the deck or pushed discards towards the scupper (two tows) and on Vessel 4 bins were discarded at the rail but outside the control point (two tows). There is a possibility that not all discards were observed for the tows where catch were discarded outside of the control points.

Observations regarding catch sorting and discarding and their impact in obtaining EM estimates were provided as feedback to vessel representatives in the in-season reports.

Table 10: Number of trips and tows in which discards were observed outside of control points.

Vessel ID	Trips with Discards Outside of Control Points	Tows with Discards Outside of Control Points
1	**4**	**6**
2	**1**	**1**
3	**1**	**1**
4	**6**	**7**
5	**0**	**0**
Total	**12**	**15**

3.4 Unidentified fish and other discards

The study recorded over 13 000 individual fish being discarded that were not identified as snapper (Table 11).

Of these, 10 504 (80%) were identified to species. The main factor precluding identification was that fish were tossed overboard so rapidly during sorting that their body shape was reduced to only a blurred outline. This mostly occurred at night although not exclusively.

The identified discards of individual fish comprised mainly porcupine fish (*Allomycterus jaculiferus*), skates and rays, and kingfish (*Seriola lalandi*).

Table 11: Summary of EM unidentified fish and non-snapper discard by fish count.

Vessel ID	Unidentified Fish	Other Species	Total Other Discards
1	160	531	**691**
2	285	1 645	**1 930**
3	556	2 536	**3 092**
4	1 362	2 257	**3 619**
5	307	3535	**3 842**
Totals	**2 670**	**10 504**	**13 174**

Additionally, there were 25 bins of unidentified fish discarded on Vessel 1 across 16 tows. There were two scenarios in which these bins were observed. The first occurred whenever catch was sorted below deck and non-snapper discards would get combined in bins and brought up to deck for discarding. In this scenario it was difficult to identify all the species in the bin. The second scenario was when crew sorted catch close to the stern and the bin was not brought into camera view. In this scenario the reviewers were able to observe the discard bin in the deck overview but it was not possible to identify the species within.

3.5 Imagery Data Review Time

A total of 274 tows were reviewed. The catch sorting time associated with these tows totalled 334 hours of imagery. The review was completed in 172 hours (Table 12) leading to an analysis ratio of 0.51. In other words, it averaged about 30 minutes to review one hour of imagery although the ratio for any given hour was highly variable.

The amount of imagery data reviewed per tow varied significantly between tows from a little as 20 minutes to as much as 25.7 hours, with a mean of 1.2 hours. There were two main reasons for this variation. One was the amount and composition of catch in the tow and the second was whether the catch was sorted and stowed promptly. The latter reason could have a large impact. For example, the catch sorting operation would sometimes be delayed on the last tow of the day when crew would go into the wheelhouse for an extended period of time before returning to the deck to sort the catch. However, review time was optimized by fast-forwarding through periods in which there was no activity on deck.

Table 12: Number of tows reviewed, the total catch sorting duration (hours), and total associated imagery review time as well as mean and coefficient of variation expressed as a percentage (CV%) for sorting time and review time per tow and mean and CV% analysis ratio per tow. CV%=Coefficient of Variation (standard deviation/mean) expressed as a percentage.

Vessel ID	Tows Reviewed	Catch Sorting (hrs)	Review Time (hrs)	Mean Catch Sorting per Tow (CV%)	Mean Review Time (hrs) (CV%)	Mean Review Ratio (CV%)
1	46	102.3	31.3	2.22 (162%)	0.68 (60%)	0.43 (61%)
2	55	66.0	31.9	1.2 (42%)	0.58 (47%)	0.53 (50%)
3	77	65.5	46.5	0.85 (66%)	0.60 (59%)	0.78 (34%)
4	59	67.6	39.3	1.14 (111%)	0.66 (78%)	0.66 (50%)
5	37	32.9	23.0	0.89 (30%)	0.62 (48%)	0.70 (35%)
Total	**274**	**334.3**	**172.0**	**1.22**[4]	**0.62**[3]	**0.63**[3]

The quality of imagery data and identity of the reviewer did not significantly affect review ratios, as shown by the overlapping box plots in Figure 15. Median review ratios were similar for imagery rated high or medium quality (0.57 and 0.59 for high and medium, respectively). Further, while the three low quality tows had a higher median review ratio of 0.78, the box plot overlaps with the high and medium quality tows.

