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PRELIMINARY STUDY ABOUT THE SUITABILITY OF AN ELECTRONIC MONITORING SYSTEM TO RECORD SCIENTIFIC AND OTHER INFORMATION FROM THE TROPICAL TUNA PURSE SEINE FISHERY

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SUMMARY

Electronic monitoring systems (EMS) are used in some fisheries to collect the same types of scientific information that human observers can collect, and in some cases for compliance with existing regulations. An EMS system was tested previously onboard a tropical tuna purse seiner in the Atlantic Ocean and it showed that the system could perform very well in many tasks. Since then, 17 purse seine vessels operating in the 4 RFMO´s, have been equipped with a different EMS that has been developed recently by SATLINK (SeaTube). In this paper, we present preliminary analyses comparing information collected by human observers from the IEO and recordings of the SeaTube system reviewed by DOS (Digital Observer Services) of 103 sets made along 4 trips in 2 different vessels in the Atlantic Ocean. We compare in particular estimates of catch per set (for target and non-target species), amounts of discards, fishing effort type and set location. We also comment on other potential uses of the electronic system including for compliance purposes.

KEYWORDS

Tropical tuna, electronic monitoring system, purse seining.

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1. INTRODUCTION

Electronic Monitoring Systems (EMS) can be a useful tool to monitor many aspects of fishing operations. Once the objectives of a monitoring program are decided, the system chosen should be operationalized to meet those objectives (McElderry, 2008; Dunn and Knuckey, 2013).

Purse seine fisheries take about 63% of the total global catch of the major commercial tuna species, and 51% in the Atlantic Ocean (ISSF, 2014). Their sampling for catch, species composition and bycatch -including discards- is usually done through combined analyses of skippers' logsheets, port sampling and observer coverage (Anonymous, 2010). Typically, total catch per set is reliably estimated by the crew and observers. However, species composition of the catch is more difficult to determine onboard because large volumes of catch are processed rapidly and stored into wells, and thus port sampling is also used. On the other hand, bycatch, especially discards, cannot be estimated through port sampling and skippers have no incentives to record these quantities accurately.

EMS systems have been tested in the past to see how they would perform in monitoring the fishing operations of tropical tuna purse seiners in the Atlantic (Ruiz et al. 2012) and Indian Oceans (Chavance et al. 2013). The data collected in these pilots was contrasted against the information recorded by human observers during the same fishing trips, with encouraging results. These learning experiences led to the development of technical guidance for the collection of various data types via EMS (Restrepo et al., 2014) with the understanding that several vendors were developing and improving new systems.

One of the new systems, "SeaTube", is manufactured by Satlink, a tech company in Spain. This system has been placed on at least 17 EU flagged and associated purse seine vessels in all oceans. The purpose of this document is to present preliminary analyses of the data collected during four trips (in two different vessels) in the Atlantic Ocean during 2014.

2. METHODOLOGY

The SeaTube system had been previously installed by Satlink and operating in the Albacora 10 and Albacora 9 purse seine (**Fig. 1**) vessels several months prior to the collection of the set of data used for the analysis.

2.1 The System

The system was installed in both vessels with the same configuration. It consists of 4 HD cameras, 2 on the upper deck, one pointing at the port side to record setting, sacking and brailing activity and a second one directed at the starboard side allowing to collect any discarding and handling of associated species. Both cameras had a top perspective of the board. Two more cameras were installed on the below deck, positioned is such a manner that all fish directed to the wells in either side of the vessel, could be recorded (**Fig. 2**). Videos are recorded at 1280x720 @ 24FPS (HDTV quality) and minimum recording capacity of the system is 4 months.

The system records nonstop all the vessels' activity from one hour before dawn until one hour after sunset. The system is connected to a separate VMS satellite tracking device that provides the GPS position, course, time and date and speed information. The VMS satellite tracking device provided with SeaTube is approved in at least one European country for Vessel Monitoring System as defined under the European Union legislation. Position, time and date, course, speed, camera # and vessel ID are simultaneously recorded in an encrypted metadata file and embedded into the video and the resulting file is sent to a central unit housing the solid state hard drives. The resulting video is portioned into files of 10 minutes, which are continuous one to the next. Position from the VMS system is recorded with a resolution of 0.0001 of a degree ~11.1 meter. The system is designed to avoid any type of manipulation, applying same standards as for VMS systems. The resulting recordings cannot be altered.

A backup system is also equipped on board where a total recording time of up to 6 months' time can be stored.

The system is checked remotely on a daily basis to ensure it is operational. Samples of the footage, cameras placement and lenses cleanliness are verified. The SeaTube systems also sends an automated daily report with information of the recorded videos, consumed memory and remaining space in the storage units which is checked by Satlink and technicians and DOS as well.

A number of other processes are monitored. Inconsistencies and malfunctions trigger a series of coded alarms communicated through the IDP system:

-Processor performance
-Recent GPS positions, date and time coherence.
-Connection with server
-Gaps between videos
-Status of backup disks
-Other

System Technical specifications can be found in **Appendix 1**.

2.2 Review of recordings

The review and analysis of the data was conducted by DOS (Digital Observer Services). DOS is an independent provider of Electronic Monitoring (EM) reviewing services specialized on the SeaTube Electronic Monitoring System. DOS reviewing is conducted by former fishing observers with an extensive experience on Purse Seine national observer programs.

The quality of the video differed from one vessel to another. Albacora 9 videos were available only in medium quality, while Albacora 10 videos were recorded in high quality. This difference was due to tests being conducted by Satlink using various systems set ups and had no methodology purposes for this analysis. However, it is noted that these differences could affect the results presented in this document.

Review and analysis were completed with the use of a specific reviewing software developed by Satlink (View Manager, VM). The analysis software allows to navigate through the entire set of recorded data applying filters in order to identify the pieces of record which are of potential interest based on the desired activity. Vessel speed and elapsed time are the variables used to filter fishing events from the rest of the recording. The selected speed and time to assume that a set is taking place are speed of 2.5 Knots and below for at least 60 min. All the periods meeting the filter conditions can be then selected and added to a project that will contain only the recordings previously identified as of interest (**Fig. 3**).

