Comparison of Low-Cost Global Positioning System (GPS) Data Loggers for Their Potential Application in Fishing Vessel Monitoring System in the Philippines

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Abstract

The current system of monitoring fishing activities to generate information to support fisheries management in the Philippines is inadequate. The high cost of the satellite-based vessel monitoring system (VMS) makes it limited to Philippines commercial fishing vessels operating in the high seas in Western and Central Pacific. This project aims to investigate the best commercial GPS data logger as an alternative to VMS for low-cost vessel monitoring in terms of accuracy, power efficiency, and price. Nine different commercial GPS data loggers (Globalsat DG-100, Canmore GT-740FL, Canmore GT-750F, Columbus v-900, Holux rcv-3000, Qstarz BT1000XT, SJ5282DL, SJ5286TH), categorised into three price groups and three different chipset groups, were tested. Data locations of several GPS data loggers were compared to a commercial VMS, and results showed that all GPS data loggers provide locations data that are very close to VMS. The position readings of the data loggers are not statistically different, except for two units. Power consumptions were statistically different among the units. Based on the three criteria, Globalsat DG-100, Canmore GT-750F, and SJ5282DL all give closest positions data to commercially available satellite-based VMS that may be acceptable for regulatory purposes in the Philippines and offer cost-effective VMS solutions for monitoring and managing both commercial and municipal fisheries in the country.

Keywords: fisheries management, food security, alternative technology

Introduction

The negative impacts of fishing activities on marine ecosystems are a growing international concern (Gislason 1995; Auster et al. 1996; Jennings and Kaiser 1998; Turner et al. 1999; Stevens et al. 2000). In the fishery, significant degradation in fish stocks has been observed worldwide (Froese and Kesner-Reyes 2002; Myers and Worm 2003; Pauly et al. 2005). The continuous increase of fishing activities due to growing demands of marine fishery products for human consumption and aquaculture use would most likely result in greater impacts on fish stocks that would eventually lead to serious food security and conservation issues (Naylor et al. 2000; Pauly et al. 2005). The decline in fish stock and concern for sustainable food security promote the implementation of required changes to make fisheries monitoring, control and surveillance (MCS), and fisheries and environmental assessment and management more effective (Botsford et al. 1997; Caddy and Cochrane 2001). The advent and growing use of vessel monitoring system (VMS) in fisheries assist in achieving this revolution.

Fishing VMS is electronic equipment with a global positioning system (GPS) that is installed on fishing vessels to provide information about the vessel's position and activity (FAO 1998). Vessel monitoring systems are primarily used in fisheries MCS, and they have greatly improved the effectiveness of the program by providing a substantially wider coverage at a much lower cost than by using other MCS measures (Molenaar and Tsamenyi 2000; Flewwelling et al. 2002). However, VMS data can also be used in fisheries and environmental assessment and management (Lee et al. 2010). The use of VMS data in fisheries has become

the focus of several studies opening up a range of potential applications which include description of spatial distribution of fishing effort (Rijnsdorp et al. 1998; Murawski et al. 2005; Mills et al. 2007; Fonseca et al. 2008; Mullowney and Dawe 2009; Lee et al. 2010; Gerritsen and Lordan 2011) tracking of the distribution of the target species (Bertrand et al. 2008); assessment of fisheries interactions with target stocks and the environment (Rijnsdorp et al. 1998; Kaiser et al. 2000; Stefansson and Rosenberg 2005; Hiddink et al. 2007) assessment of changes in fishing activity following changes in regulations, area closures, and fuel costs (Anon 2007; European Commission 2008a, b; Piet and Quirijns 2009) description of fishing behaviour and interactions among vessels (Mackinson et al. 1997; Rijnsdorp et al. 2000; Bertrand et al. 2005, 2007; Poos and Rijnsdorp 2007; Marchal et al. 2007; Mullowney and Dawe 2009) and establishment of track records that the fishing industry can use when debating access rights and conflicts with other fishers and users of the sea (Eastwood et al. 2007; Stelzenmuller et al. 2008).

