Vessel Monitoring Systems and their Role in Fisheries Management and Monitoring, Control and Surveillance

1.0 Vessel Monitoring Systems: Overview

Fisheries managers started utilizing Vessel Monitoring Systems (VMS) in the 1990s[i] to track the locations and monitor the activities of fishing vessels in order to bolster the efficacy of fisheries management measures. This capability also enhanced enforcement capacity by facilitating more effective and cost efficient enforcement actions by providing a level of monitoring, control and surveillance (MCS) not possible with traditional and more conventional methods of aerial and surface surveillance. Satellite-based VMS are described by the United Nations' Food and Agriculture Organization (FAO) as:

> *"…comprised of several components. Each participating vessel must carry a VMS unit. This shipboard electronic equipment is installed permanently onboard a fishing vessel and assigned a unique identifier. Most shipboard VMS equipment types use satellite communication systems that have an integrated Global Positioning System (GPS). The system calculates the unit's position and sends a data report to shoreside users. The standard data report includes the VMS unit's unique identifier, date, time and position in latitude and longitude…"*

Initially, VMS was used as an instrument for flag States to track the activities of their own domestic fishing vessels, and for coastal States to monitor foreign-flagged fishing vessels licensed to operate within their Exclusive Economic Zone (EEZ). The United Nations Convention on the Law of the Sea provided the legal basis for this as it gave coastal States the primary responsibility for managing all living marine resources within their 200 nautical mile EEZ. The United Nations (UN) Fish Stocks Agreement specifically called for the implementation of VMS by flag States in the framework of sub-regional, regional and global agreements[ii]. In this spirit, most Regional Fisheries Management Organizations (RFMOs) have mandated VMS for vessels authorized to fish on the high seas within each respective Convention Area.

States are increasingly engaging in multilateral data sharing agreements that provide "peer-to-peer" VMS data exchanges, as well as broader arrangements, such as the agreement between members of the Forum Fisheries Agency (FFA) that provides for near-real time sharing of VMS data among members for all foreign-flagged fishing vessels licensed to fish within their collective waters.

With recent advancements in technology and reductions in equipment and transmission costs, the functionality of VMS has improved and expanded, allowing the system to be fully integrated into fisheries management plans. Service providers now offer an extended suite of applications to complement the original tracking capability of VMS including:

- *Electronic catch reporting (e-logs)*: This capability facilitates near-real time catch reporting that will allow fishery managers to more easily cross-correlate the data with VMS position information and inspection reports;
- *Integrated catch documentation schemes (CDS)*: CDS are systems that track and trace fish from the point of capture through unloading and throughout the supply chain by recording and certifying information that identifies catch origin that the fish were harvested in a manner consistent with relevant management measures. Where possible, a CDS should be integrated with a range of complementary MCS measures including VMS;

- *Product traceability*: Traceability allows the tracking of seafood as they move through the entire supply chain, from catcher vessels to processors, suppliers, distributors, retailers and food service operators; essentially providing tracking "from hook to plate". VMS can be used to provide the at-sea tracking component of a traceability solution;
- *Management of observer programs*: Observers provide an independent source of data collected at sea, such as bycatch, catch composition, and gear configuration data. This information, when coupled and verified with VMS, is critical for responsible fisheries management; and
- *Support for catch share or quota monitoring*: Catch shares, or quotas, allocate a specific area or percentage of a fishery's total catch to an individual, community or association. VMS can be used to assist in holding participants directly accountable to stay within their catch limit or quota by providing near-real time information on vessel position as well as catch reporting via e-logs.

Today, VMS is used in a large number of commercial domestic and high seas fisheries worldwide, providing authorities effective monitoring of thousands of fishing vessels. However, to be effective authorities must regularly monitor VMS data and share it appropriately for enforcement or scientific purposes. To this end, RFMOs and other regional organizations are increasingly choosing to manage a centralized data-secure VMS on behalf of their Secretariat and flag and coastal State members to improve the timeliness and technical capabilities of their VMS and maximize cost efficiencies.