Filters can also be applied using dates and positions, by EEZ or designing a custom area with the VM software. VM also allows to display the entire trip in a regional map, showing EEZ boundaries and vessel course. Each point displayed in the map represents a 10 min file (**Fig. 4**).

Once the data has been filtered to identify times when sets likely took place, the review consists in determining: the positions, dates and times of the start and end of the set, the type of set (if possible at this stage) the percent fullness of each brail, the % of each target species, whether there has been any discard on target species and the estimated amount and species. The non-target species caught are recorded in number of individuals. The species code for the non-target species, its approximate size and its fate are also noted.

The VM features an input system which allows the reviewer to record data for each event. For each set, a dialog box is displayed to enter the type of set. Then each brail is numbered, level of fullness is estimated as well as species composition, associated species, fate and if discards take place or not and their amount. The current time and position are extracted directly from the metadata embedded in the video onto the report. Each time the footage is stopped and a note is inputted, a still thumbnail image is also recorded (**Fig. 5**). The analysis process and report are pictured in **Figure 6**. Extra View Manager images can be found in **Appendix 2**.

The 4 cameras are synchronized by default, but VM allows the reviewer to synchronize any combination of cameras at any time. Playback can be fast forwarded up to 10x and zoomed in.

At the end of a set's analysis, the reviewing software produces a detailed report. The report's format is similar to the observer's data entered into the regional observer database system at Spanish Institute of Oceanography (IEO) and both sets of data can be compared.

2.3 Available datasets

Since January 2013 OPAGAC put in place a voluntary observer program to have 100% observer coverage for its purse seiners in the ICCAT convention area. The observers are recruited and trained by the IEO who also manages and organizes the program (Sarralde et al. 2005). Each of the four fishing trips analyzed in this document had an observer from this program onboard. Thus, two datasets were available for comparison: one from the review of the SeaTube recordings and a second one, kindly provided by the Spanish Institute of Oceanography from observers deployed on board the two vessels.

Both periods were recorded in each vessel during the course of two separate fishing trips. The observers remained the same for the two separate trips on each vessel. A landing occurred between the 2 periods, allowing for any adjustments or maintenance in the EM system. At the end of the second fishing trip, the hard drives were extracted by Satlink technicians and forwarded to DOS for its revision.

The data sets compared correspond to the following periods for each vessel:

Vessel	Comparison period	N of Sets	Comparison period	N of Sets	Total
Albacora 10	13/12/2013 27/12/2013	30	4/1/2014 23/1/2014	25	55
Albacora 9	2/12/2013 22/12/2013	29	1/1/2014 24/1/2014	19	48

Although the EM performed successfully for the entire period under study, footage was not recorded for two fishing events due to the system´s configuration to stop recording one hour after sunset.

The datasets for the IEO observer on board the vessels comprise a much more detailed set of information than the report produced after DOS review, these included:

-Data Sheet on Route and environmental parameters
-Data Sheet on Catch Data and Fishing
-Data Sheet on Size Samples for target species
-Data Sheet on FAD related activities

All the onboard observer data for the comparisons of this study was extracted from the Catch Data and Fishing Sheet.

The dataset produced after reviewing the SeaTube recordings consists of: Total number of sets and their type, tuna catch per set and per species, discards, associated species in numbers and their fate; as well as date, time and position for each set.

2.4 Statistical Analyses

Geographical positions were compared with the purpose of assessing the level of correspondence between the two sets. Both sets were plotted together onto a regional map. Latitude and longitude absolute differences were also calculated and studied.

Comparison of the two sets of catch data - the one collected by onboard observers and the reviewed EMS set - were compared for the main category of tuna catch. This comparison was done separately for retained and discarded catch.

Total catch per set estimated by both systems (EM and OBS) were compared through a number of EM vs OBS regressions and their slopes. ANOVA test was used to determine which of the proposed models offered a better explanation of the data. Subsequently, a series of nested models were tested to assess the significance of Trip and Vessel as explanatory factors.

Given the limited amount of data available and reservations about the normality of their distribution, it was decided to also run a series of non-parametric tests in order to compare the medians. In particular, Wilcoxon Sign Rank Test was used to compare estimates of total catch per set by EM and OBS, tuna proportion per species per set, tuna proportion per species per set by fishing mode and discards. Also Mann Whitney U test was used to compare whether the medians of the absolute value of differences per set between EM and OB estimations differed depending on the vessel.

For associated species no statistical tests were conducted, only number of major species individuals estimated by each method were counted and represented in a table for comparison.

3. RESULTS

3.1 Trip statistics

Trip & Method	1 EM	1 OBS	2 EM	2 OBS	3 EM	3 OBS	4 EM	4 OBS
Vessel	Albacora 9	Albacora 9	Albacora 9	Albacora 9	Albacora 10	Albacora 10	Albacora 10	Albacora 10
Nº Sets	29	29	19	19	30	30	25	25
Nº null sets	0	0	0	0	3	3	4	4
Fad sets	29	29	5	5	26	26	7	7
Free School sets	0	0	14	14	4	4	18	18
Total catch in period (tn)	980	865	500	541	897	930	569	679

Since no particular camera was installed for this purpose, the determination of the type of set by the EM reviewer was based in subjective criteria derived from the reviewer´s previous at sea experience, catch composition, presence of associated species, time of set and the vessel´s behavior interpreted using the VM map display. For the 4 trips both methods identified the same amount of effort in number and type of sets.

After geographically overlapping both sets of coordinates (EM and OBS), there seemed to be an exact match of trajectories (**Figure 7a**). Nevertheless, to assess the level of trueness of the EM positions compared to those recorded on board, the absolute value of the latitude and longitude differences in decimal degrees was calculated. The results showed that most of the pairs of coordinates only differed in 0.01 decimal degrees (~1km). (**Figure 7b**)

3.2 Major tuna catch

<u>Comparison of catch per set and overall species composition</u>

A first exploratory analysis of the datasets was performed to assess if the slope of the regression of total catch (EM) vs total catch (OBS) differed substantially from 1.0 when only subsets of the dataset (each trip or each vessel) were used in said regressions. Although the value of all slopes were always close to 1 (±5.5%), an ANOVA test was conducted with a series of models in order to determine if the factors Trip and Vessel had a significant effect in the regression. (**Table 1**).

