# Coupling Logbooks and Vessel Monitoring System for Investigations of Large Pelagic Fishing Activities by Sri Lanka

Sudheera Gunasekara[1], Jagath Rajapaksha[1],

Email: s22gtech@gmail.com, jagath_r@hotmail.com

1 Institute of Oceanography and Marine Sciences, National Aquatic Resources Research and Development Agency (NARA), Crow Island, Colombo 15. Sri Lanka.

**KEY WORDS:** VMS, logbooks, fishing forecast, R

**ABSTRACT:**

Sri Lanka has implemented a Vessel Monitoring System (VMS) in 2015 to monitor fishing activities of offshore and high seas large pelagic fishing activities. Vessel monitoring system provides information on fishing activity at large spatial scales. Logbooks have been introduced for systematic fishery data collection in parallel to the VMS. Even though readily available software packages available for VMS data analyses, logbook data of Sri Lanka's VMS and logbook data were not in required formats. Therefore, a methodology was developed based on free and open-source R software for the data processing, analysis and visualization of VMS and logbook data. The attributes of VMS data consist of position, time, speed, heading and vessel identification number *etc* while logbooks have records on fishing activities including catch information. The VMS data from January to March 2016 and corresponding fishery logbook records were obtained from the Department of Fisheries. VMS and logbook data were link using a unique vessel identifier, position and the date of fishing. The VMS and logbook data analysis involves extracting VMS pings from cruise track records that matches with fishing activities. More than 40 % of logbook records were found with correct geographical locations with 0.3-degree precision. However, successive position records have 4-hour interval and the movements within that interval is not known. Operating fishing gears include longlines, gillnets and ring nets which are impossible to identify based on speed criteria as described in the literature. VMS verified data was used to assess the accuracy of fishing ground forecasts produced based on ocean environmental parameters derived from satellites. The results shown 66% accuracy during the study period. Integrating, real-time VMS information and catch data will helpful to improve the accuracy of fishing ground forecasts.

## 1. INTRODUCTION

Total marine fish production of Sri Lanka in 2014 amounted to 459,300 tons while offshore and high seas fishery contributed 180,450 tons, 39.2% (MFAR, 2015). Operated fishing boats have been 4,447 and 1500 boats have been equipped with VMS. Sri Lankan offshore high seas fishery sector operated with by longline, gillnets and ring net or combination of them. Longline fleets mainly targeting large pelagic species such as yellowfin tuna (*Thunnus albacares*), big eye tuna (*Thunnus obsesus*). Major target of the gillnet operators is skipjack tuna (*Katsuwonus pelamis*) and ring net targets for Indian scad (*Decapterus russelli*).

VMS introduced by the European union employed for fishing vessels over 24 meters and transmitting their location at least every 2 hours and all vessels over 15 meters transmitting location as well as speed and course information (EC. 2003). VMS identity, position, speed, and heading data from SL vessels fishing in all areas are transmitted to the Department of Fisheries and Aquatic Resources (DFAR). Ping interval is set to default value of 4 hours to compliance with IOTC minimum requirements (IOTC, 2015).

DFAR had introduced logbooks since 2012 as a systematic approach to develop a database which was initiated in 2015. Logbook data has been seen as a source of fisheries data since it became widely recorded and compiled. In many instances the catch data is used for scientific research when none is available (Thomas-Smyth, 2013). However, the logbook information has been continuously argued as unreliable and not verified as accurate. There was no cost effective alternative to validate accuracy of fisheries logbooks until VMS is introduced.

The coupling of logbook and VMS data has already proven powerful for describing the spatial distribution of the marine biota habitat at a much finer spatial or temporal resolution (Hintzen *et al*. 2012). VMS are primarily used for fisheries management but also capable for using various applications such as improve the accuracy of fish stock assessment, with limitations such as incomplete coverage of vessel activities, lack of catch information, long duration between position records, whether a vessel is actually fishing when the activity recorded (Chang and Yuan, 2014; Bastardie *et al*., 2010).

Most of the previous studies to estimating fishing effort from VMS data was used in different types of trawl or dredge and purse seine fisheries (Lee *et al*. 2010, Table 1; Lambert *et al*. 2012; Gerritsen and Lordan , 2010.;Deporte *et al*., 2012). Compared to towed or fish-surrounding gears, pelagic longline is a passive gear, and differs in operation from the active gears such as trawls, dredge and purse seines (Chang and Yuan, 2014). Chang and Yuan (2014) developed classification methods for the pelagic longline fishery of Taiwan vessels based on fishing time and speed criteria.

