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COMPARING OBSERVER DATA WITH VIDEO MONITORING ON A FRENCH PURSE SEINER IN THE INDIAN OCEAN.

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SUMMARY

Data collected through an Electonic Monitoring feasability study are presented. The study demonstrates that for for some variables, EM is able to provide reliable fisheries information from French tropical tuna purse seiners. Specifically, these variables are: i) location and time of all fishing events, ii) species composition of catch per event, and iii) total catch weight by species for main target species (yellowfin and skipjack). These results are encouraging and directly correspond with the compliance related objectives of the current observer program. These results also indicate that progress is still required to be made for EM to be considered as an equivalent or complementary option to the scientific observer programme. Set type and non-target species identification are the primary areas where further work is required to improve the data collection processes and outputs.

KEYWORDS
Electronic monitoring, Observer, data collection, by-catch, discards, tuna fisheries, purse seining

Introduction

The data collected by independent observers during fishing operations are commonly used to complement other data, such as those from port sampling or skippers' logbooks. For some types of data, such as discards, observer programs can be the most reliable, and sometimes the only source of information available for management of the fishery. Observer programs are becoming an increasingly important tool to monitor tropical tuna fisheries. Under the IOTC regulations, there is a resolution of 5% coverage of fishing operations for fishing vessels larger than 24 m (IOTC resolution n°11/04).

There are, however, several difficulties involved in placing observers onboard fishing vessels; these difficulties are related to the high costs involved in observer placement, debriefing and data handling, and the limited availability of space to accommodate observers onboard vessels. In some cases, such as in the western equatorial Indian Ocean, problems such as piracy make it extremely difficult, dangerous, or impossible to place human observers onboard.

Electronic monitoring (EM) systems are being used in some fisheries as an alternative and/or a complement to human observers onboard. 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. The International Seafood Sustainability Foundation (ISSF) worked with Institut de Recherche pour le Développement (IRD), Compagnie Française du Thon Océanique (CFTO) and Archipelago to complete this study examining the possibility of using EM to monitor the commercial tropical tuna purse seine fishery within the Indian Ocean.

Success in other regions with the use of EM has shown positive results (Dalskov, and Kindt-Larsen, 2009, Ruiz et al. 2012). In addition to pilot studies, EM has been used successfully in the Canadian British Columbia Groundfish Fishery since 2006 (Stanley et al. 2009, Stanley et al. 2011).

The purpose of this study was to test the use of an EM system on a tropical tuna purse seine vessel during two fishing trips in the Indian Ocean, with a view to examining the possibility of effectively implementing EM in tropical tuna purse seine fisheries. The main objectives of this study are to compare the data collected using EM and observers to determine if EM systems can be used to reliably collect data on commercial purse seine vessels.

The French tropical tuna fishing fleet was comprised of about 20 vessels in 2012, fishing roughly 100,000 tonnes in the Indian and Atlantic Oceans. Two primary fishing methods are used to capture fish: one on free schools and one on schools associated with floating objects (natural or artificial) such as fish aggregating devices (FADs). This latter method has increased in use since the end of the 1980s, and is generated level of bycatch and discards evaluated by Amande et al. (2008, 2010) to be less than 8 % of commercial tunas.

Observer programs have been implemented on the tuna purse seine fishery since 1995 on a project basis (Associated Fauna, Bigeye program). In 2003 for Spain and 2005 for France, these programs entered a regular program within the Data Collection Framework, targeting a coverage rate of 10%. Recently, the IOTC adopted a resolution (Res 11-04) implementing a regional observer program for all fisheries. These observer programs are focused on collecting data from the fishery related to a variety of variables including target catch, bycatch, fishing strategy, and set-type. Additionally, the program is intended to create data that can be used to validate data reported in fisher logbooks.

As shown, for example, by Amande 2012, the main challenge in implementing and maintaining observer programs within the fishery is ensuring that there is proper statistical sampling coverage of vessels. Numerous factors reduce the observer program coverage, including limited space, security, and cost. As an example, since mid-2009, it has not been possible to place observers onboard European purse seiners within the Indian Ocean due to the presence of military forces, and limited space.

Additionally, the annual cost of the French observer program when it was covering 10% of trips was 300 000 €. This study is the first stage in evaluating technically EM, and if this study is successful, costs of a program can be evaluated later on.

Methods

A vessel owned by Compagnie Française du Thon Océanique, the F/V Torre Guilia was selected to take part in the pilot study. The Torre Guilia is a tropical tuna purse seine vessel based in Victoria, Seychelles.

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 ObserveTM v4.2 system with four closed circuit television cameras, a GPS receiver, a hydraulic pressure sensor, and a rotational sensor (Figure 1). The central computer is controlled by software, called EM RecordTM, which collects high-frequency sensor data throughout the entire trip, and records imagery during fishing activity. 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.

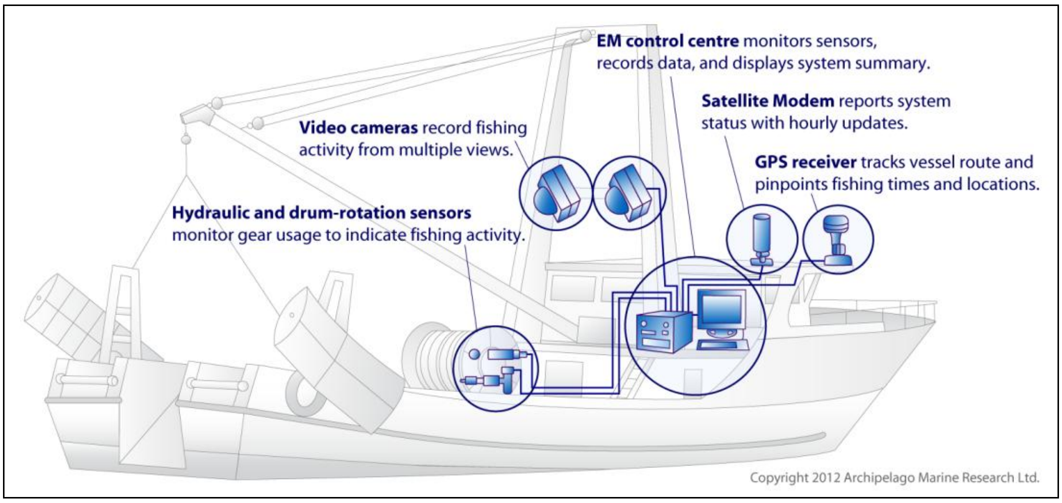

Figure 1. Schematic of a standard EM ObserveTM v 4.2 system that was used during this study