The results showed that the models that better explained the data variability were those with a different slope for each trip and/or vessel, verifying that these two factors have an influence in the difference between catch estimations from the two observers.

Nevertheless, the nested models conducted subsequently demonstrated that the actual contribution of the factors Trip and Vessel to the model fit was in no way substantial, given the low "R^2 change" values returned by the models and its statistical significance (**Tables 2 and 3**). Overall, estimates of total catch per set were slightly lower (-5%) for EM compared to OBS.

Results of Wilcoxon signed Rank test for EM vs OBS estimates showed that there was no significant difference between the medians of the estimated catch per set by each method. The same test was also applied for comparison of the estimated species composition per set by each observer, which showed that the median of the proportions of Skipjack and Bigeye tuna per set cannot be considered equal while in the case of Yellowfin they can (**Table 4**).

Comparison of species composition per set depending on set type

When the same analysis was applied separately depending on the mode of fishing, similar results were obtained regarding estimated species composition by EM and OBS (**Table 5**).

Comparison of differences of estimated catch per set by EM and OBS in each vessel

The median of the differences between the estimated catch per set by EM and OBS in each vessel was compared using a Mann Whitney U test for non-paired samples. The results indicate that the median difference is significant between vessels (**Table 6**).

Comparison of species composition for each trip

	SKJ/ EMS	SKJ/ OBS	YFT/ EM	YFT/ OBS	BET/ EM	BET/ OBS	OTH/ EM	OTH/ OBS	EM Total catch	OBS Total catch
Trip 1	84%	74%	14%	2%	1%	21%	1%	3%	980	865
Trip 2	13%	7%	87%	89%	0%	3%	0%	1%	500	540
Trip 3	84%	79%	6%	13%	10%	0%	1%	8%	896,5	930
Trip 4	22%	4%	77%	90%	1%	3%	0%	3%	568,5	679

Comparison of tuna discards

Total amount of discards, all species included, for the sets were discards occurred, were compared for the estimation made by each method. Results indicate that there is no significant difference between the median of discards estimated by EM and OBS (**Table 7**). Dataset includes a single entry with a significant difference (30 t) in the estimated discard, which could be an error. Taking into account that during the same set, discard of small tunas was estimated with only 2 t of difference between the two methods, it is unlikely that 30 t of discarded Skipjack would go unnoticed by the reviewer.

3.3 Other species

Due to the preliminary nature of this analysis and the limited amount of data, no statistical analyses were conducted for associated species catch. Nevertheless the following table summarizes the estimated number of associated species per group recorded by each method.

	Trip	TUR-EM	TUR-OBS	BIL-EM	BIL-OBS	MR-EM	MR-OBS	SHK-EM	SHK-OBS
Albacora 9	1	2	3	17	19	1	1	17	21
Albacora 9	2	0	0	4	1	0	0	3	5
Albacora 10	3	0	0	12	12	0	1	21	34
Albacora 10	4	1	2	12	5	0	2	3	16

It appears that EM estimated a lower number of sharks than OBS did in all trips. For the other species groups, there were no consistent differences. It is possible that the resolution of the EM cameras deployed in the two vessels had an influence in these comparisons, at least for sharks.

4. CONCLUSIONS AND FUTURE PLANS

There seem to be statistical differences in the observations collected between EM and OBS by vessel. However, they are small in magnitude, and probably within the range of variability that would also be expected between different human observers deployed in different vessels (however, more extensive analyses would be needed to test this possibility). EM estimates of catch per set tended to be 5% lower, on average, than those from the human observer.

One of the sources of difference between EM and OBS in total catch per set might be attributed to the fact that no camera was placed to allow a side view of the brail at deck level. On the other hand, information about the distribution of fish holds and their capacity allowed for improved estimation by the EM.

The difference between vessels could be explained possibly by several factors such as the difference in quality of video available for revision of each vessel. Also, differences on gear set up on board each vessel, such as brail capacity. Process for catch and associated species handling could also be a source of difference in estimates. Lastly, both EM and OBS methods are estimates and comparison at this level is only providing relative differences between one method and the other. In the future, it would be useful to compare the two to the overall catch estimated at the end of the trip from port sampling.

On a per-trip basis, the EM and OBS estimates to total catch, discards, fishing effort (number of sets), fishing mode, and bycatch of major species (sharks, billfishes, turtles and rays...) were very similar.

Differences were noted to be more apparent in the estimation of number of sharks, where the EM identified fewer individuals per trip. On the other hand, the EM was able to identify a greater number of billfishes than the OBS in one of the trips. The capability of the EM system to review upper and lower deck activity simultaneously during one set allows to detect some individuals that go directly to the lower deck.

Significant differences were encountered in the estimation of species composition of the catch by each method. The fact that Yellowfin was correctly identified by both suggests the presence of this species with a particular type of set might be an important factor to correctly identify it. On the other hand, Bigeye and Skipjack of same sizes will commonly appear associated during FAD sets, making especially difficult to determine the amount of each for both EM and OBS. It is likely that port sampling will remain the primary method to determine species composition in the ICCAT area, unless improved digital methods and algorithms are developed to do this on board.

These preliminary analyses suggest that the SeaTube electronic monitoring system is capable of delivering and/or validating many of the same observations that a regular observer program can deliver.

Beyond the capabilities of the SeaTube system to provide reliable observations for the same type of data collected by observer programs, it has the potential to be a very useful tool for enforcement and assessment of compliance of certain management measures, such as time area closures, for which there are many examples currently adopted in various RFMOs i.e. ICCAT (Rec 10-01), IATTC, IOTC, WCPFC. The encrypted recording of GPS positions throughout the trip is a key component of this.