[4] Note that overall variation for the total estimate (not shown) will depend on stratification.

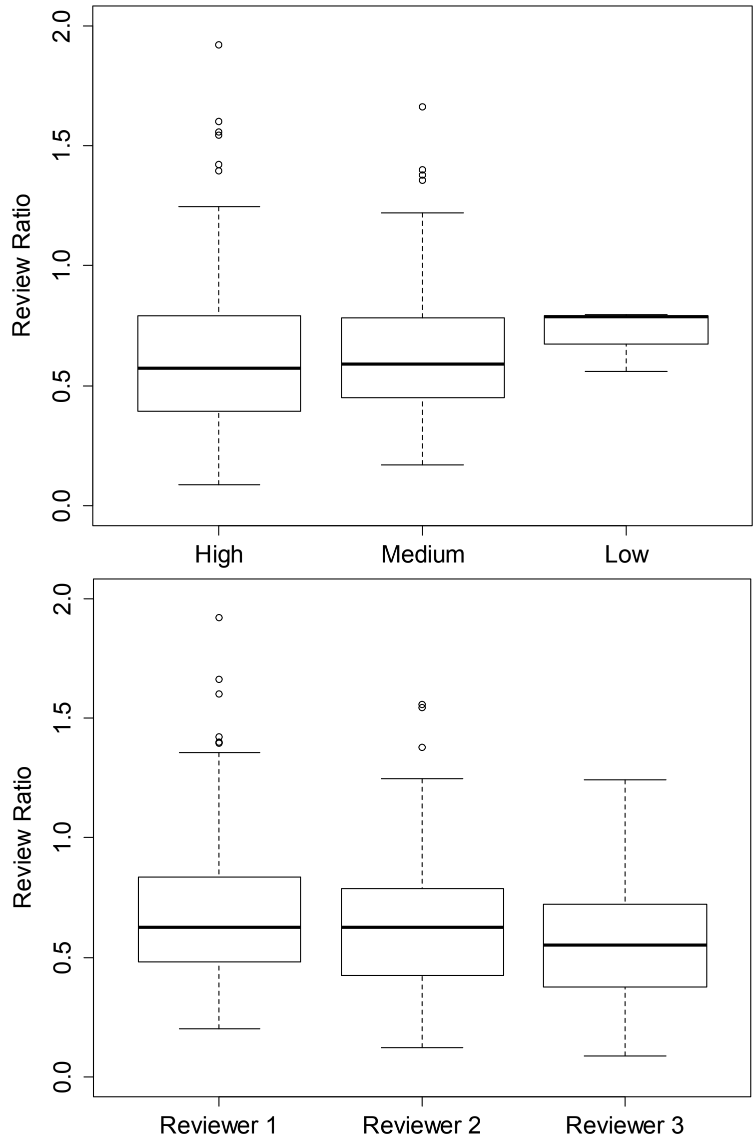


Figure 15: Box plot showing the review ratio by imagery quality (top) and by imagery reviewer (bottom) for all the participating vessels. The line in the middle of the box represents the median, the lower and upper lines of the box are the 25th and 75th percentile, the whiskers represent the 95% confidence intervals, and the points outside the whiskers represent the outliers. Reviewers are ordered from less (#1) to more experienced (#3).

4.0 DISCUSSION

This trial was successful at providing a general methodology for equipment set-up and catch-handling requirements, and testing data review protocols for estimating snapper discards. It also provided initial verification of catch effort data in situations where sub-MLS snapper are binned before being returned to the sea. Furthermore, EM was demonstrated to be an effective way to monitor large amounts of fishing activity in a cost-effective way- a 3.5 day fishing trip with 12 tows could be fully reviewed in nine hours.