Given the size and complexity of the vessel and onboard catch handling practices, two four-camera EM systems were installed on the vessel to effectively record all fishing activities. A system installed above deck was set to record the capture of fish and general fishing activity, including setting, pursing, brailing, and some discarding. A system installed below deck was set to capture movement of fish along the sorting conveyor belts and discard conveyor.

Fishing activity on the Torre Guilia occurs in the same way during each set; the set begins when the net boat enters the water and begins to pull the net to encircle the school. All fishing activity occurs on the port side of the vessel where the net is set, pursed, sacked and then the fish are brailed aboard. While fish are being sorted the crew removes large bycatch from the brailer for either retention or discarding depending on the species, and discarding occurs on the starboard side after fish are measured and handled by the observer. The bulk of the fish are then transferred through the hatch to the below-deck area and they are sorted on three conveyors, one of which is for discarding fish.The Torre Guilia vessel has three main control points for catch handling:

- Fish sorting area at the hatch entrance,
- Discard handling area on the port side of the deck, and
- Discard conveyor in the below deck area.

Two EM systems were installed; the central computer of the first was installed in the wheelhouse, and the second was installed in an electrical control room on the main deck. Components of the two systems and their objectives were:

- Eight cameras (Figure 2):
  - two views from the port side of the vessel to record gear setting and hauling;
  - two views of the deck activity and brailing of fish into the hold;
  - one view of each of the two conveyors below deck;
  - one direct view of the discard conveyor below deck; and
  - one broad view of the wet-deck area;

- Hydraulic sensor – determined when gear is in use, and triggered imagery recording;
- GPS – determined vessel location and speed; and
- Satellite modem – transmitted an hourly synoptic data report, called a Health Statement to an FTP site.

Figure 2. Above and below-deck camera views from the EM system shown with fishing activity visible

The systems operated independently, and were set to record imagery when there was hydraulic activity (typically associated with use of the winch or brailer), and continue to record for 30 minutes after hydraulic activity had stopped. This setup ensured that at a minimum, the setting, pursing, and brailing of the net were recorded, and that imagery was recorded when the fish were being transported to storage wells below deck.

EM Data Review Methods

The data sets collected using EM were reviewed using the Archipelago EM InterpretTM software. EM Interpret is a specialized software package designed to help the reviewer quickly process, evaluate, and report on fishing activity. The EM Interpret software integrates thousands of video, sensor, and GPS records into a single synchronized profile, and presents it along a common timeline, 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. The EM data were reviewed by an Archipelago EM reviewer at the end of each fishing trip to produce a summary of data. In an effort to match the IRD observer data that were collected, EM reviewers identified a number of variables including:

- set location and time (start/end),
- time of events components (i.e., start pursing, rings up, start brailing),
- set type (to identify if FAD was seen), and
- retained estimated weight by species, and
- discarded catch estimated weight , total piece count, and estimated length.

The EM reviewer used EM Interpret to review sensor data and watch the imagery to create annotations at the appropriate point in the data set. The reviewer used all of the above deck and below deck imagery to document the key components of the fishing event. These annotations were exported from EM Interpret to a Microsoft Access database for further analysis and comparison to IRD observer data.

Estimating Catch from EM Data

The EM data outputs created by an Archipelago EM reviewer quantified the number of trips, sets, and brailers per set which were then used to estimate the tuna catch. Each brailer annotation required the reviewer to enter the "brailer fullness", species, and species composition percentage. This information was then used to estimate the total weight of tuna that were retained according to equation (1):

Total catch (kg) = full brailer (kg) * brailer fullness * species percentage

The "full brailer" (6 metric tonnes) was provided by the observer (personal communication P. Dewals November 21, 2012), and used for each of the brailers for this study (note: this value is dependent on the vessel's gear). The relationship between brailer fullness and brailer weight was assumed to be constant, therefore the same full brailer weight was used for each calculation.

Data Capture Success

Data capture success is defined by two key components including: overall sensor data, and overall imagery data. These metrics are useful in assessing the success of the EM system for collecting data at-sea, and for achieving the monitoring objectives. Overall sensor data success as defined as the amount of time for which the EM system was running and collecting sensor data (i.e., GPS, hydraulic pressure, and rotational data), or the duration of the trip minus the total timegaps. This metric reflects when the EM system was functioning normally and collecting sensor data. Incomplete data collection could be caused by a variety of factors related to either the system itself or vessel and crew behaviour (system powered off, or vessel power loss). A complete data set (100%) was expected for each of the systems, and includes continuous sensor data collection from the time the vessel left port to the time the vessel returned to port. In addition, the imagery data success, which was defined as the amount of time for which the systems were functioning as expected during fishing events (i.e., collecting sensor and video data). Imagery success of 100% indicates that for all sets, there was imagery collected when it was expected. Imagery success rate only reflects when video was recorded, and does not include a measure of image quality or usefulness.

Statistical Analysis

This study consists of systematic comparison between data collected by the IRD observer on board during the trip and data derived, after the trip, by the analysis of sensor and imagery captured by the EM system and reported by the Archipelago EM reviewer. All statistical analyses and comparisons were performed by IRD and compared the data provided by IRD (referred to as observer data) with that provided by Archipelago (referred to as EM data). The comparisons were made on the 5 following variables:

1. Set position,
2. Set type detection for each fishing event (Figure 3),
3. Total catch and species diversity estimation,
4. Catch species composition,
5. Discarded species composition and length structure.