There are other measures that limit the type of fishing effort (object vs free school set), its compliance supervised by on board observers that could eventually be also surveyed with the use of EM systems as long as a reliable and objective method of determining the type of set has been implemented (i.e., a camera looking over the side; see Restrepo et al 2014). As well, the graphical representation of the vessels activity and the possibility of partitioning the periods at sea identifying various behaviors proved to be useful, It could serve as a valuable tool for effort standardization allowing to separate effort by mode of fishing.

Other modes of fishing, such as dolphin associated sets in the eastern Pacific, have also the potential to be successfully identified by the use of an EM system, providing support to the existing 100% observer coverage that is being put in place for this purpose in the IATTC.

Adherence to compliance to self-regulating codes of conduct, certification schemes are good candidates to be verified by this method (management of associated species, full retention and others).The system also provides an opportunity for companies to verify the activities that take place on their fleet at sea.

The high geographical resolution of the system´s, together with the recording of footage of the vessel´s actual activity by EEZ could be useful for coastal states to verify fishing activities in their waters as well as a method to clarify alleged cases of IUU fishing.

It is understood that several vendors have developed or are developing other electronic monitoring systems. If they are going to be used as a complement to official observer programs, it is recommended that the SCRS develops technical standards for the accreditation of such systems, including the data review and submission process.

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Table 1. Catch per set analyses: slopes, Trip and Vessel significance.

REGRESSION	SLOPE
All data	0.96178
Trip_1	1.07167
Trip_2	0.9253
Trip_3	0.956604
Trip_4	0.82990
VESS_1 (Albacora 9)	1.03306
VESS_2 (Albacora 10)	0.91815

REGRESSION (TRIPS)

```
TOTe = TotalCatch(EM)
TOTo = TotalCatch(OBS)
TRIPo = Trip
VESS = Vessel
```

Analysis of Variance Table

```
Model 1: TOTe ~ 0 + TOTo
Model 2: TOTe ~ 0 + TOTo + TRIPo
Model 3: TOTe ~ 0 + TOTo * TRIPo
  Res.Df    RSS Df Sum of Sq      F    Pr(>F)
1     93 3222.8
2     92 3190.5  1     32.36  1.599    0.2093
3     91 1841.4  1   1349.09 66.671 1.741e-12 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

REGRESSION (VESSELS)

Analysis of Variance Table

```
Model 1: TOTe ~ 0 + TOTo
Model 2: TOTe ~ 0 + TOTo + VESS
Model 3: TOTe ~ 0 + TOTo * VESS
  Res.Df    RSS Df Sum of Sq       F    Pr(>F)
1     93 3222.8
2     92 3221.1  1      1.70  0.0625    0.8031
3     91 2473.3  1    747.85 27.5157 1.008e-06 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Table 2. Nested Models: OBS + trip + vessel

Variables Entered/Removed[b,c]

Model	Variables Entered	Variables Removed	Method
1	TOTo[a]	.	Enter
2	TRIPo[a]	.	Enter
3	VESS[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: TOTe

c. Linear Regression through the Origin

Model Summary[e,f]

					Change Statistics				
Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.993[a]	.985	.985	5.8867900	.985	6243.488	1	93	.000
2	.993[c]	.985	.985	5.8889113	.000	.933	1	92	.337
3	.994[d]	.989	.989	5.1668266	.003	28.512	1	91	.000

a. Predictors: TOTo

b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.

c. Predictors: TOTo, TRIPo

d. Predictors: TOTo, TRIPo, VESS

e. Dependent Variable: TOTe

f. Linear Regression through the Origin

Table 3. Nested models: OBS + vessel + trip

Variables Entered/Removed[b,c]

Model	Variables Entered	Variables Removed	Method
1	TOTo[a]	.	Enter
2	VESS[a]	.	Enter
3	TRIPo[a]	.	Enter

a. All requested variables entered.

b. Dependent Variable: TOTe

c. Linear Regression through the Origin

Model Summary[e,f]

Model	R	R Square[b]	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.993[a]	.985	.985	5.8867900	.985	6243.488	1	93	.000
2	.993[c]	.985	.985	5.9171358	.000	.049	1	92	.826
3	.994[d]	.989	.989	5.1668266	.004	29.660	1	91	.000

a. Predictors: TOTo

b. For regression through the origin (the no-intercept model), R Square measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R Square for models which include an intercept.

c. Predictors: TOTo, VESS

d. Predictors: TOTo, VESS, TRIPo

e. Dependent Variable: TOTe

f. Linear Regression through the Origin

Table 4. Wilcoxon signed Rank test. Total catch per set and species composition

Wilcoxon Signed-Rank Test		
EM vs OBS Total catch per set		
	TOTe	TOTo
median	18,5	17
count	103	
# unequal	92	
T+	2048	
T-	2230	
T	2048	
	one tail	two tail
alpha	0,05	
mean	2139	
T-crit	1716,08154	1635,15736
p-value	0,36154034	0,72308068
sig	no	no

Wilcoxon Signed-Rank Test		
Species proportions		
	SKJe %	SKJo %
median	0,78488372	0,5
count	94	
# unequal	68	
T+	434	
T-	1912	
T	434	
	one tail	two tail
alpha	0,05	
mean	1173	
T-crit	903,308761	851,738855
p-value	3,1576E-06	6,3152E-06
sig	yes	yes

Wilcoxon Signed-Rank Test		
Species proportions		
	YFTe %	YFTo %
median	0,14421318	0,16904762
count	94	
# unequal	69	
T+	1167	
T-	1248	
T	1167	
	one tail	two tail
alpha	0,05	
mean	1207,5	
T-crit	931,892392	879,189066
p-value	0,404333	0,80866601
sig	no	no

Wilcoxon Signed-Rank Test		
Species proportions		
	BETe %	BETo %
median	0	0
count	94	
# unequal	55	
T+	442,5	
T-	1097,5	
T	442,5	
	one tail	two tail
alpha	0,05	
mean	770	
T-crit	573,18274	535,573557
p-value	0,00303501	0,00607002
sig	yes	yes

Table 5. Wilcoxon signed rank test for species composition depending on set type

Free School

Wilcoxon Signed-Rank		
	YFTe %	YFTo %
median	0,14421318	0,16904762
count	94	
# unequal	69	
T+	1167	
T-	1248	
T	1167	
	one tail	two tail
alpha	0,05	
mean	1207,5	
T-crit	931,892392	879,189066
p-value	0,404333	0,80866601
sig	no	no