In general, skippers and crew effectively conformed with the operational practices required to facilitate the success of EM. As documented from other EM applications, such as the BC groundfish hook and line (HL) fishery in Canada and the mid-water trawl Pacific whiting fishery in the USA, it is expected that conformance would improve over time as modifications in fishing practice necessary to support this monitoring method (e.g., catch handling) became mainstream (McElderry et al. 2014; Stanley et al. 2011, 2015). Just as it occurred in those fisheries, EM can play a role in building awareness around discarding practices in the fishery and improvements in conformance are expected as appropriate incentives, regulations and feedback mechanisms are put in place.

One of the goals of implementing an EM program in the SNA 1 fishery would be to provide reliable, independent information on snapper discarding. Below we explore the efficacy of EM from a technical and methodology perspective. We identify the key assumptions of the trial and assess how sensitive the results are to these assumptions. We also suggest next steps to build on the success of this trial EM deployment.

4.1 Data Collection Performance

During the trial EM captured a total of 101 trips and 1187 tows across the five participating vessels. The catch effort returns recorded 105 trips and 1313 tows for the same time period. EM data collection of sensor data was high, with 90% of tows reported by the catch effort returns captured by EM, and imagery data successfully collected for 70% of the randomly-selected tows. Overall, the main issues that affected data collection success were implementation, technical and behavioural (not powering the EM system).

Data loss is a common occurrence at the start of an EM programme due to a variety of start up matters, which we refer to as implementation challenges. These include trial and error testing of system configuration and component placement as well as testing of on-board methodologies. It is often difficult to fully anticipate the monitoring setting when the vessel is dockside. Also, technicians working on the system and vessel personnel can make mistakes which reduce data collection efficiencies. These problems usually settle down after a few service events and become streamlined for longer term deployments.

Camera connectivity and colour saturation issues (preventing the collection of imagery from 10% of the tows selected for review) are being reviewed by Archipelago as a technical matter. They are related to the introduction of newly released technology, and have been resolved. Since this trial took place, Archipelago has successfully deployed similar EM system configurations in other jurisdictions without experiencing these problems.

Four vessels experienced data loss due to lack of power. One vessel identified the power supply issue and installed an additional battery to power the EM system, which resolved the issue. It appeared that independent vessel owners were more hesitant to make changes to their vessels, or incur costs, to accommodate the EM system, presumably because of the temporary nature of the trial. Skippers on three vessels turned their EM system off at night, or when the engine was off for an extended period of time. The main reason was to conserve battery power, although one skipper also reported that the EM system disturbed their sleep. The vessels were permitted to turn off the EM systems for the purpose of the trial, with agreement from MPI and the EM technical group. Unfortunately skippers sometimes forgot to turn the system back on before fishing, resulting in 3% of the total tows (44) being missed by EM. In future deployments, this issue can be addressed through one of two measures. One is to install an engine sensor, which will turn the EM system on and off automatically depending whether the engine is on or not. Whether this measure is appropriate will depend on whether imagery recording must occur for the entire duration of a fishing trip, including whenever the engine is off. The second measure is to further test and update vessel power systems as necessary.

Overall, of the tows that could not be reviewed, the data loss resulted from issues that would be expected to be resolved in a longer term deployment. This is consistent with experience from other EM programs, in which data collection success increased between the trial and operational deployments. For example, the BC groundfish HL fishery collected usable data for about two-thirds of fishing trips during its pilot deployment but collected usable imagery data for 93% of trips in its second year as an operational project and over 99% in fishing year 2012 (McElderry et al. 2003; Archipelago, 2007; Archipelago, 2013).