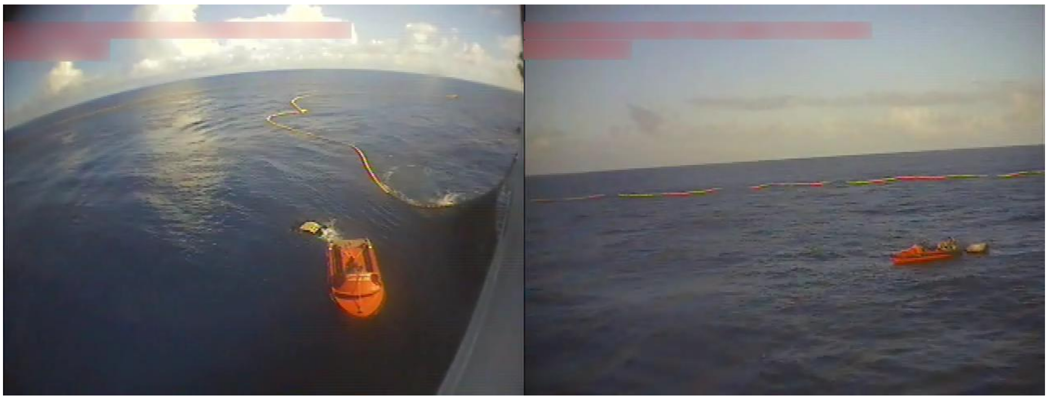

Figure 3. Examples of a FAD visible within camera views during Trip 1 on the Torre Guilia.

Set position

For this comparison we used the distance calculated between set position as recorded by the observer and EM for all trips. Comparisons were made to determine the proximity of the observer starting point to the EM starting point.

Set Type Detection

Set type may be identified by EM reviewer using sensor data only (speed, pressure or drums), videos only or both.

Using sensor data, it is possible to distinguish FAD and FSC sets looking at the vessel track before setting the net. Typically, a FSC set is characterized by a significant time period at moderate speed dedicated to various encirclements of the school in order to assess its size, depth and speed which parameters will determine set deployement and characteristics. A FAD set, in contrast, is more rapid: once localized (by eye or GPS) and assessed to be rich in tuna, the object is fixed by a speed boat and encircled.Videos images are useful identifying FAD set if an object is observed but this requires a camera being installed in a good position to capture object manipulation and works well.

We compared the total number of sets identified as FAD or FSC by the observer and using EM for both trips. We present a comparison matrix of event classification by monitoring method.

Total Catch and Species Diversity

We summarised and compared the total catch per event, and number of species recorded (species diversity) recorded by the EM reviewer and observer. To support this analysis, we used analysis of variance (ANOVA) to determine if the two monitoring methods produced significant different data for total catch and species diversity at the event level.

Species Composition

Analysis of variance was conducted on EM and observer total catch per trip data (1) for all species recorded, and (2) for those species with a total weight larger than 0.1 metric tonnes. This was done to determine if EM and observer data report the same overall catch per species at the trip level.

Discard Species Composition and Length

The EM reviewer used the length estimation tool in EM Interpret to estimate the length of discarded catch items for three fishing events during Trip 2 (events 1, 13, and 20). This was done based on the markings made along the discard conveyor belt. These markings were made by the technician during installation and were measured for calibration (Figure 4). The discard conveyor is the last location on the vessel where small individual discards of non-target species were handled prior to being discarded, however larger species were handled above deck so did not come within view of the discard conveyor camera, and as a result length was not measured using EM. The EM reviewer used the measurement tool to mark the nose and tail (see Appendix A) to estimate fish length. Fish were not measured if they were only partially in view, or a part of the fish was outside of the lines marked on the conveyor.

Figure 4. Example of the view from camera 3, which was used to determine length using EM. Reference points on the discard conveyor were used to estimate length using EM Interpret

Data from the EM length estimates were compared to the observer data sub-sample of bycatch. It is important to note that EM was used to census the discard conveyor, whereas the observer measured a sub-sampled of the overall catch

Results

EM Data Collection

The EM system was in use during two fishing trips that took place between April and August, 2012. Some changes were made to the camera positioning during the first trip, but no changes were made during the second trip to the camera position. A total of 43 events occurred during the fishing trip, of those, 40 fishing events that were recorded using EM, and 39 were reviewed by the EM reviewer, for a total of 351 hours of video imagery collected. One event on April 25, 2012 (Trip 1) was not documented due to EM reviewer error; the reviewer did not identify the start and end of the set, therefore the video was not reviewed thus highlighting the need for quality assurance protocols in an operational program.

Throughout the two trips, there were a total of 74 time gaps in the sensor data, which resulted in an overall sensor data collection success of 96% across both trips (Table 2). This indicates that the system was functioning and able to record sensor data for nearly all of time that the vessel was out of port.

There were no video gaps found in the data (Table 3). This means that there was imagery collected for all periods of time for which video imagery was expected.

Set Position

Comparisons between the set location recorded by the IRD observer and EM reviewer indicate that there are three obvious outliers in Trip 1 (Figure 5 and Figure 6), which are likely latitude errors made by the observer. Data collection protocol uses the four quadrants (NE, NW, SE and SW) and this frequently leads to sign inversion of latitude or longitude. The average distance between EM and observer set positions is 1153.2608 m with a standard deviation of about 625.5566 m, when the three sets with latitude inversion error are excluded. This difference corresponds to the degree resolution (0.0001) of data recorded by the observer.