Wilcoxon Signed-Rank		
	SKJe %	SKJo %
median	0,78488372	0,5
count	94	
# unequal	68	
T+	434	
T-	1912	
T	434	
	one tail	two tail
alpha	0,05	
mean	1173	
T-crit	903,308761	851,738855
p-value	3,1576E-06	6,3152E-06
sig	yes	yes

Wilcoxon Signed-Rank		
	BETe %	BETo %
median	0	0
count	94	
# unequal	55	
T+	442,5	
T-	1097,5	
T	442,5	
	one tail	two tail
alpha	0,05	
mean	770	
T-crit	573,18274	535,573557
p-value	0,00303501	0,00607002
sig	yes	yes

Associated

Wilcoxon Signed-Rank		
	YFTe %	YFTo %
median	0,1	0,11473881
count	81	
# unequal	68	
T+	1115	
T-	1231	
T	1115	
	one tail	two tail
alpha	0,05	
mean	1173	
T-crit	903,308761	851,738855
p-value	0,36151938	0,72303876
sig	no	no

Wilcoxon Signed-Rank		
	SKJe %	SKJo %
median	0,8175	0,56980519
count	81	
# unequal	68	
T+	434	
T-	1912	
T	434	
	one tail	two tail
alpha	0,05	
mean	1173	
T-crit	903,308761	851,738855
p-value	3,1576E-06	6,3152E-06
sig	yes	yes

Wilcoxon Signed-Rank		
	BETe %	BETo %
median	0	0
count	81	
# unequal	54	
T+	434,5	
T-	1050,5	
T	434,5	
	one tail	two tail
alpha	0,05	
mean	742,5	
T-crit	550,964927	514,36767
p-value	0,00400145	0,00800291
sig	yes	yes

Table 6. Mann Whitney U test for non-paired samples. Catch per set in each vessel.

Mann-Whitney Test		
	Albacora Nueve	Albacora Diez
count	48	55
median	1,5	-0,5
rank sum	3033,5	2322,5
U	782,5	1857,5
	one tail	two tail
alpha	0,05	
U	782,5	
mean	1320	
U-crit	1070,697198	1023,033176
p-value	0,000190105	0,000380211
sig	yes	yes

Table 7. Wilcoxon signed rank test for tuna discards

Wilcoxon Signed-Rank Test		
	DESNe	DESno
median	0	0
count	32	
# unequal	8	
T+	6	
T-	30	
T	6	
	one tail	two tail
alpha	0,05	
mean	18	
T-crit	5,753395548	3,503057482
p-value	0,04644597	0,092891941
sig	yes	no

Wilcoxon Signed-Rank Test		
After removal of outlayer		
	DESNe	DESno
median	1,1	5,1
count	9	
# unequal	7	
T+	6	
T-	22	
T	6	
	one tail	two tail
alpha	0,05	
mean	14	
T-crit	3,76891471	1,9046967
p-value	0,08814819	0,17629637
sig	no	no

Vessel	Albacora 9	Albacora 10
Built	1976	1977
Type	Purse Seiner	Purse Seiner
Flag	Curaçao	Panama
Nº IMO	7403639	7403641
LOA	66,95 mt	76,75 mt
Fish Hold Volume	1.358,3 m^3	1.650m^3
Max Speed	16 Knots	16 Knots
Power KW	2944	2944

Figure 1. Fishing vessels Albacora 9 (top) and Albacora 10 (bottom).

Figure 2. Location of cameras.

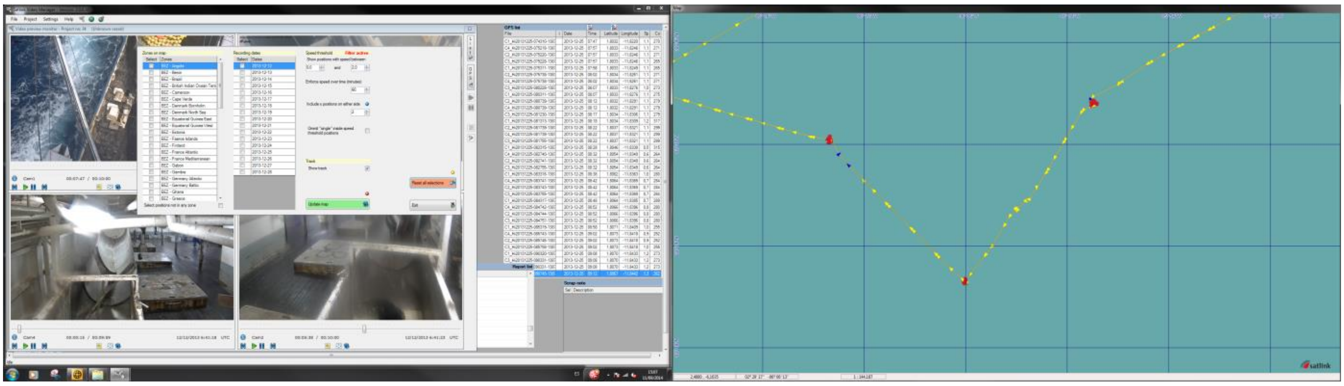


Figure 3. Satlink View Manager.