National Aquatic Resources Research and Development Agency (NARA) produce potential fishing zone forecast for tuna. This forecasts are produced on every Monday and Thursday and disseminated via email, fax, telephone and SSB radio to fishermen. Fisheries log book data used to develop and validate fisheries forecasts. Accuracy of logbook data was major drawback of validation process as some fishermen not provide correct information.

At present, VMS is mainly used for fisheries management specially monitor illegal unregulated and unreported (IUU) fishing in Sri Lanka. This is the first attempt that was made to combined the VMS data with the corresponding logbooks to identify vessel behaviors and logbook data validation.

## 2. DATA AND METHODS

VMS position, time, speed, heading and vessel identification data from fishing vessels and logbook data including fishing position, time, catch composition and gear specifications were obtained from the DFAR for the period from January 2016 to April 2016 (Figure 1).

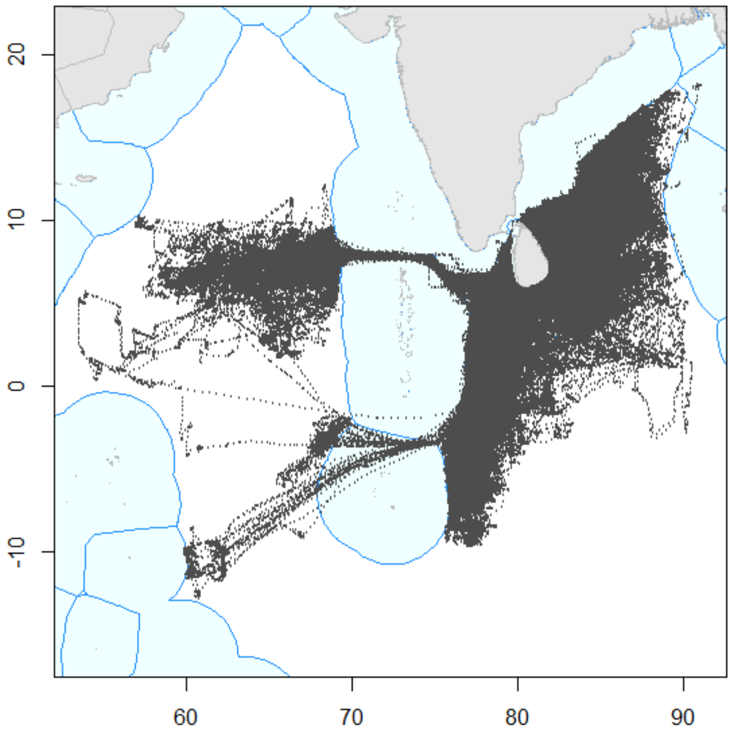

Figure. 1: Study area with all VMS pings during study period

VMS information were provided as cruise arrival reports to fishery harbors. These reports content, file format, file structure and file naming conventions were differed as individual officers of VMS unit followed different conventions to archive this data daily. Therefore, this raw dataset was brought in to comma separated values (csv) format with file name convention with vessel registration number with arrival date to a harbor by inspecting each file manually. File content was checked for position, time, speed, heading and vessel identification information and discarded files with missing and incomplete data. All cruise records were imported in to database with unique identifier for each fishing trip.

Before analysis, duplicate VMS records and records close to (within 10 km of) port were removed, along with erroneous position records allocated to land (5044 pings from 503796 pings). This data set composed with 3275 trips of 1311 boats.

Logbook data set consist of 25758 catch records for boats arrival during between 1st of January 2016 to 31st March 2016. 1999 trips from 1037 boats. 2205 fishing operations (gear combinations) were applied during 1999 trips. Logbook data were obtained as sql tables and relationships were established after import in to MySQL database. Data entry errors of logbook data were corrected by filtering.

The vessel registration number was used to link vessels in the VMS and logbook databases. The number is unique to each vessel. Both VMS and logbook data were matchup with 0.3-degree precision. Duplicated matchups were removed by few steps and final VMS verified logbook records dataset included 7755 records from 450 vessels. VMS verified fisheries data was matched with forecast maps. Fishing locations of forecasting day and next three successive days were match with forecast area polygon.