Set and set type detection

The EM data revealed that there is a specific signature visible in the EM sensor data for this vessel during fishing (Figure 6). The pattern is as follows: the start of a set was identified by high vessel speed (11 to 13 knots) while steaming to a fishing location. During the setting of the net, the vessel moved at low speed (1 knots) briefly, then at high speed (>9 knots). This period indicated that the crew was setting the net and encircling the tuna. After setting, the sensor data typically showed high pressure followed by several hours (~3) of low speed (<1 knots), while the net was being pursed, and the fish were brailed. The rotational sensor on the main winch showed rotation following the set, and near the end of pursing. In addition to line graphs, a map displaying the vessel cruise track can be used to help identify sets; the distinct combination of speed and direction indicates where a set has taken place. In this study, the cruise track indicated that the vessel typically approached and encircled the fish, and then drifted for several hours while fish were brailed.When the vessel was not taking part in fishing operations, the typical cruising speed was around 11-12 knots while steaming. Additionally, the vessel speed usually dropped to roughly 1 knot between the evening and morning (about 19:00 to 06:00).

Table 1. Summary of trips and total events and total video collected during two fishing trips on the Torre Guilia

Trip	EM System Start Date	EM System End Date	Recorded Fishing Events	Total Video (hours)
Trip 1	02/04/2012	08/05/2012	17	219.2
Trip 2	05/07/2012	07/08/2012	22	131.4
Total			39	350.7

Table 2. Summary of overall sensor data collection success during two fishing trips on the Torre Guilia

Trip	Total Trip Hours	Total Gaps	Gap Time (hours)	Data Collection Success (%)
Trip 1	913.5	57	58.5	93.6
Trip 2	793.0	17	2.7	99.7
Total	1706.5	74	61.1	96.4

Table 3. Summary of gaps in the video data during two fishing trips on the Torre Guilia

Trip	Total Event Hours	Total Video Gaps	Video Gap Hrs	Video Collection Success (%)
Trip 1	39.8	0	0.0	100
Trip 2	57.4	0	0.0	100
Total	97.2	0	0.0	100

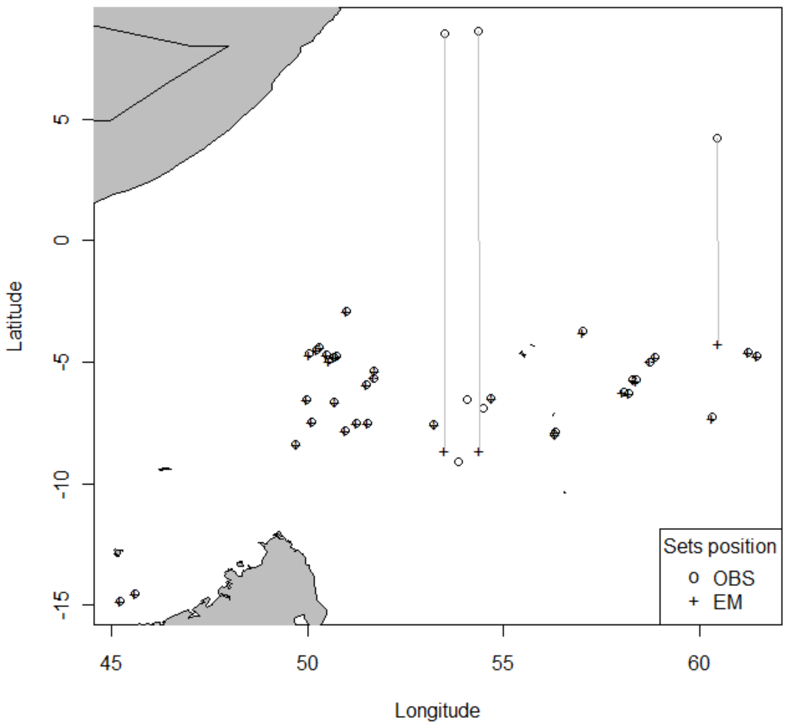

Figure 5. Set positions according to observers (OBS) and electronic monitoring (EM)

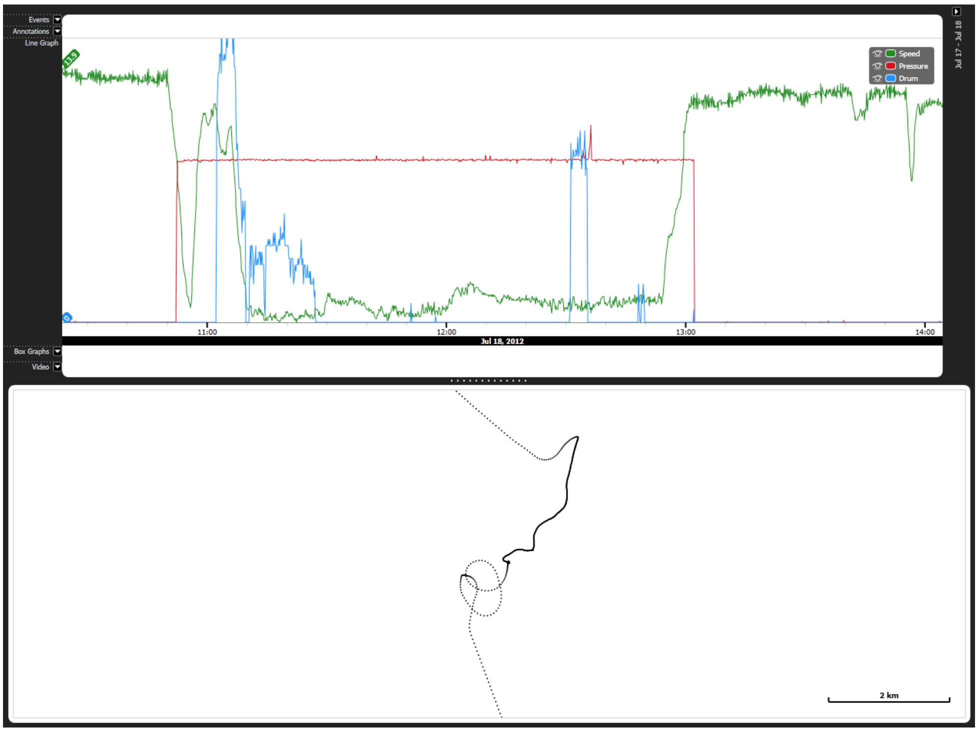

Figure 6. Example of EM sensor data and cruise track collected for a typical purse seine FAD set (July 18, 2012)

The set type (FAD or FSC) was correctly identified by the EM reviewer for 31 of the 40 observed events (78%) during the two trips (Table 4). During Trip 1, one fishing event was missed by the EM reviewer during the sensor data review process, and consequently, was not categorized as a FSC or FAD set. A two-sided Chi-squared test was used with an alpha of 0.05 to test if the observer and EM reviewer data were significantly different, with the observer data being the expected values. The event which was not classified by the EM reviewer was not included in the analysis. The Chi-squared value was 10.256, which is greater than the critical value of 5. 024 ($\alpha = 0.05$), indicating that the data are significantly different. A significant number of the FAD events were incorrectly classified as FSC fishing events.