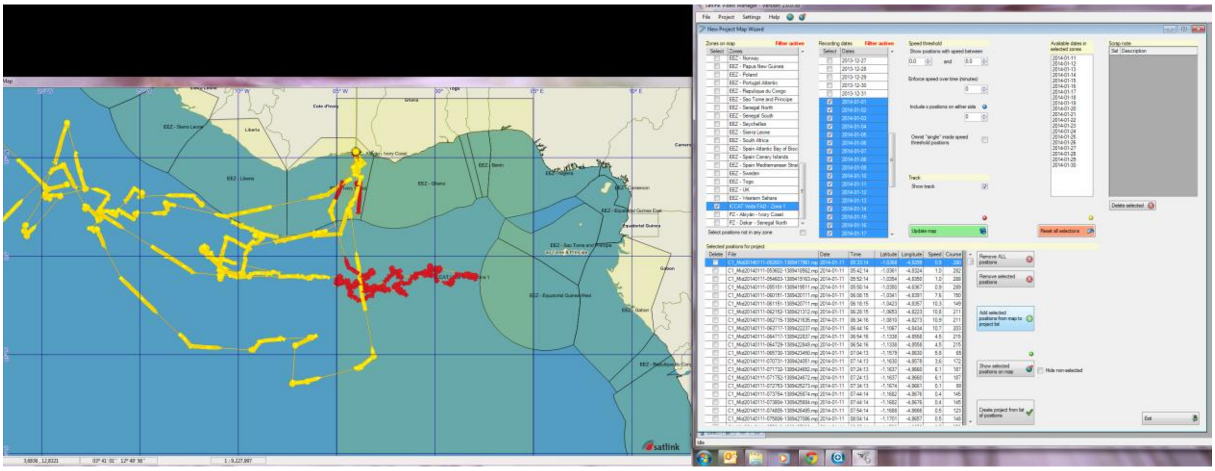


Figure 4. Detail of filtering process. Includes Time-area closure. Points meeting filter conditions highlighted in red.

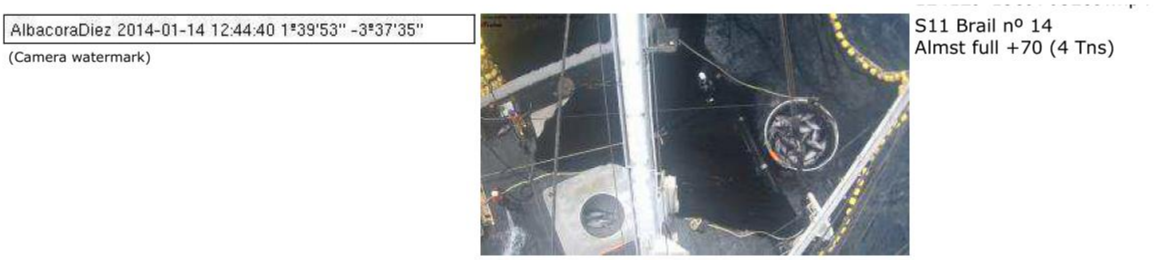


Figure 5. Thumbnail and annotation from an Inspection report

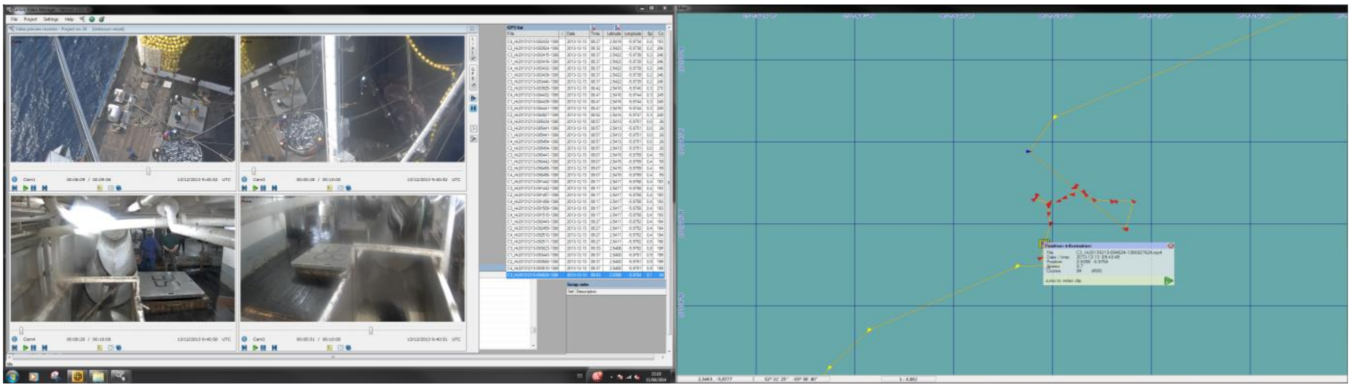


Figure 6. Analysis process.

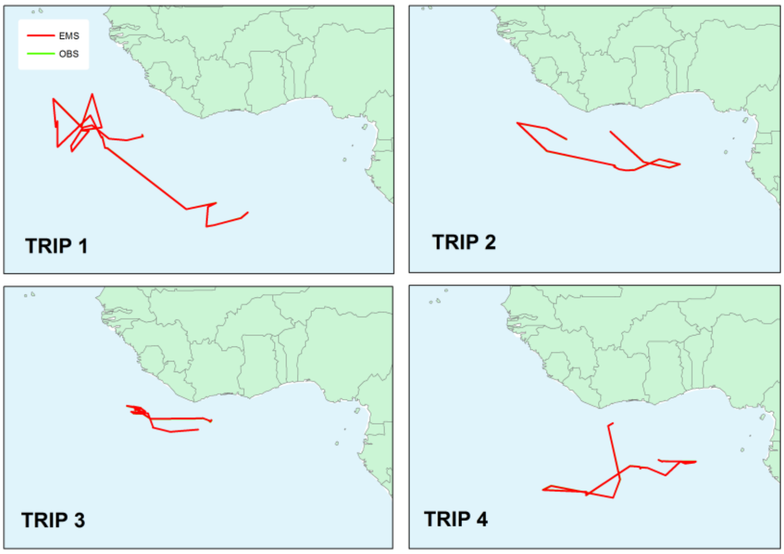


Figure 7a. Overlap of EM and OBS trip trajectories. Note that OBS trajectories are plotted underneath EM trajectories.