Composition of VMS by gear type was analyzed. Due to mixed nature of gear types and gear combinations speed based fishing activity recognition schemes difficult to apply. Also higher interval between pings reduced ability to differentiate different fishing types.

The main steps of the procedure for linking VMS with logbook data are depicted in Figure 2. The entire process has been developed in R (R Development Core Team, 2015). Some R-specific extension packages were also used (‘geo’, ‘maptools’, ‘stringr’, ‘sp’, ‘rgdal’, ‘grid’, ‘limma’ and ‘RODBC’).

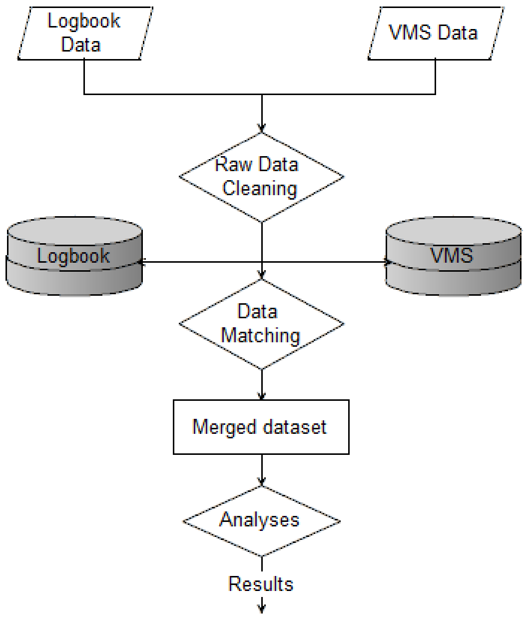


Figure 2: The flowchart shows the main steps of the procedure for coupling VMS and logbook data to generate merged dataset for analyses

**3. RESULTS**

VMS was provided 596778 pings from 3367 trips by 1325 fishing vessels. But logbook data available for 2180 trips of 1094 boats which provided 137481 pings during study period. This pings represents 23.04% total pings by VMS system. This indicate low recovery rate of logbook sheets to DFAR by fishers.

Due to mixed nature of gear types and gear combinations speed based fishing activity recognition schemes difficult to apply. Longline pings were 8.9% of total pings and 53114 pings (38.6%) from pings associated with catch data. 21376 pings (15.5% from pings associated with catch data.) are gill net fishery. 42204 pings (30.7% from pings associated with catch data.) are gill net fishery.

**3.1 Coupling Logbooks and Vessel Monitoring System**

VMS positions matched with 7755 fisheries logbook data records without considering instantons speed. 42.6% logbooks were matched with VMS data. Those logbook data records were recorded with correct geographical locations with 0.3-degree precision.

Verified logbook data belongs to 702 fishing trips of 454 vessels including 340 trips of 248 longline, 165 fishing trips of 117 gillnets and 245 fishing trips of 132 ring net operations (Table 1).

Table 1: Gear type/combination verified by VMS

| Gear type/ combination | Number of trips | verified trips | % |
|---|---|---|---|
| Longline | 637 | 339 | 53.2 |
| Gillnet | 429 | 179 | 41.7 |
| Ring net | 742 | 252 | 34.0 |
| Longline/ Gillnet | 82 | 31 | 37.8 |
| Longline/ Ring net | 24 | 8 | 33.3 |
| Gillnet /Ring net | 70 | 36 | 51.4 |
| Longline /Gillnet /Ring net | 15 | 7 | 46.7 |

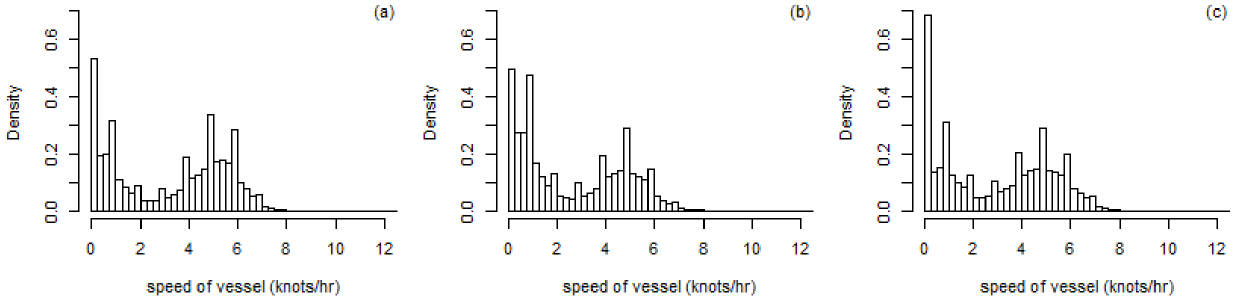


Figure 3: Probability density of vessels speed by gear types longline (a), gillnets (b), ring net (c).