Most of the mis-classified events were during the second trip, when the camera view did not show the FADs being handled, so were based on sensor data alone. Using only sensor data for this vessel proved to be less reliable than the combination of sensor and video data. For example, Figure 7 shows a fishing event that was incorrectly classified as a FAD set based only on the sensor data because the vessel's approach to the fish is consistent with the pattern that is expected for FAD sets.

Table 4. Number and percentage of success or failure to correctly determine set type as free school (FSC) or object (FAD) for both trips combined

Set-type identification	FAD	FSC	Total	Percent
Failure	6	2	8	20%
Success	31	0	31	78%
Unidentified set		1	1	3%
Both Trips Total	37	3	40	

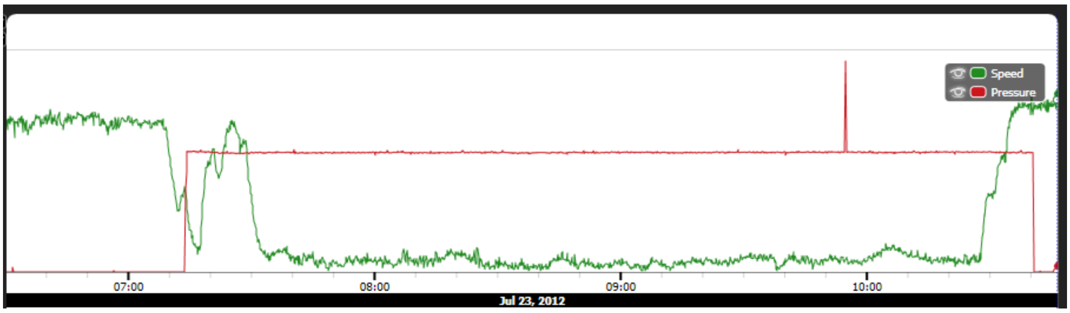

Figure 7. Example of a FSC fishing event that was incorrectly classified as a FAD set by the EM reviewer.

Total Catch and Species Diversity

For the two observed trips, the total catch per trip recorded by the EM reviewer and by the observer was similar (Table 5), with observer data being slightly higher. At the event level, there is correlation between EM and observer data for total quantities of catch and species diversity per event (Figure 8).

Regarding the total number of species observed per event, the two sets of data sets are highly variable with no evident trends (Figure 9). Additionally, analysis of variance (Table 6 and Table 7) indicates that there is no significant difference between the two sources of information for quantities of species and species diversity.

Table 5. Quantities in tonnes and number of species estimated by the IRD observer and the EM reviewer for each trip.

Source	Quantity (tonnes)	Species Diversity
Observer	882.7	38
EM	858.4	30

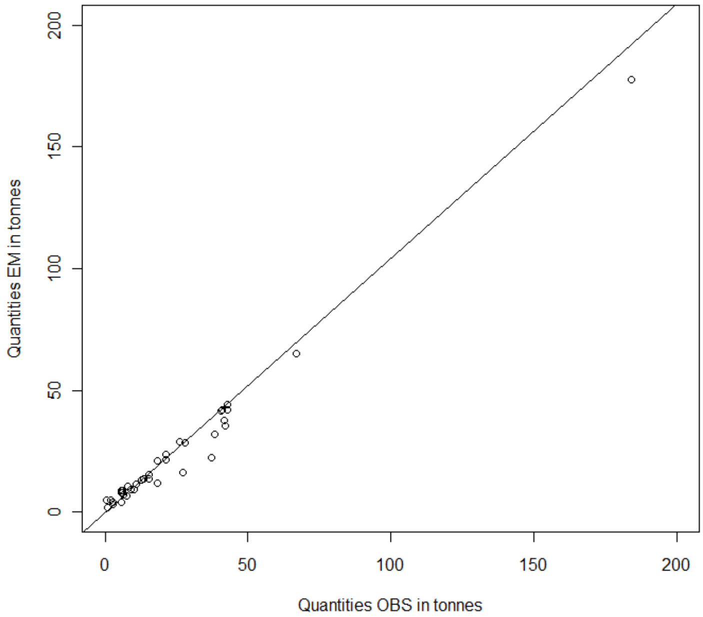

Figure 9. Comparison of EM reviewer and IRD observer (OBS) estimates of total catch per fishing event.

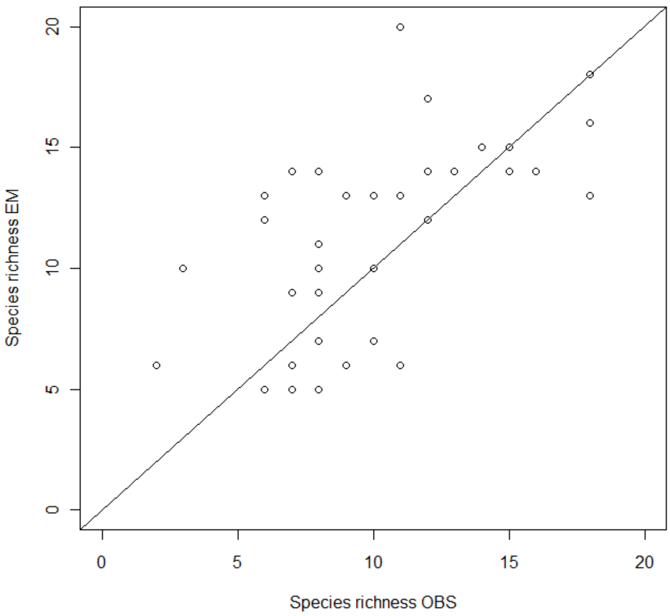

Figure 10. Comparison of the estimated total number of species observed for each event by the EM reviewer and the IRD observer