Despite having aforementioned benefits such as tracking of certain species and assessment of fishing activities, the use of VMS in developing countries is limited due to three specific issues: 1) assuring that the hardware installed is operational aboard each vessel, 2) obtaining a base station capable of handling the received data, and 3) gaining access to satellite communication systems to receive the data and command the VMS device. The cost of the VMS elements is often high for developing countries impeding their use as a fisheries management tool (FAO 1998). Indeed, despite having a large fishing industry, the Philippines does not have a national or local fisheries VMS. Being a member of the Western and Central Pacific Fisheries Commission (WCPFC), the Philippines has complied with the various conservation and management measures of WCPFC which include implementation of WCPFC VMS (called Commission VMS; WCPFC 2012a, b). However, only commercial vessels fishing on the high seas, and in particular areas in Western and Central Pacific Ocean determined by the WCPFC (in the area of Convention Area south of 20°N, and east of 175°E in the area of the Convention Area north of 20°N), are being tracked by the Commission VMS.

The limited use of VMS in Philippine marine fisheries has resulted in a variety of unresolved issues on fisheries management and research. For instance, MCS is still implemented through patrol boats, limiting its coverage and effectiveness. Spatial and temporal distributions of fishing efforts of different fishing gears used in the country and their impacts on the marine resource have not been accurately characterised because of the absence of VMS data. To address this concern, we started an initiative to utilise existing and emerging electronic (e) technologies to develop local and low-cost VMS. This is part of our program at the

University of the Philippines Visayas to develop practical and affordable fisheries management solutions in the Philippines using e-technologies. The GPS data loggers are the simplest VMS option for fisheries costing as little as $165 (Caslake 2009). Recent technological advances and growing consumer demand for location-aware technologies have made commercially available GPS technologies, equipment, and services more available, accurate, and cost and energy efficient (Vazquez-Prokopec et al. 2009; RNCOS 2011). Thus, GPS data loggers are now much more usable and accessible to fisheries researchers and managers, making them a probably appropriate VMS for fishing vessels operating in municipal waters of the Philippines.

In this pilot study, we compare different commercially available GPS data loggers for application in VMS, based on accuracy, price, and power efficiency. Accuracy of GPS data loggers are in reference to the location data of VMS and not in reference to the true absolute values of longitude and latitude. Prices are measured in United States dollar which includes shipping and custom dues, while power efficiency is assessed using power consumption of the devices in Watts. Low power consumption means a highly efficient device. The GPS data loggers should have location data which differs by 1-50 millimetres only using the satellite-based VMS as the true or reference values of location data. The GPS data loggers should also have a minimal power consumption of less than 2 watts to be used for longer periods in fishing activities without charging the battery.

Materials and Methods
Vessel tracking and study site

The study was conducted by tracking the positions of a contracted motor passenger vessel navigating in Guimaras Strait, between Iloilo City and Guimaras Island, Philippines. Positions data were recorded concurrently by nine GPS data loggers and a satellite-based VMS (Fig. 1). The recording was done while the boat was travelling from Parola, Iloilo City to Alubihod Beach Resort, Guimaras and then to Buenavista Wharf, Guimaras before returning to Iloilo City. Collection of position data was done for 2 days, 7 h (0900 h to 1600 h) per day.

Vessel monitoring system (VMS)

A subscription to low earth orbit (LEO) Global VMS and Electronic Logbook Terminal manufactured by Collecte Localisation Satellites (CLS), listed in Table 1, was arranged for this study. This brand is the only device approved for use in the Philippines by the WCPFC. The device generates real-time and variable frequency position reports accessible at the website of CLS. It also has an alarm triggered by a geographic

event such as entry or exit of the zone, loss of Iridium or GPS signal, power supply failure and battery back up on/off. It can communicate to a mini laptop to send emails and electronic catch report. For this study, the researchers modified the subscription to burst speed of one location data for every ten minutes in contrast to a usual plan of one location data for every hour.
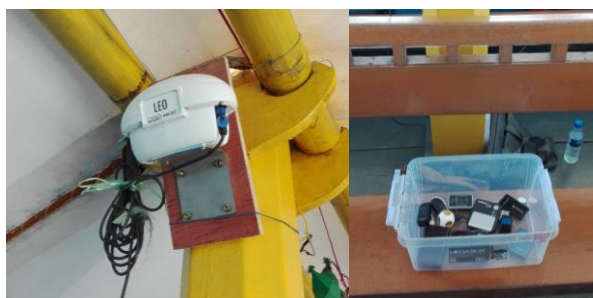
Fig. 1. Placement of a satellite-based vessel monitoring system and global positioning data loggers in the motorised boat used for the study.