VMS speed matched with nearest fishing locations shows bimodal distribution for longline, gillnets and ring net fishery (Figure 4). First peak in between 0.1-3 Knots indicate fishing activity and second peak between 3-8 knots indicate steaming of vessel.

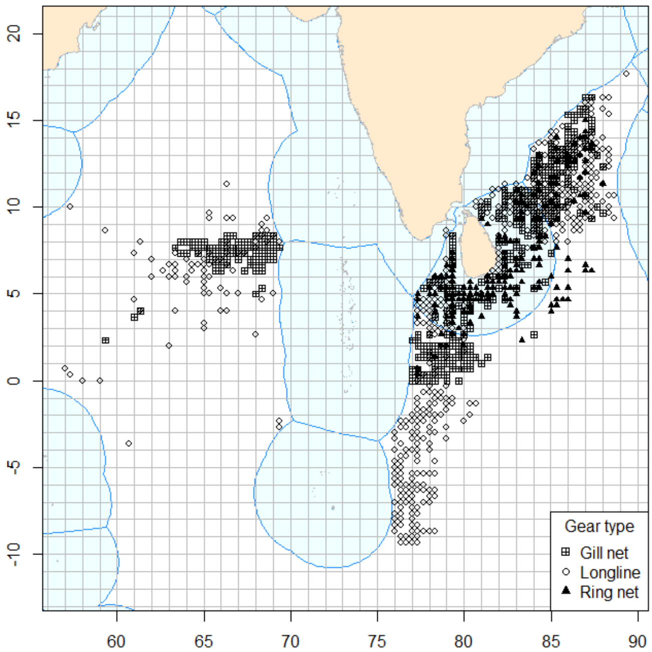


Figure 4: Fishing locations by gear type during the study period.

The distribution of fishing effort varied among gears. Longline operating vessels prominently fishing in distant waters; southern latitudes and Arabian sea. Gillnet operation also common practice in northern latitudes but not below equator. Ring net mostly operate within EEZ and closer to EEZ.

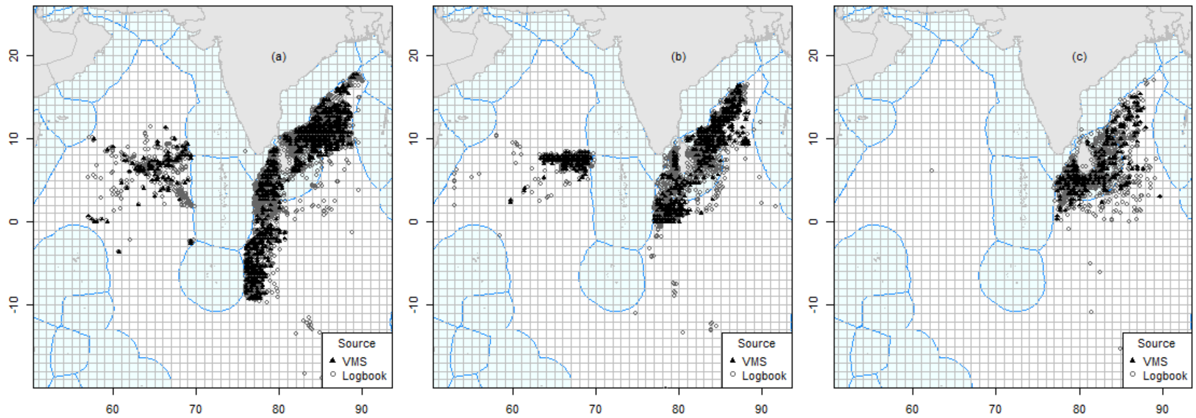


Figure 5: Fishing activities of Sri Lankan fishing vessels by VMS and logbooks; longline (a), gillnets (b), ring net (c).