Table 6. Analysis of variance of catch quantities (tonnes) estimated per event according to source of information (Observer or EM)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Id	36	2926050646	81279184.6	1.611	0.0133
Source	1	1189794.37	1189794.37	0.0236	0.8780
id:source	36	463928955	12886915.4	0.2555	0.999998
Residuals	1046	5.276E+10	50439557.6	NA	NA

Table 7. Analysis of variance of species diversity per trip according to source of information (Observer or EM)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Source	1	25.0	25.0	1.591	0.2113
Residuals	72	1131.0	15.7	NA	NA

Catch Species Composition

There was no statistically significant difference detected between the EM and observer data for total weight for all species. This was also the result for comparisons between EM and observer data for species for which the total catch was greater than 0.1 metric tonne (Table 8 and Table 9).

Catch composition data from the two datasets (Table 10) indicate that some target species (yellowfin and skipjack tuna) are similarly estimated by EM reviewers and IRD observers at the trip level. Bigeye tuna catch appear to be rarely documented by the EM reviewer when it was identified by the observer. This discrepancy is likely due to the difficulty distinguishing between yellowfin and bigeye tuna by non-experts. Species identification was generally made at the species level by IRD observers while species groups, family or order (such as Carcharhiniformes, Osteichthyes, and Scombridae) were used by the EM reviewer, who in this experiment, did not have hands-on experience in Indian Ocean species identification. This discrepancy may then be improved if experienced observers with hands-on experience in the Indian Ocean conduct the reviewing process. In addition, Sharks and Istiophoridae were potentially missed by the observer but were captured by the EM reviewer.

Table 8. Analysis of variance of relative weight by species for all species caught according to source of information (Observer or EM)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Source	1	8.256	8.256	0.0548	0.8156
Residuals	66	9937.1	150.562	NA	NA

Table 9. Analysis of variance of relative weight by species for species with relative weight larger than 0.1 according to source of information (Observer or EM)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Source	1	5.77	5.768	0.0116	0.9154
Residuals	17	8441.2	496.543	NA	NA

Table 10. Estimated weight (kg) by species for both trips according to the IRD observers (OB) and Archipelago EM data

Species code	Scientific name	Common Name	EM	Observer
Tuna				
MAX	Family *Scombridae*	Mackerels, and tunas	46,588	0
WAH	*Acanthocybium solandri*	Wahoo	567	8,107
FRI	*Auxis thazard*	Frigate tuna	600	825
ALB	*Thunnus alalunga*	Albacore	840	1,000
BET	*Thunnus obesus*	Bigeye	4,200	54,942
YFT	*Thunnus albacares*	Yellowfin	197,144	170,163
SKJ	*Katsuwonus pelamis*	Skipjack	582,592	621,226
			832,531	**856,263**
Sharks				
CVX	Order Carcharhiniformes	Ground shark	969	0
RSK	Family *Carcharhinidae*	Requiem shark	1,282	50
FAL	*Carcharhinus falciformis*	Silky shark	0	1,013
			2,251	**1,063**
Other Species				
BIL	Family *Istiophoridae*	Marlin	900	111
MZZ	Paraphylum *Osteichthyes*	Bony fish	16,163	0
DOL	*Coryphaena hippurus*	Mahi	1,822	6,399
GBA	*Sphyraena barracuda*	Great barracuda	136	870
RRU	*Elagatis bipinnulata*	Rainbow Runner	803	8,438
CNT	*Canthidermis maculata*	Triggerfish	3,002	7,401
			22,826	**23,219**

Discard Species Composition and Length

Of the 2643 fish that were observed by the EM reviewer on the discard conveyor area, 2449 fish were measured with a mean length of 32.2 cm across all species. For the same events, the observer data contained a total of 107 measurements with a mean length across all species of 60.5cm (Table 11). An examination of mean length by species from each data collection method reveals that large differences (> 45cm) were common from larger species types and those that would be valued by the kitchen (e.g., Wahoo and Great Barracuda) (Figure 11) suggesting that EM reviewer length estimates did not include the larger catch items that were recorded by the IRD observer.

Table 11. Main results from discards comparison between source of information (Observer or EM)

Result	EM	OBS
Number of species/groups identified and measured	16	15
Number of species/groups not identified by alternate system	3	3
Number of measurements	2449	107
Mean Length (cm)	32.2	60.5
Standard deviation (cm)	8	28.4

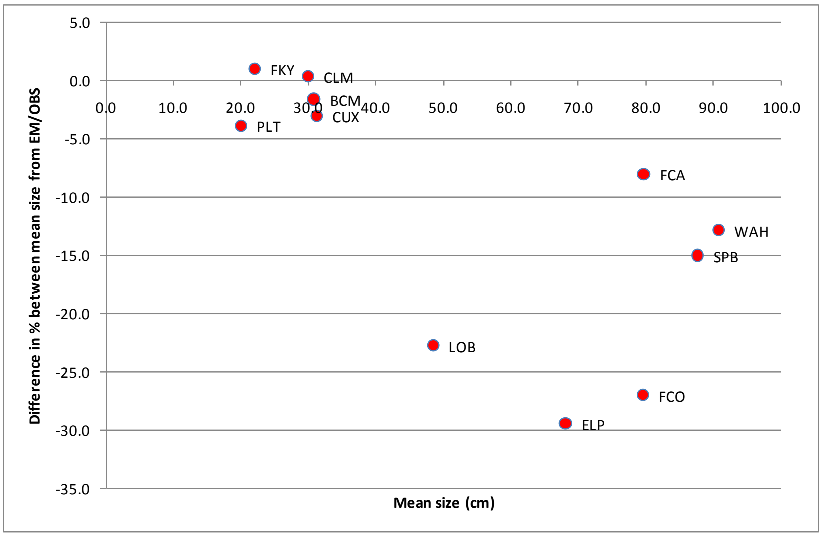

Figure 11. Mean length (cm) comparison by species discarded between observer and EM data. X –axis is the mean size according to the observer, the y-axis is the difference in mean size between EM reviewer and observer data. See Appendix for species codes and names