4.2 EM Onboard Methodologies

The EM equipment set-up and catch handling requirements along with the data processing protocols used to estimate snapper discards tested in this trial appear to have been generally successful at providing an independent estimate of snapper discards, which could then be compared to catch effort data. However, because of the way this trial was designed and implemented, this conclusion relates to situations where sub-MLS snapper are binned before being returned to the sea. The results from this trial show that it is imperative that vessel operators follow the catch handling protocols developed in order to obtain reliable EM sub-MLS snapper discard estimates.

A reliable independent estimate of snapper discards using EM data relies on the overarching assumptions that all discards were observed by EM in some way and that all snapper discards were estimated without significant bias.

Observing all discards

While the emphasis during the trial was on observing discarding from deck (i.e., once catch was brought onboard), the methodology also included reviewing the trawl net haul back to verify that catch was brought onboard instead of being discarded directly from the codend.

Furthermore, reviewers were confident that they observed all deck discards when vessel operators followed the catch handling protocols to handle catch on deck within camera view and discard at the control points during catch sorting. However, discarding outside of control points (which occurred in 5% of the tows reviewed) affected the ability of the reviewer to identify species or estimate discard amounts. Discarding outside of control points mainly occurred when catch was brought onboard and sorted at the stern on certain vessels, which was not standard catch-sorting practice and not contemplated in the IVMP. In those situations, crew would discard off the stern, close to where the catch was being sorted. In many cases, crew would make an effort to show the bin to the camera but would not carry them to the control point for discarding. This issue could be addressed in several ways, including eliminating the practice of changing catch-sorting locations, bringing discards to the control point whenever discards are sorted at the stern, or installing additional cameras. When assessing the option of adding cameras, the volume of data capture would need to be taken into account, and the frequency of scheduled data retrievals to eliminate the risk of lost data due to hard drives being filled to capacity. Over time, as EM monitoring bedded in on vessels, the issue of discarding outside control points would be addressed on a case-by-case basis with vessel operators.

The trial focused on monitoring the catch sorting operations and reviewers would watch the imagery data until all catch was observed to be stowed and all sorting and discarding appeared to be complete. This included situations when catch sorting was delayed. However, it is possible that crew could carry out secondary sorting at a later time after the catch was initially stowed. While the trial did not address this, it did collect imagery for the entire fishing trip and the methodology could easily accommodate reviewing imagery data for the entire trip (at least after the first tow) to look for secondary sorting.

An alternative scenario would be to amend the catch handling methodology to specify that secondary sorting is not to occur (i.e., discards could only occur during the initial catch sorting period). Under this scenario compliance with secondary-sorting rules could be addressed in two ways. One way would be to review a random portion of the data simply to verify that no secondary sorting is taking place. A second way to verify that no significant amounts of secondary sorting are taking place is by verifying retained catch per tow in the catch effort return using EM, and then comparing total landings to the sum of all retained catch in the catch effort return (see Appendix A for an example of how a similar situation is addressed in the BC groundfish HL fishery).

Estimating sub-MLS Snapper Discards

A total of 3682 kg of snapper were estimated to have been discarded across 274 tows (assumed to be sub-MLS). The results from this trial indicate that an EM programme would effectively assist MPI and SNA 1 Commercial efforts to develop accurate catch monitoring in this fishery. Through the data collected in only six months, it provided a reasonable characterization of snapper discarding on the participating vessels. Overall, sub-MLS snapper discards were observed in 59% of the tows reviewed, and in only 17% of the tows did sub-MLS snapper discards exceed 15% of the total snapper captured.

The methodology also provided a very precise time and area footprint of the fishery. The trial results revealed strong spatial patterns in the catch and subsequent discarding of sub-MLS snapper. Most snapper discards, in amount discarded per tow as well as total weight discarded, were observed north of the Hauraki Gulf. Differences in fishing practices (e.g., target species, tow depth, tow duration, gear, etc.) may also have a contributed to these differences.