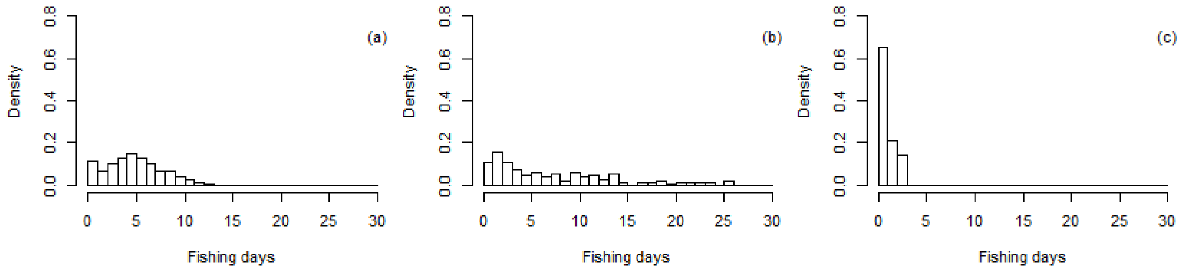


Figure 6: Probability density of fishing days by gear types longline (a), gillnets (b), ring net (c).

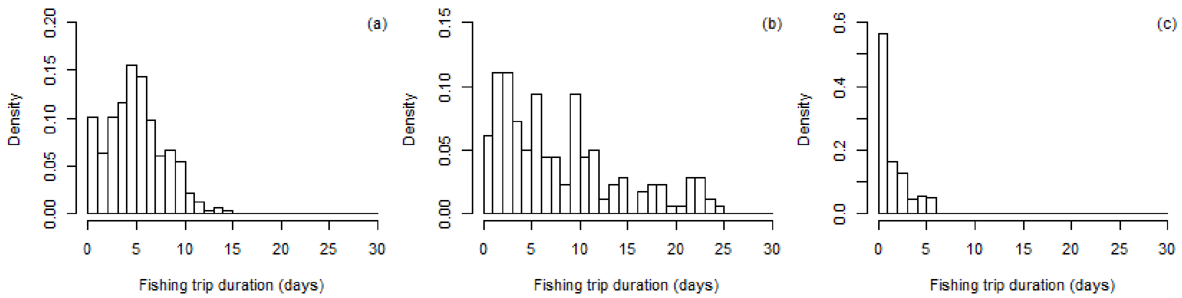


Figure 7: Probability density of fishing trip by gear types longline (a), gillnets (b), ring net (c).

Fishing days per trip was vary with gear type (Figure 6). Average time of longline fishing was 5 (±3.3) days and average fishing time of gillnets and ring net was 2.2 (±5.3) days and 0.6 (±1.1) days respectively. Fishing trip duration also varied with gear type (Figure 7). Average time of longline fishing trip was 5.3(±2.8) days and average time of fishing trip of gillnets and ring net was 7.5 (±6.2) days and 1.5 (±0.7) days respectively. Mean catch of longline fishing trip is 1023.0 kg (±662.3). Mean catch of gill net fishing trip is 1342.3 kg (±1175.2). Mean catch of ring net fishing trip is 2183.8 kg (±1570.6).