Discussion

This project was designed and conducted to meet three objectives related to the potential use of EM for monitoring the tune purse seine fishery; these objectives are to:

- Evaluate electronic monitoring technologies (sensor, videos) and methods of implementing automatic collection of at sea fisheries data (catch, bycatch, set location, set type);
- Systematically compare data collected by EM with those collected through observer program; and
- Evaluate needs of an operational program for the use of EM for monitoring the Indian Ocean tropical tuna purse seine fishery.

The discussion below touches on the relevant results and related objectives of the study, and draws comparisons to other EM pilot projects and papers.

The EM system performed well during the project after some initial trouble-shooting. The scientists onboard fixed minor problems with the GPS connection during the first few days of the first trip. Following the adjustments data collection was 96%, which is similar to the level of success (100%) observed on the Playa de Bakio during the first ISSF EM pilot study (Ruiz et al. 2012). Some limitations of the image quality and resolution were noted by the scientists involved (Dagorn et al. 2012, Cauquil, 2012). Throughout the life of the project, there have been several advances in EM technology that will likely help to mitigate the challenges highlighted by this project; the latest EM systems are now capable of using up to eight digital cameras with three times the resolution of the analogue cameras that were used in this study (Figure 12). This advancement will be particularly useful for tuna fishing vessels where catch handling is dispersed throughout the vessel, and the improved video quality will enhance species identification.

Figure 12. Example of analogue imagery (left) and digital camera imagery (right). This project used analogue cameras, and future work could be enhanced by the use of digital imagery

In this study, the set type of 78% of the events were correctly identified by the EM reviewer using a combination of sensor and video data; this result is lower than the 98% success that was reported on the Spanish purse seiner the Playa de Bakio (Ruiz et al. 2012). The Torre Guilia fishing behaviour results in a sensor data pattern that was not as indicative of set type. A heavy reliance was placed on imagery, but in the second trip, a change in camera placement resulted in the imagery not capturing the FAD use. In some cases (Ruiz et al. 2012), sensor data alone can be used, however, in this study a heavy reliance on the video data was required for determining typeset type (FAD and FSC).

Set type identification is absolutely necessary for scientific studies because it greatly influences the species and sizes encountered within an event. Improvements in this area could be made through further examination of the high frequency positioning information that is provided by the EM system. As demonstrated by Ruiz et al. (2012), and the results of this study, we know that different set type events require different vessel trajectories and movement. Modifications to the camera position and adoption of the newer digital cameras could improve set type information.

Comparisons of EM and observer data for total catch, and species diversity at the event and trip level, indicate that EM is able to collect similar data to that which are collected by observers because catch composition and total catch weight by event were not shown to be statistically different in this study. EM has proven to be extremely reliable for the estimation of catch volume within the purse seine fishery; Ruiz et al. (2012) also reported that EM was able to accurately report tuna catch. When reviewing imagery, the EM viewer frequently relied on family rather than species to identify fish, and was unable to identify bigeye tuna correctly. This classification is due partially to image quality and camera view. Improved imagery quality would allow a better identification of species although this would impact data storage costs, which should be more thoroughly evaluated. Additionally, ensuring that EM reviewers are familiar with the target and bycatch species of the specific fishery will aid in the reliability of species determination. All imagery review for this project was conducted by an Archipelago EM reviewer who has extensive knowledge of the tuna and bycatch species, but does not have onboard experience in the Indian Ocean fishery. Ideally, in an operational monitoring program the EM reviewers will be current or former at-sea observers with experience in the fishery in question, and will have extensive species identification experience. Under such a scheme, active observers could be trained to use EM InterpretTM to conduct EM reviews between at-sea deployments, and would provide the expertise to identify catch.

EM was used to measure the length of all fish on the discard conveyor for a total of three events; in these events, EM measured 23 times as many fish as were sampled by the observer. This discrepancy is largely due to differences in sampling methods between the EM review and the observer sub-sampling. EM length measurement is a very promising tool for this fishery, and results indicate that it allows for high quantities of reliable catch observations. As this tool is used, catch handling processes will need to be modified, or installation altered to remove size-based bias in length measurements.

This pilot project is the first step in the overall move toward using EM as a monitoring tool, and has focused on the proof of concept and testing of the basic functionality of the EM suite of tools. The outcome of the pilot project highlights some of the data gaps, and areas on which more focus will be required. It is important to recognize the difference between pilot studies and operational monitoring programs, and to learn from the pilot projects to define where future technical efforts should focus.

During the transition from a pilot to operational program, several standards must be developed to enhance the data collection quality. Each of these should be focused specifically on a program objective, or a variable that helps to achieve a given objective. Examples of standards are:

- Installation standards for defining what technology will be used and how it will be installed;
- Camera placement and views for defining the required areas or activities that must be captured;
- Data review quality assurance protocols such as data audits and logbook comparisons;
- Vessel monitoring plans outlining the installation and how the data will be used;
- Length measurement sampling protocols;
- EM reviewer qualifications, experience, and training programs; and
- System function requirements that define when the system must be on and how the data will be collected.

Based on the first EM pilot project, ISSF created data collection standards for EM use on tropical tuna purse seiners (Restrepo, 2012). This is an important first step and these standards should continue to be updated based on the results of current and future projects.