The data collected in the trial could be analyzed further to provide more information on the specific spatial and temporal patterns of snapper discards. This could help vessels adjust their fishing plans to minimize the catch of undersized snapper. These analyses could be performed at a fleet level (the primary interest of fisheries managers) or a vessel level (the primary interest of industry). Furthermore, these data could be used to support the industry led move-on rule as well as to understand the efficacy of the rule and its impact on fishing effort. For example, in the shore-based Pacific whiting fishery, greater visibility into the fishery activity and discards from the EM programme fed into new discard management and fisheries regulations (McElderry el al. 2014).

Snapper discard weight estimates in this study were primarily based on visual estimates of bin volumes, converted to weight using a volume-density factor. The accuracy of this method is influenced by a number of factors deserving mention. First, variation in the type of bin used may influence the density of fish contained within the bin. The two standard bins had capacities of 20 kg and 30 kg. As well, the size of fish may influence the volume density with small fish packing more densely. Further, estimation of bin fullness may vary between viewers or differentially with bin volume, particularly at lower levels where the distinction between trace (less than 10%) and 25% could occur. The effect of these biases is unknown and should be considered in future studies.

The study design did not measure the accuracy of EM estimates against a control (such as observers). However, by analysing the methodology we are able to identify aspects that impacted the EM estimates. There are two factors that may be affecting the accuracy of EM estimates and that continue to highlight the importance of following catch handling procedures: batching snapper with other species; and not being able to identify all discards.

First, the EM sub-MLS snapper discard estimates may have been overestimated by assuming that 100% of mixed species bin weight was snapper. The total estimate of sub-MLS snapper discards from the five bins observed to have other species mixed in with snapper was 218 kg, or 4% of the total EM sub-MLS snapper discards in the study. The assumption of 100% snapper in mixed bins could presumably have led to EM overestimate of 1–2% given that in reality not all of the bin weight was snapper. While this bias is small it does serve as a reminder to ensure that catch handling protocols are developed and followed.

Second, the EM sub-MLS snapper discard estimates may have been underestimated by recording some snapper as unidentified fish. Non-snapper species were not required to be batched in bins before being discarded and 20% of the individual fish discarded were returned to the sea in a manner that was not conducive to identifying them to species. Occasionally physical features such as colouration or fin shape were faintly visible, and suggested that fish could have been snapper. This issue could be readily addressed by changing discarding practices to facilitate their identification through imagery. For example, control points could be reduced in size to allow for an even closer-view of the area, which would allow for better species identification. Had monitoring objectives for this project included non-snapper discards, methods with which to handle these species in order to quantify them would have been included in IVMPs and followed up on during the trial. The success with which non-snapper discards were identified, when this was not a focus of the trial, confirms the broader potential efficacy of monitoring catch in this fishery using the EM method.

Finally, snapper discards were not verified to be sub-MLS during this trial. If discarding of legal size snapper is considered to be an issue, there would be opportunities to address it within an EM programme. This would however involve a much higher level of cooperation by crew (it is likely that crew would need to adjust their catch handling practices to some degree) and more effort to review the data (i.e. a larger review ratio). The increased amount of crew cooperation and review effort needed would be determined by the level of accuracy required to verify fish length. For example, in a simple scenario, a marker could be placed on the edge of the bin to reference snapper's MLS with a buffer, and reviewers could roughly check that snapper in the basket do not exceed the buffer. In a much more complex but comprehensive scenario, individual snapper could be placed in a calibrated discard chute or ramp for the EM reviewer to take a measurement (Pria et al. 2014b). This method has been found to provide length estimates within 0.5% of actual size but can be time consuming and requires very strict catch handling protocols to ensure that all discards go through the measurement area one at a time.

4.3 Catch Effort Return Comparisons

Catch effort return estimates tended to underestimate sub-MLS snapper discards compared with EM but results varied by vessel. For four of the vessels, catch effort return estimates tended to be 70% to 80% of the EM estimates. For Vessel 1, catch effort estimates tended to be 30% of the EM estimates overall.