GPS data loggers

Nine units of GPS data loggers were purchased (Table 1) and categorised in terms of the chipsets used and their prices (Table 2). The selected GPS chipsets are SiRF, MediaTek and SkyTraq, and are the most commonly available in the market (OpenStreetMap Wiki contributors 2019). The GPS units provide varied accuracy for locations data because the chipsets they use have different sensitivities to satellite signals (Wing et al. 2005). Sensitivity is the measure of the minimum amount of signal power required to produce an output. The higher absolute value of sensitivity (dBm) signifies a better GPS chipset in acquiring location data because of the low satellite signal power needed to acquire the data. Table 3 presents the chosen GPS chipsets used in this study, their sensitivities, and the minimum signal power needed to acquire a data location. As shown, the differences in signal power nearly double from one GPS chipset type to the next. Three GPS units were purchased for each chipset group, and each GPS unit belongs to one of the three price categories: low (0–US$66), middle (US$66–US$99), high (US$99–US$150).

Placement of GPS units

The VMS was positioned at an exposed fore portion of the motorised boat. The nine GPS units were contained inside a plastic container box with dimensions of 30 cm × 19.05 cm × 15.24 cm. The plastic box container was fully exposed and placed about 1.5 m right below the VMS unit. The VMS and GPS data loggers were placed concentrically relative to a vertical axis to minimise deviations in positions data that they recorded, especially when the boat rolls and pitches due to surface water waves.

Accuracy tests

Location data from the nine GPS units were recorded every second. Meanwhile, location data from VMS were recorded every 10 min. The accuracy of each GPS unit was computed by calculating the spherical distances between geographical location points recorded by the GPS data logger and the satellite-based VMS using the following Haversian formula (Gade 2010):

$$s_{AB} = \left(\sqrt{ sin^2\left(\frac{\varphi_B - \varphi_A}{2} \right) + cos(\varphi_A)cos(\varphi_B)sin^2\left(\frac{\mu_B - \mu_A}{2} \right) } \right) * R$$

Where s_{AB} is the great circle, orthodomic distance, or shortest spherical distance between two geographical points; φ_A is the latitude of the 1st point in radians; φ_B is the latitude of the 2nd point in radians; μ_A is the longitude of the 1st point in radians; μ_B is the longitude of the 2nd point in radians; R is the mean radius of earth; the 1st point A refers to a position recorded by the satellite-based VMS, and 2nd point B refers to position recorded by any one of the nine GPS units. Hypothetically, s_{AB} is 0 for 100 % accuracy for a GPS data logger considering the satellite-based VMS data as the standard values. Thus, smaller values of the s_{AB} would imply a more accurate GPS data logger.

Power efficiency tests and price comparison

Power consumption by each device was measured by attaching a bench multimetre (BM) that can measure voltage and current simultaneously. Each device was turned on for an hour with a fully charged battery while voltage and the current flowing in the device were recorded using the BM. Data were recorded every second, and the average power consumption of each device was determined.

Actual prices of each GPS data logger, including the shipping and customs dues, were compared. The GPS loggers were then ranked according to their actual prices, where rank one is the cheapest. The ranking was used for the evaluation of subsequent options to select the best GPS data logger as described below.

Statistical analysis and options evaluation

For spherical distances, some data points were identified as outliers. These outliers were manually removed in the set of data before they were subjected to statistical analysis. Power consumption in Watts and spherical distances data for each data loggers were averaged, and the means were compared using One-way analysis of variance (ANOVA). Post-hoc tests were then used to determine the means that are statistically different. The GPS data loggers were then ranked according to their mean power consumption

Table 1. Global positioning system, vessel monitoring system and electrical power measuring devices used with their corresponding brand and model number.