Fig 7b. Results from comparison of Latitude and Longitude differences (absolute values) from EM and OBS sets of coordinates. Note that around 70% of the values are below the 0.01 threshold (~1km)

Statistics

LATITUDE (ABS)

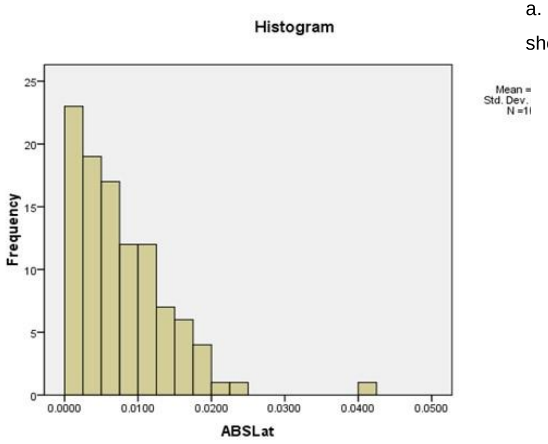
N	Valid	103
	Missing	0
Mean		.007641
Median		.006761
Mode		.0072
Std. Deviation		.0064073
Minimum		.0001
Maximum		.0410
Percentiles	10	.000668
	20	.002134
	25	.002794
	30	.003348
	40	.004981
	50	.006761
	60	.007841
	70	.010334
	75	.010928
	80	.012135
	90	.015955

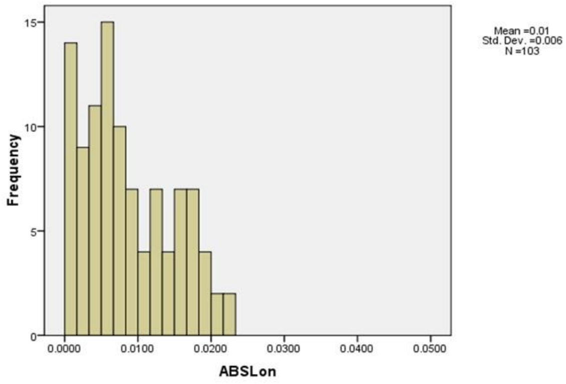
Statistics

LONGITUDE (ABS)

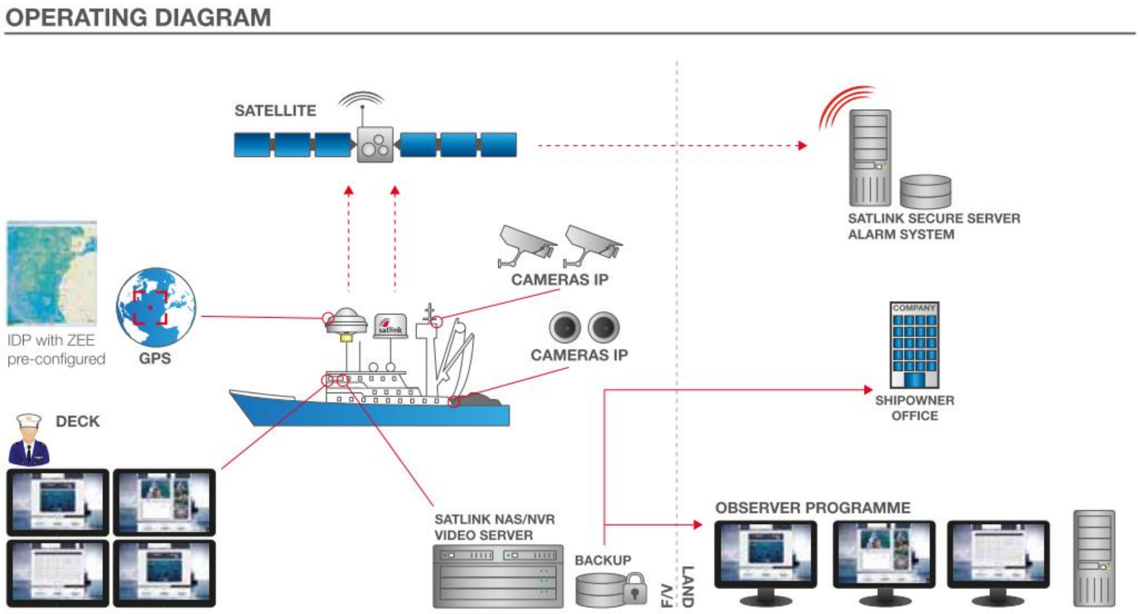
N	Valid	103
	Missing	0
Mean		.008617
Median		.007128
Mode		.0002[a]
Std. Deviation		.0061789
Minimum		.0002
Maximum		.0232
Percentiles	10	.001066
	20	.002577
	25	.003528
	30	.004528
	40	.005568
	50	.007128
	60	.008968
	70	.012460
	75	.013860
	80	.015261
	90	.017528

a. Multiple modes exist. The smallest value is shown





Appendix 1



SYSTEM	• Onboard Camera: Axis IP
	• Number of Cameras: 1-8(default 4)
	• Camera lens type:
	  ○ 6 mm
	• Onboard NAS/NVR: Synology Hardware with Satlink Application
	• Alert system equipment / GPS: Skywave IDP-690
	• Encryption technique: AES-12
	• Terrestrial Server: Satlink SeaTube Server Spain
	• Web Server
	  ○ 138.100.53.166
	  ○ 2.139.220.221
	  ○ Port used
	    ▪ 22
	    ▪ 5554 for foto
	    ▪ 1935 for video
	    ▪ 5000

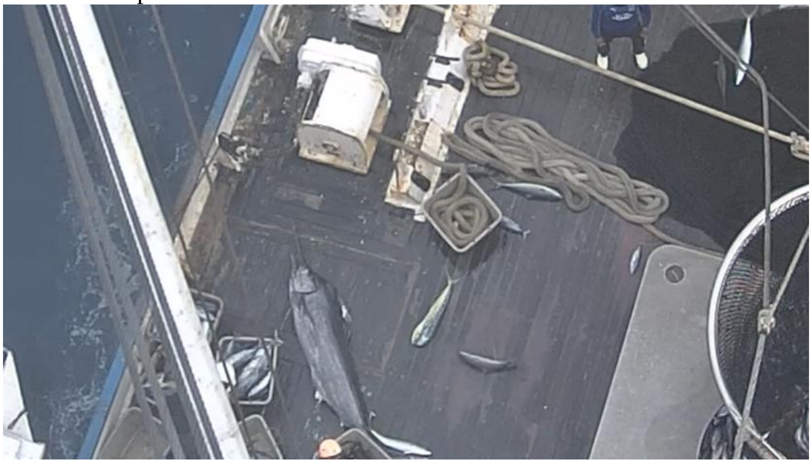
HISTORICAL VIDEO	• Format: .mp4 (codec H264) • Frame rate: 24 FPS • Resolution: 1280 x 720 • Video Length: Fragmented into 10 min clips • Recording time: Daily from 0 to 24 h / only recording daytime (configurable) • Storage: Locally in the onboard NAS/NVR/Backup • Viewing: extracting backup videos an viewing them using Satlink View Manager