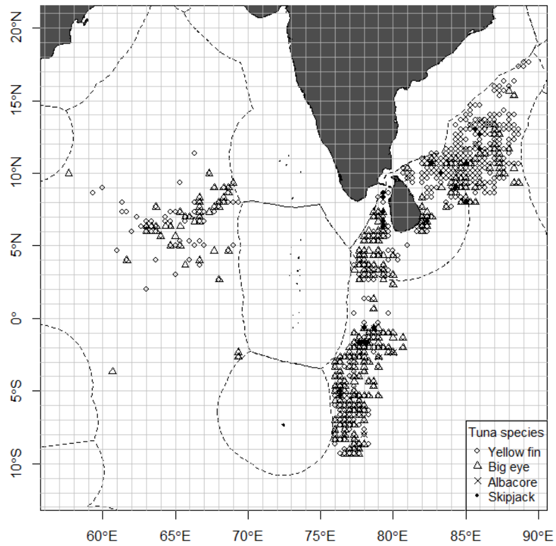

Figure 8: Tuna catch distribution of longline fishery

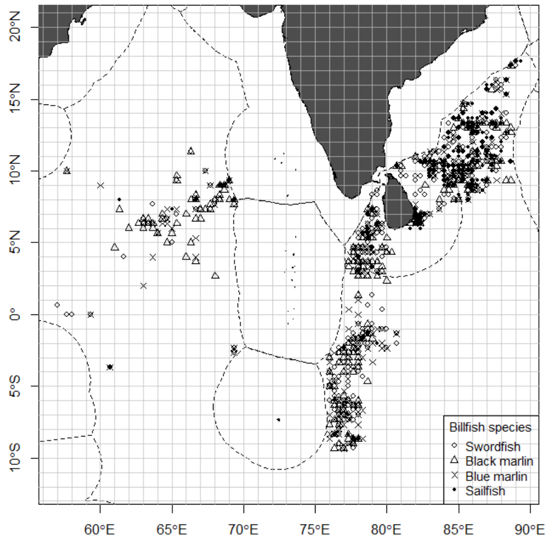

Figure 9: Billfish catch distribution of longline fishery

Longline fishery catch distribution is spread over Northern Indian Ocean. Yellowfin tuna is prominent species in catch representing 46% of total catch by longline. Big eye tuna and skipjack tuna represent 14% and 7% respectively. Albacore tuna is only 0.5% of total catch. Billfishes are the next important group and they represent about 20% of total catch. Swordfish (*Xiphias gladius*), Black marlin (*Istiompax indica*), Blue marlin (*Makaira nigricans*) and Indo-Pacific sailfish (*Istiophorus platypterus*) are major species in catch composition.

### 3.2 Validation of tuna fishing ground forecast

Total number of fishing ground forecast issued during study period were 90 and success fishing were recorded in 60 forecasted grounds. Thus, the accuracy of forecast is about 66% during the study period. Fishing success would have been increased, if the fishing gears could reach the appropriate depths. However, there are numerous reasons for unsuccessful fishing although the predicted location is accurate.

## 4. DISCUSSION

VMS data cannot be directly used to indicate whether vessel is fishing or not, which is a key factor to estimate fishing effort (Bastardie *et al*., 2010). It's not possible to identify fishing activity just based on speed as high interval between successive pings (4 hour). EU member countries use ping rate at either hourly or every 2 hours (ICES, 2010). Even 2 hour polling frequency for most VMS in Europe that provides limited information for reconstructing tracks (Lee *et al*., 2010). One of the drawbacks of point summation with 2 h intervals is that shorter fishing activities may be missed. However, VMS can be thought of as a sampling approach, and provided data are sufficient, they are likely to produce a good picture of areas visited, with the possible exception of areas used rarely (Lee *et al*., 2010).

Reduction in polling frequency from 2 hour to 30 min would provide significant benefits when VMS data are used for mapping activity and assessing fishing impacts (Lambert *et al.* 2012). In Sri Lankan context, DFAR not willing to decrease ping interval due to double the cost. If fishing boat operate for one-month period, VMS data charge is 14.4 US$ with 4 hour interval ping rate (cost of one ping **-** 0.08US$). Cost will be double (28.8US$), if ping interval will decrease to 2 hours.

Under the EU projects TECTAC and CAFÉ common data exchange format for logbook (EFLALO2) and VMS data (TACSAT2) were developed (ICES, 2010). Sri Lanka also must adapt to standard data formats to proper data management, analysis and sharing. It is very important to have accurate data in fisheries resource assessment purposes. Sri Lankan VMS system initiatives will beneficial for many aspects of fisheries sector. VMS system and logbook data collection is still not perfect as complex and incomplete data structures and lack of technological expertise in system management. Unmatched records are outnumbered than matched records due to misreporting of logbook data, device failure, or data entry errors. Fishermen misrepresent fishing locations unintentionally or intentionally. Fishermen fill logbook at the end of trip or later time causes to errors. Some fishermen need to keep their fishing grounds secretly. Also data entering process may cause some errors as most of data entry operators were not aware about fishing.

VMS verified fisheries logbook data has proven valuable resource for validation of potential fishing ground forecasting. Fishermen find fishing location mainly by massages from other vessels, random locations and by experience. Fishing forecasting system is able to predict fishing grounds with certainty, but fishermen still not ready to completely depend on fishing ground forecasts. Sri Lankan fishing vessels operation in international waters far away from country as a group and not randomly distributed. Also few fishing vessels able to do fishing operation in far locations where PFZF indicated. Integrating, real-time VMS information and catch data will helpful to improve the accuracy of fishing ground forecasts. Despite unforeseen errors, this study demonstrates with reasonable certainty that the logbook records of the Sri Lankan multi-day fishing vessels are located with sufficient accuracy to be used for development of fisheries forecast.