Pilot studies often do not include the opportunity to consider what is required to make EM work as an operational monitoring program. This is a process of aligning the goals of deploying the technology and the operations of the vessel. As noted by McElderry (2013), fully operationalizing EM is more extensive than a pilot study alone, and involves a thoughtful design process, carefully balancing a range of technology/methodology options to ensure that the information needs link with the specific monitoring objectives.

Conclusion

This study onboard a French tuna purse seiner demonstrates that for some variables, EM is able to provide reliable fisheries information from tropical tuna purse seiners. Specifically, these variables are: i) location and time of all fishing events, ii) species composition of catch per event, and iii) total catch weight by species for main target species (yellowfin and skipjack).

These results are encouraging and directly correspond with the compliance related objectives of the current observer program. These results also indicate that progress is still required to be made for EM to be considered as an equivalent or complementary option to the scientific observer programme. Set type and non-target species identification are the primary areas where further work is required to improve the data collection processes and outputs.

While more development of the application and use of EM as a monitoring tool is required within the fishery, this work is the first step in opening the door to the use of EM within the tropical tuna purse seine fishery.

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APPENDIX

All species codes and scientific names used.

IRD Code	Scientific Name	IRD Code	Scientific Name
ALB	*Thunnus alalunga*	COI	*Carangoides orthogrammus*
ANA	*Aetobatus narinari*	CRS	*Caranx sexfasciatus*
ASU	*Alopias superciliosus*	CUH	*Uraspis helvola*
AVA	*Abudefduf vaigiensis*	CUP	*Cubiceps spp*
AVU	*Alopias vulpinus*	CUS	*Uraspis secunda*
BAE	*Abalistes stellatus*	CUX	*Uraspis spp*
BAS	*Aluterus scriptus*	DCC	*Dermochelys coriacea*
BAT	*Aluterus monoceros*	DDE	*Delphinus delphis*
BBO	*Balaenoptera borealis*	DIH	*Diodon hystrix*
BCM	*Canthidermis maculata*	DIO	*Diodontidae*
BEA	*Ablennes hians*	DIY	*Diodon eydouxii*
BED	*Balaenoptera edeni*	DUS	*Carcharhinus obscurus*
BET	*Thunnus obesus*	DVI	*Dasyatys (Pteroplatytrygon) violacea*
BLM	*Makaira indica*	EHN	*Echeneis naucrates*
BLT	*Auxis rochei*	EIM	*Eretmochelys imbricata*
BMU	*Balaenoptera musculus*	ELP	*Elagatis bipinnulata*
BPH	*Balaenoptera physalus*	EPL	*Phtheirichthys lineatus*
BRA	*Bramidae*	ETM	*Etmopterus spp*
BUM	*Makaira nigricans*	FAL	*Alopias spp*
CCA	*Carcharodon carcharias*	FAT	*Feresa attenuata*
CCC	*Caretta caretta*	FBA	*Balistidae*
CCH	*Cyclichthys orbicularis*	FBL	*Belonidae*
CEX	*Mammalia*	FCA	*Carcharhinidae spp*
CFA	*Carcharhinus falciformis*	FCO	*Coryphaenidae*
CLM	*Decapterus macarellus*	FCR	*Carangidae*
CLO	*Carcharhinus longimanus*	FDA	*Dasyatidae*
CLP	*Clupeidae*	FEC	*Echeneidae*
CLU	*Caranx lugubris*	FEP	*Ephippidae*
CMM	*Chelonia mydas*	FEX	*Exocoetidae*
COE	*Coryphaena equiselis*	FFI	*Fistularia spp*
COH	*Coryphaena hippurus*	FIS	*Istiophoridae*

IRD Code	Scientific Name	IRD Code	Scientific Name
FKY	*Kyphosus spp*	MAL	*Masturus lanceolatus*
FLA	*Lamnidae*	MAN	*Mobulidae*
FMO	*Molidae*	MAZ	*Scomber spp*
FPO	*Pomacentridae*	MBA	*Manta birostris*
FRH	*Rhincodontidae*	MCO	*Mobula tarapacana*
FRI	*Auxis thazard*	MDE	*Mesoplodon densirostris*
FRZ	*Auxis spp*	MIW	*Balaenoptera acutorostrata*
FSC	*Scombridae*	MMO	*Mola mola*
FSE	*Serranidae*	MNO	*Megaptera novaeangliae*
FSP	*Sphyrnidae*	MNT	*Manta spp*
FTT	*Tetraodontidae*	MOM	*Mobula mobular*
GCU	*Galeocerdo cuvier*	MPE	*Megachasma pelagios*
GES	*Gempylus serpens*	MRA	*Mobula japanica*
GGR	*Grampus griseus*	MYS	*Mysticeti*
GMA	*Globicephala macrorhynchus*	MZZ	Osteichthyes
GME	*Globicephala melas*	NAD	*Naucrates ductor*
IBR	*Isistius brasiliensis*	OCA	Carcharhiniformes
IOX	*Isurus oxyrinchus*	ODO	*Odontoceti*
KAW	*Euthynnus affinis*	OHT	Heterodontiformes
KBR	*Kogia breviceps*	OHX	Hexanchiformes
KPC	*Kyphosus cinerascens*	OLA	*Lamniformes*
KPV	*Kyphosus vaigiensis*	OOE	*Orectolobiformes*
KSI	*Kogia sima*	OOR	*Orcinus orca*
LAG	*Lampris guttatus*	OPR	*Pristiophorus spp*
LAM	*Lampris spp*	OSR	*Squaliformes*
LDI	*Lactoria diaphana*	OST	*Squatinidae*
LHO	*Lagenodelphis hosei*	PCR	*Pseudorca crassidens*
LLA	*Lagocephalus lagocephalus*	PEP	*Peponocephala electra*
LOB	*Lobotes surinamensis*	PGL	*Prionace glauca*
LOL	*Lepidochelys olivacea*	PLS	*Platax spp*
LOT	*Thunnus tonggol*	PLT	*Platax teira*
MAK	*Isurus spp*	PMA	*Physeter macrocephalus*