Vessel 1 was observed to change their patterns for catch handling and divert from the catch handling protocols developed for this trial. For example, catch was sorted below deck, in the middle of the deck or at the stern, it was the only vessel that mixed sub-MLS snapper with other species, and it was the only vessel that used non-standard containers. Vessel 1 also had higher sub-MLS snapper discard volumes and estimates were especially heavily underestimated for larger values (i.e., EM estimates larger than 100 kg). It is possible that not having a systematic way for sorting catch and dealing with sub-MLS snapper discards, particularly when dealing with large amounts of sub-MLS snapper, may have impacted the ability of the vessel operator to keep track of discards. Other than some potential overestimation of bins with mixed species, there are no reasons to believe that EM had a specific bias that could have resulted in results from one vessel being considerably different to the other vessels.

Overall, sub-MLS snapper catch effort estimates have the potential to improve as timely feedback is provided over a longer time period. Stanley et al. (2011) reported on the positive effects of the BC groundfish HL fishery audit approach which included timely and regular detailed feedback in improving vessel operators' data accuracy. It also reports that vessel operators' level of engagement and willingness to make the system work has been a key ingredient in the success of the programme.

4.4 Other Considerations

The most important next step following this trial is to continue the data collection and maintain port infrastructure to allow ongoing socialization of stakeholders with the programme and the technology as well as to allow the programme operations to evolve. However, this section covers additional aspects to the programme design that could be considered.

The EM programme described in this report was a pilot study, designed to test specific objectives relating to sub-MLS snapper in the SNA1 fishery. Moving towards an operational programme for the SNA 1 fishery will require a programme design process that could include modification (and expansion of the breadth) of the objectives addressed here, given the findings of this pilot study. The design process links the fishery characteristics and monitoring needs with technology capabilities, monitoring options, regulatory framework, incentive systems, and programme operational requirements (i.e., field service infrastructure, data analysis specifications, and other programme components) to ensure that the programme is efficient, effective, and integrated with management needs. The return on investment of EM programmes, in terms of cost efficiencies and the volume and quality of monitoring data collected, has been shown to increase significantly as trials develop into broader-scale deployment programmes (Stanley et al. 2015).

The following sections list some key considerations in the SNA 1 fishery EM programme design based on our experience and the results from this trial.

Data Collection Models

The trial identified that EM was able to provide independent estimates of sub-MLS snapper discards and to confirm that catch effort return snapper discard estimates tended to align with EM estimates in situations where sub-MLS snapper are binned before being returned to the sea. This provides the basis to consider two different data collection models that could be pursued — a random sample model or an audit model.

It is expected that an EM operational programme in the SNA 1 fishery would entail collecting EM data on a large portion of the fleet (up to 100% by October 2015) and reviewing a portion of the data. The reviewed sample can be chosen randomly, hence eliminating concerns with observer bias because fishers do not know which events will be reviewed they cannot systematically alter their fishing to influence the data. Because there is no observer effect, the resulting sample can be extrapolated across the entire fleet.

Alternatively the portion of the EM data that are analyzed can be compared with catch effort data. This "audit model" uses the data reported by the vessel operators in the catch returns as leverage. The random selection of EM data analyzed is compared (the "audit") with the catch effort return entries for the same hauls to validate industry reported data. The key element is that the catch effort returns, in their entirety, are then accepted as the official record of discards, which provides a better understanding of the discard activity across the entire fleet as compared with simply extrapolating the EM sample to the entire fleet. It effectively provides a 100% monitoring coverage based on validated catch effort data. It also provides other benefits such as increased involvement of industry in the data-collection process, which can lead to increased buy-in from industry in the programme. This is mainly because the official discard estimates comes from industry's own records rather than a "black-box" (Stanley et al. 2011).