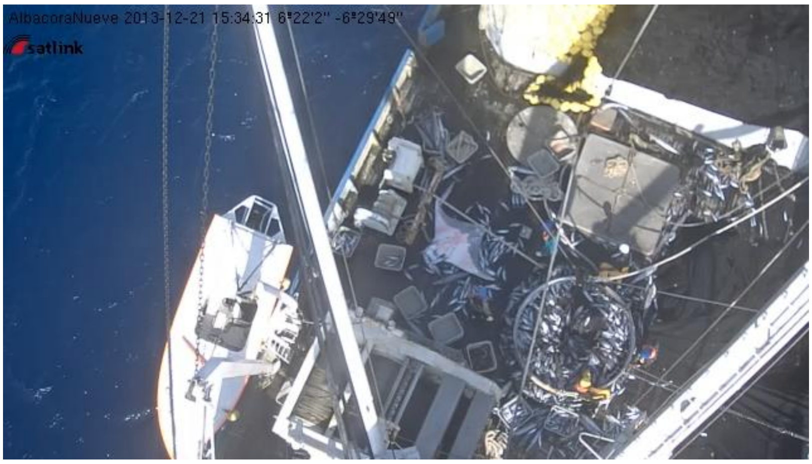
The following system features are only available if there is installed an onboard Communication: Satlink FB250 / Sailor FB250

INTERVAL THUMBNAIL PHOTO	• Format: JPG

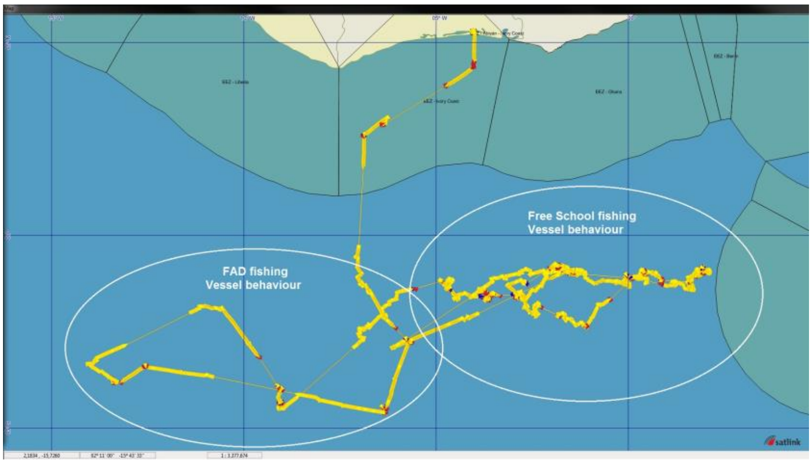
Appendix 2

Associated species on deck

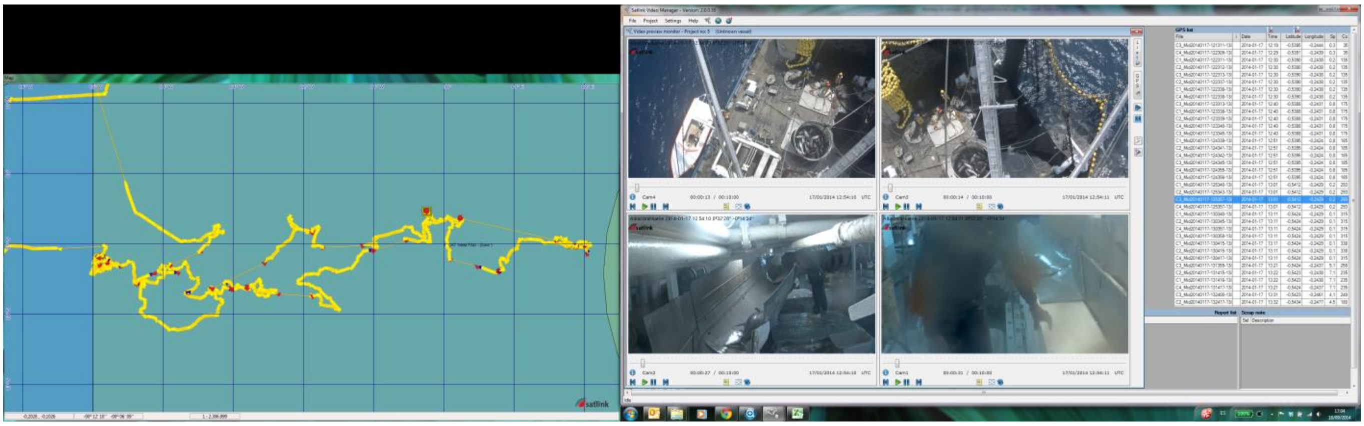




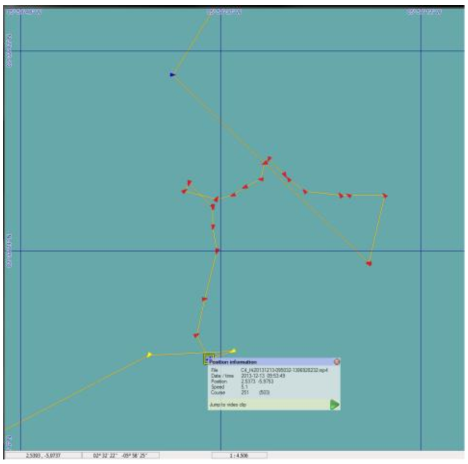
Different fishing behaviors during a trip (FAD vs FS)



A number of sets highlighted within a period of FS fishing



Detail of number of points identified as a set by VM



Below deck images

Fishing operation with FAD