Equipment	Brand Name	Model Number	Country	Website
Multimetre	Iso-tech	IDM-8342	UK	https://www.isotech.co.uk/
GPS	Sheng Jay	SJ 5282DL	China	http://www.sja.com.tw/index-english.html
GPS	Canmore	GT-750-FL	Taiwan	http://www.canmore.com.tw/
GPS	Sheng Jay	5286TH	China	http://www.sja.com.tw/index-english.html
GPS	Holux	RCV-3000	Taiwan	http://www.holux.com/
GPS	Columbus	V-900	Germany	https://www.columbus-gps.de/
GPS	Qstarz	BT-Q1000XT	Taiwan	http://www.qstarz.com/GPS_products.html
GPS	Globalsat	DG-101	Taiwan	https://www.globalsat.com.tw/
GPS	Canmore	GT-740FL	Taiwan	http://www.canmore.com.tw/
GPS	I-gotU	GT-820 pro	Taiwan	http://www.mobileaction.com/web/en/index/
VMS	Collecte Localisation Satellites (CLS)	LEO100	France	https://www.cls.fr/

Table 2. Global positioning system data logger units studied categorised by chipset and price range.

Chipset	Low Price		Middle Price		High price	
	GPS Unit Make and Model	Price (USD)	GPS Unit Make and Model	Price (USD)	GPS Unit Make and Model	Price (USD)
SkyTraq Venus 6	SJ 5282DL	36.98	Canmore GT-750F	69.1	SJ 5286TH	99.65
MediaTek GPS chipset MT3329	Holux RCV-3000	65.19	Columbus V-900	69.95	Qstarz BT-Q1000XT	133.95
SIRF Star III or IV	Globalsat DG-100	44.9	Canmore GT-740FL	72.95	I-gotU GT-820 pro	143.99

Table 3. Global positioning system chipset sensitivities and signal power.

GPS Chipset	Sensitivity, dBm	Satellite Signal Power, Watts
Skytraq Venus 6	-161	$7.9432823472 \times 10^{20}$
SiRF IV	-163	$5.0118723363 \times 10^{20}$
MediaTek II	-165	$3.1622776602 \times 10^{20}$

and spherical distances. In both cases, the lowest value was ranked one while the highest was ranked nine. Devices with mean values that are not significantly different were assigned with equal rank. Subsequently, the Goeller Scorecard was used to identify the best satellite-based VMS alternative device based on the determined criteria of accuracy, power consumption, and price. Cost of the GPS was assigned 40 % weight, and accuracy was also assigned a weight of 40 %. The remaining 20 % of the criteria was for power consumption. The GPS units should use a very small amount of power so that location data can be stored for the whole duration of the fishing activities. In using the GPS data loggers in

VMS, we should consider that most small and medium scale fishing vessels do not always have a steady power supply to keep VMS device charged and working.

Results

Accuracy of the GPS data loggers

A total of 99 pairs of location data for both the VMS and GPS data loggers were collected in this study. Some of the data points in each GPS data logger were discordant, and thus, they were removed from the data set. We observed that a few s_{AB} values were

greater than 250 mm and were not included in the analysis. Mean s_{AB} for GPS data loggers are small (8.9 to 15.6 mm) which imply that the GPS data loggers tested in this study could be a reliable alternative to satellite-based VMS. Millimetre range s_{AB} values of the GPS data loggers showed that its location data were very much close in values as compared to the traditional satellite-based VMS location data. Figure 2 shows the closeness of the longitude and latitude data between the satellite-based VMS and GPS data logger Globalsat DG-100. On all location points, data from VMS and Gobalsat DG-100 almost coincide with each other.
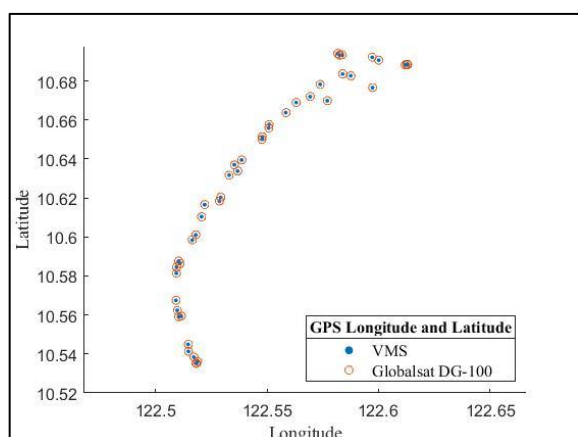

Fig. 2. Comparison of longitude and latitude data between the vessel monitoring system and Globalsat DG-100.