Other Information Needs

The focus of this project was snapper discards; however, the results also demonstrate the potential for EM systems to support broader fisheries management objectives. For example, beyond snapper, other species of fish discards were clearly observable with the systems deployed (e.g. porcupine fish, skates, etc.). One of the outcomes of the 2013 review of sustainability and management controls of the SNA 1 fishery was the establishment of the SNA 1 Strategy Group. The remit of this group, comprising commercial, recreational, and customary fishing interests, includes considering the management of the target species (Guy, 2013) in addition to the impacts of snapper fishing on other fish stocks and on the marine environment (S. Halley, pers. comm., cited in Hauraki Gulf Forum 2014). Information on catch composition, including non-target species, is clearly an important component of the knowledge base necessary to support this scope of work, and one that EM systems can effectively address.

4.5 Next Steps

This trial was successful at providing important information on sub-MLS snapper discarding in the fleet and providing insight on how catch effort data compares with independent estimates, at least in situations where sub-MLS snapper are binned before being returned to the sea. It builds on over a decade of pilot trials of EM in New Zealand inshore fisheries that have demonstrated the capability of EM to address a range of fisheries monitoring objectives (McElderry et al. 2007; McElderry et al. 2011; Pria et al. 2014a). Over time, the return on investment in EM systems tends to increase, as systems are bedded in on vessels, technical issues are resolved, cost efficiencies are realised, and monitoring data accumulate (McElderry et al. 2014). Having demonstrated, at a pilot scale, the efficacy of EM in monitoring discards in the SNA 1 trawl fishery, the main key next step is to continue use of EM in the fleet and maintain port infrastructure working. This would harness the momentum and acceptance already generated during the initial trial, expand the understanding of fishing practices, and allow the programme to evolve.

Additional suggested next steps include the following:

- Expand the programme so a greater proportion of the fleet become familiar with the technology and its application;
- Continue to resolve issues relating to data collection on a vessel by vessel basis, to increase data quality;
- Ensure data analysis is timely to provide feedback on improvements needed at the vessel level;
- Continue to build local capacity through increased and repeated contact with the technology;
- Build efficiencies into the programme to reduce costs while not compromising the quality of data collected – this might include optimizing data and field services to be more efficient and extending more responsibility to vessels, especially where there is demonstrated capacity; and
- Consider broadening the objectives of EM deployments to address other data needs for fisheries management.

5.0 ACKNOWLEDGEMENTS

This research was funded by the Ministry for Primary Industries (MPI). Authors M.J. Pria, H. McElderry, and M. Beck are from Archipelago Marine Research Ltd. (amr@archipelago.ca) and J.P. Pierre is from Johanna Pierre Environmental Consulting Ltd. (johanna@jpec.co.nz). The authors wish to thank MPI for their support, in particular Jacob Hore for programme design advice and on the ground support. We are also appreciative of Snapper 1 Commercial policy and technical groups for their commitment and support to the trial. We would also like to thank Bill Westphall and Wayne Limbrick, the local EM field technicians, and Gustav Kessel, the local EM data reviewer. The report greatly benefited from comments and edits from Mr. Rick Stanley, Dr. Martin Cryer, Mark Geytenbeek, and Gustav Kessel. Several Archipelago staff were responsible for the operational components of the trial including Roth Wehrell, Chantal Levesque, Mike Turner, and Mike Reichert. A very special thank you goes to the vessel representatives, skippers and crew that participated in this trial as none of this would have been possible without their participation.

6.0 REFERENCES

Archipelago Marine Research Ltd. (2007). 2007 Groundfish Hook and Line/Trap Catch Monitoring Program Final Results Summary March 13, 2007 – March 9, 2008. Unpublished report prepared for the Commercial Industry Caucus Monitoring Subcommittee.

Archipelago Marine Research Ltd. (2013). 2013 Groundfish Hook and Line/Trap Catch Monitoring Program Final Results Summary 2012 –2013. Unpublished report prepared for the Commercial Industry Caucus Monitoring Subcommittee.