Fishermen should be acknowledged for their data recording in logbooks which is valued fishery-dependent data source and should encourage for accurate data recording. VMS data provide a uniquely valuable description of fishing activity, but restrictions on data access and the absence of standardized methods of analysis hamper data exchange and their use in assessment and planning (Lee *et al*., 2010). Sri Lanka will be implemented e-logbook system in 2017 and that will ensure proper logbook data with more The e-logbook system has the benefits of making the process of gathering and transmitting logbook data more efficient, accurate, and less costly (Chang, 2011).

The research in this paper is important for further analysis of distribution of fishing effort, develop a classification criterion specially for a tuna longline fishery which has been studied limited before.

## ACKNOWLEDGEMENT

This work was conducted as a part of the project “Improvements of an existing tuna forecasting system of NARA based on ocean status forecast” of National Aquatic Resources Research and Development Agency (NARA), Sri Lanka. We would like to thank the Department of Fisheries and Aquatic Resources, Sri Lanka and Mr. M.C.L Fenando, Director General of DFAR, who kindly provided access to the VMS and logbook data that was used in the present study.

## REFERENCES

Bastardie, F., Nielsen, J.R., Ulrich, C., Egekvist, J., Degel, H., 2010. Detailed mapping of fishing effort and landings by coupling fishing logbooks with satellite-recorded vessel geo-location. Fisheries Research. 106: pp. 41–53. doi: 10.1016/j.fishres.2010.06.016.

Chang, S.K., 2011. Application of a vessel monitoring system to advance sustainable fisheries management benefits received in Taiwan. Marine Policy, 35(2), pp.116-121.

Chang, S.K., and Yuan T.L., 2014. Deriving high-resolution spatiotemporal fishing effort of large-scale longline fishery from vessel monitoring system (VMS) data and validated by observer data. Canadian Journal of Fisheries and Aquatic Sciences 71.9: pp.1363-1370.

Deporte, N., Ulrich, C., Mahévas, S., Demanèche, S. and Bastardie, F., 2012. Regional métier definition: a comparative investigation of statistical methods using a workflow applied to international otter trawl fisheries in the North Sea. ICES Journal of Marine Science: Journal du Conseil, p. 197.

EC. 2003. Commission Regulation (EC) No. 2244/2003 of 18 December 2003 laying down detailed provisions regarding satellite based vessel monitoring systems. Official Journal of the European Union, L333: pp. 17–27.

Gerritsen, H. and Lordan, C., 2010. Integrating vessel monitoring systems (VMS) data with daily catch data from logbooks to explore the spatial distribution of catch and effort at high resolution. ICES Journal of Marine Science: Journal du Conseil, p.fsq137.

ICES. 2010. Report of the Study Group on VMS data, its storage, access and tools for analysis (SGVMS), 8-9 September 2010, Hamburg, Germany. ICES CM 2010/SSGSUE:12. p. 46.

IOTC. 2015. RESOLUTION 15/03 ON THE VESSEL MONITORING SYSTEM (VMS) PROGRAMME. The Indian Ocean Tuna Commission (IOTC). pp. 25-27.

Lambert, G.I., Jennings, S., Hiddink, J.G., Hintzen, N.T., Hinz, H., Kaiser, M.J. and Murray, L.G., 2012. Implications of using alternative methods of vessel monitoring system (VMS) data analysis to describe fishing activities and impacts. ICES Journal of Marine Science: Journal du Conseil, 69(4), pp. 682-693.

Lee, J., South, A. B., and Jennings, S. 2010. Developing reliable, repeatable, and accessible methods to provide high-resolution estimates of fishing-effort distributions from vessel monitoring system (VMS) data. ICES Journal of Marine Science, 67: pp.1260–1271.

Lee, J., South, A.B. and Jennings, S., 2010. Developing reliable, repeatable, and accessible methods to provide high-resolution estimates of fishing-effort distributions from vessel monitoring system (VMS) data. ICES Journal of Marine Science: Journal du Conseil, p.fsq010.

Ministry of Fisheries and Aquatic Resources. 2015. Fisheries in Sri Lanka. Retrieved September 03, 2016, from http://www.fisheries.gov.lk/content.php?cnid=ststc

R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Thomas-Smyth, A., 2013. Assessing the Accuracy of Logbook Data Using VMS Data in the California Groundfish Fishery (Doctoral dissertation, Duke University). pp. 2-10.