Figure 3 depicts that the mean distances for GPS data loggers (ranging from 8.9 to 12.3 mm) were not significantly different (Kruskal-Wallis: P < 0.05), except for Igot-u and SJ5282DL (15.6 and 14.8 mm, respectively).
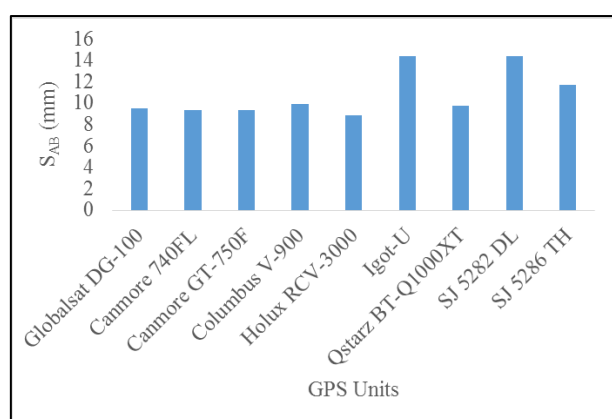

Fig. 3. Comparison of mean spherical distances (s_{AB}) in millimetres of each Global Positioning System data loggers.

Power efficiency

A total of 3600 power consumption (PC) data points were obtained for each of the nine GPS units. Power consumption measured in Watts were significantly different between the GPS units (Kruskal-Wallis Test: F = 68662, $P < 0.0001$). Igot-u had the lowest power consumption, making it the most efficient among the GPS data loggers understudy while Columbus v-900 had the highest power consumption, making it the least efficient (Fig. 4).

The differences between power consumption means of nine global positioning system (GPS) units and vessel monitoring system (VMS) with each other were statistically significant, with P value less than 0.001.
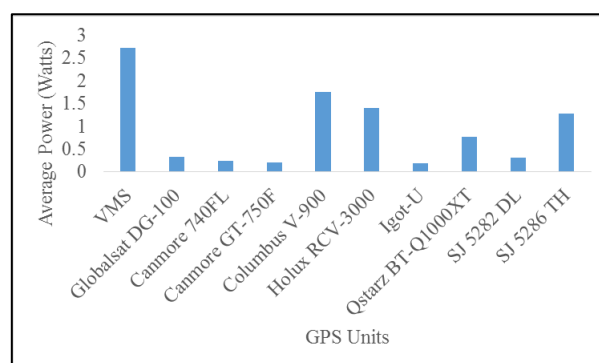

Fig. 4. Comparison of the power consumption in Watts of the global positioning system data loggers with the vessel monitoring system.

Price

All prices were listed in United States (US) dollars and were the lowest prices available in the market during the time of the study (Table 4). Supposedly, shipping fees and customs duties are not included in evaluating the GPS units based on price. However, custom fees and shipping costs were included in the evaluation of the GPS devices because fisherfolks from the Philippines pay a higher price when buying GPS data loggers from other countries. Custom fees and shipping costs make a difference in the prices of GPS data loggers when ordered abroad. Some of the units were shipped by groups, and the fees were not standard rates. To compute for the price of GPS data loggers shipped by group, the group shipping cost was divided by the number of GPS units in the group package.

Cost-effectiveness is an important consideration in selecting an alternative to satellite-based VMS. Among alternative devices, GPS data loggers are the cheapest (Caslake 2009).

Table 4. Global positioning system data loggers ranked according to its actual market price including shipping and customs dues.

Rank	GPS Unit Make and Model	Price (US$)
1	SJ5286DL	36.98
2	Globalsat DG-100	44.90
3	Holux RCV-3000	65.19
4	Canmore GT-750F	69.10
5	Columbus V-900	69.95
6	Canmore GT-740FL	72.95
7	SJ 5282TH	99.65
8	Qstarz BT-Q1000XT	133.95
9	I-gotU	143.99

Options evaluation

Nine GPS units were ranked in ascending order from one to nine based on their Goeller Scorecard (Table 5). A low score means that the device was low-cost, power efficient, and accurate. The following devices got the lowest scores: SJ5286DL (2.2), Globalsat DG-100 (2.2), and Canmore GT-750F (2.4).

Table 5. Ranking of nine global positioning system units based on their Goeller Scorecard.