Hauraki Gulf Forum. (2014). State of our Gulf 2014. State of the environment report. Hauraki Gulf Forum. Available: http://www.aucklandcouncil.govt.nz/EN/environmentwaste/coastalmarine/Documents/stateofourgulf2014.pdf

Mangi, S.C.; Dolder, P.J.; Catchpole, T.L.; Rodmell, D.; de Rozarieux, N. (2015). Approaches to fully documented fisheries: practical issues and stakeholder perceptions. *Fish and Fisheries 16:* 426–452 . doi: 10.1111/faf.12065

Middleton, D.A.J.; Williams, C.; Nicholls, K.; Schmidt, T.; Rodley, A.; Rodley, C. (2016). A trial of video observation in the SNA 1 bottom trawl fishery. New Zealand Fisheries Assessment Report 2016/56. 58 p.

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

McElderry, H.; Beck, M.; Pria, M.J.; Anderson, S.A. (2011). Electronic monitoring in the New Zealand inshore trawl fishery: A pilot study. *DOC Marine Conservation Services Series 9*.

McElderry, H.; Beck, M. Schrader, J. (2014). The 2004 to 2010 US Shore-based Whiting EM Program: What did we learn? Report prepared by Archipelago Marine Research Ltd. for the Pacific States Marine Fisheries Commision.

McElderry, H.; Schrader, J.; Anderson, S. (2007). Electronic monitoring to assess protected species interactions in New Zealand longline fisheries: a pilot study. *New Zealand Aquatic Environmental and Biodiversity Report No. 24.* Available: http://doc.org.nz/Documents/science-and-technical/drds264.pdf

McElderry, H.; Schrader, J.; Illengworth, J. (2003). The Efficacy of Video-Based Electronic Monitoring for the Halibut Longline Fishery. Canadian Science Advisory Secretariate Research Document 2003/042.

MPI and SNA 1 Commercial. (2013). Memorandum of Understanding between the Ministry for Primary Industries, SNA 1 Commercial and the vessels owners in the SNA 1 EM programme. 14 March 2014.

MPI. (2013). Review of Sustainability Measures and Other Management Controls for SNA 1 for the 2013-14 Fishing Year. Final Advice Paper. *MPI Information Paper 2013/08*. 6 September 2013.

Guy, H.N. (2013). Review of sustainability measures and other management controls for snapper 1 (SNA 1). Letter from the Minister for Primary Industries. B13-189.

Pria, M.J.; Archibald, K.; McElderry, H. (2014a). Using Electronic Monitoring to Document Inshore Set Net Captures of Hector's Dolphins. Unpublished report prepared for the Ministry of Primary Industries by Archipelago Marine Research Ltd., Victoria, British Columbia, Canada. 49 p.

Pria, M.J.; McElderry, H.; Stanley, R.; Batty, A. (2014b). New England Electronic Monitoring project Phase III. Report prepared by Archipelago Marine Research Ltd. for the U.S. Department of Commerce. Available: http://www.nefsc.noaa.gov/fsb/ems/new-england-em-project-phase3-final-aug15-2014.pdf

Snedecor, G.W.; Cochran, W.G. (1967). Statistical Methods. Iowa State Univ. Press. Iowa. 593 p.

Stanley, R.D.; Olsen, N.; Fedoruk, A. (2009). Independent validation of the accuracy of Yelloweye Rockfish catch estimates from the Canadian groundfish integration pilot project. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1*:354–362.

Stanley, R.D.; McElderry, H.; Mawani, T.; Koolman, J. (2011). The advantages of an audit over a census approach to the review of video imagery in fishery monitoring. *ICES Journal of Marine Science 68:*1621–1627, doi:10.1093/icesjms/fsr058.

Stanley, R.D.; Karim, T.; Koolman, J.; McElderry, H. (2015). Design and implementation of electronic monitoring in the British Columbia groundfish hook and line fishery: a retrospective view of the ingredients of success. *ICES Journal of Marine Science 72:* 1230–1236; doi: 10.1093/icesms/fus212.

Appendix A: Addressing post-retention discards through catch effort comparisons- An example from the BC Groundfish Hook and Line fishery.

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

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

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

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