Category	Weight	Globalsat DG-100	Canmore GT-	Canmore GT-750F	Columbus V-900	Holux RCV-3000	Igot-U GT-820 pro	Qstarz BT-	SJ 5282DL	SJ 5286TH
Price	0.4	2	6	4	5	3	9	8	1	7
Power consumption (PC)	0.2	5	3	2	9	8	1	6	4	7
Accuracy	0.4	1	1	1	1	1	3	1	1	2
Total	1	2.2	3.4	2.4	4.2	3.2	5	4.8	2.2	4.4

Discussion

The GPS data loggers SJ5282DL and Igot-u had significant differences in longitude and latitude data with the other GPS data loggers in this study. Possible reasons for the results include the sensitivity of the chipset and possible correction algorithm in high-priced data loggers. Even if SJ5282DL belongs to the low-price group of GPS data loggers, it uses a more sensitive SkyTraq Venus 6 chipset. Igot-u belongs to a high price category and has a lesser sensitive SIRF Star III or IV chipset. However, the accuracy of its location data can be attributed to possible correction algorithm found in higher priced GPS devices. The lower are the values of the mean distances, the higher is the accuracy.

The differences in power consumption of the data loggers depend on a variety of factors but mainly on the efficiency of the device's electric components. Some devices have components with high power consumption, while others have components that are more power efficient. The discussion on the specific details of the electronic components of the individual GPS device is out of the scope of this study. Being a battery powered wireless device, battery consumption is a critical factor of the GPS data logger's performance. Using this information and the battery rating from the manufacturer labels, we could assess the overall power efficiency of the device and its components. Thus, the results of this study would enable us to accurately evaluate the reliability of GPS data loggers to operate as VMS, based on its power consumption.

Including the price of GPS loggers in the options evaluation becomes important in the context of municipal fisheries in the Philippines. There are many registered small and medium-scale fishers in the country, and their number is expected to increase (BFAR 2014). Tracking these vessels for control and surveillance and fisheries management purposes would entail high cost. In this regard, the use of cost-effective GPS data loggers would be ideal.

The importance of potential application of GPS data loggers in VMS is emphasised by the fact that the majority of the vessels in municipal fisheries in the Philippines are of small- and medium-scale fishers. These fishers could not afford the cost of a satellite-based VMS.

The result showed that three GPS data logger units SJ5286DL, Globalsat DG-100, and Canmore GT-750F could be considered the best alternative to satellite-based VMS among the GPS units evaluated in this study. SJ5286DL has excellent accuracy and is the cheapest among the tested loggers, but has average power efficiency. GlobalSat DG-100 has the same accuracy rating as SJ5286DL, the second cheapest and is more power efficient than SJ5286DL. Canmore GT-750F exhibits excellent accuracy and power consumption but has a moderately high price. When applied for fishing vessels in the Philippines, the final selection of these best GPS unit to use should be based on the realities faced by a fisher who goes out fishing.

The use of the low-cost GPS data loggers as VMS would be ideal in municipal fisheries in the Philippines. Here we were able to select the best options among commercially available devices. The next step would be to pilot the implementation of this alternative VMS for Filipino fishers to instill fishermen's compliance with local fisheries and environmental management regulations. The success of the implementation would lead to a wide range of advantages related to solving Philippine marine fisheries management issues. The VMS can provide fishing effort data which in turn can be used in a variety of purposes such as describing the impacts of

fishing on the target stocks and the environment (Hiddink et al. 2007); determining the distribution of target stocks (Bertrand et al. 2008); and assessment of changes in fishing activities due to regulations such as area closures (Anon 2007). Such data and applications are currently absent in Philippine marine fisheries, and this may have contributed to the ineffectiveness of fisheries management strategies that we have implemented.

Conclusion

A set of GPS receivers were compared in terms of how close their geographical data are to VMS data. This study reveals that position data recorded through commercial GPS units are relatively close to those recorded by a standard satellite-based VMS unit. Considering the much lower price of commercial GPS units, it is recommended that Filipino fishers use them instead of a VMS, which is prohibitively expensive. Although some commercial GPS units have very good qualities such as accuracy of position data (e.g. Holux RCV-3000 GPS receiver) or low power consumption (e.g. Igot-U GT-820 pro), selecting the best GPS units is usually based on several criteria. Researchers rate nine commercially available GPS units based on accuracy, power consumption, and price. It was shown that the best units are Globalsat DG-100, SJ 5282DL, and Canmore GT-750F. These GPS units have longitude and latitude data that is within 50 mm difference to satellite-based VMS data and are therefore recommended for monitoring commercial and municipal fishing vessels operating within the waters of the Philippines.

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