2.0 Vessel Monitoring Systems: how they work, components and options

2.1 The Building Blocks

VMS uses hardware installed on fishing vessels called an Automatic Location Communicator (ALC), also known as a Mobile Transmitting Unit (MTU), to transmit information to communication satellites. As outlined in Figure 1, the data is then relayed to Land Earth Stations (LES) managed by Mobile Communication Service Providers (MCSP) and then sent by secure landline or via secure internet protocols to Fisheries Monitoring Centers (FMCs) and RFMO Secretariats. FMCs can be managed on a national, sub-regional, or regional basis as established through either national policies or international agreements.

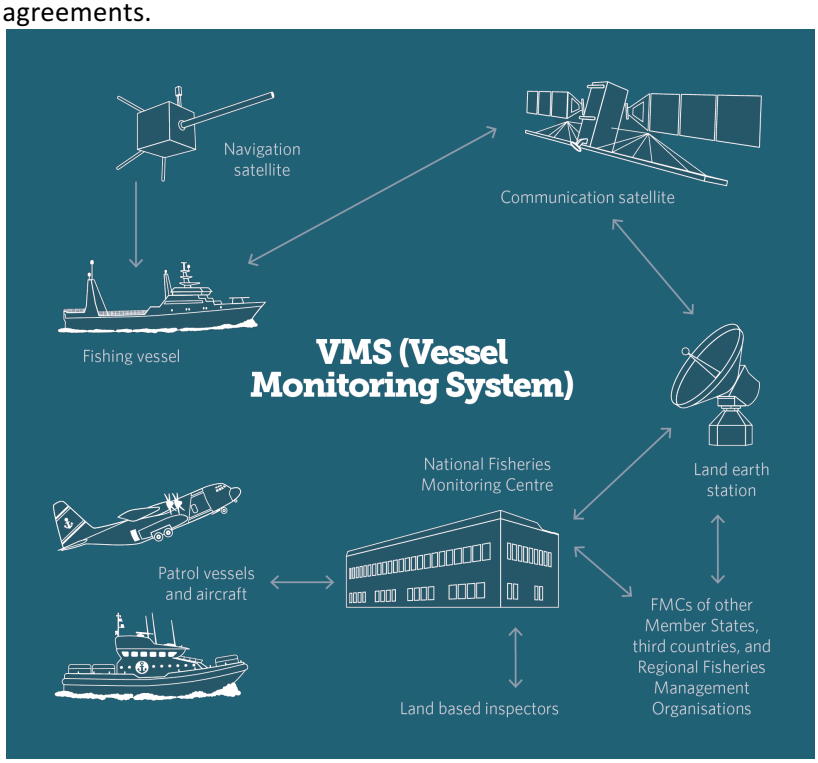

Figure 1: Typical Vessel Monitoring System

Source: European Union, 1995-2016

A typical "*vessel-to-authority*" VMS scheme can be divided into three distinct sub-groupings:

1. *Shipboard Hardware:* The ALC/MTU (hereafter called VMS unit) is installed on a vessel and integrated with the shipboard GPS. VMS units have a unique identifier that corresponds to that specific vessel. Data reports are automatically sent from the VMS unit according to pre-determined periodic times – considered the "VMS reporting rate" – and are of specific data size. These reporting rates typically range in frequency based on monitoring requirements established by management authorities, from a minimum of one time to a maximum of 24 times a day. Depending on management arrangements, the purchase, installation and maintenance of shipboard VMS units may rest either with a fisheries management authority or be borne as a direct cost by the vessel owner/operator.

2. *Satellite Communications:* The communication satellites and LES that receive VMS data from fishing vessels are the vehicles through which the data is securely sent to the responsible FMC. MCSPs are the commercial entities that run and maintain the communication satellites and LES, process the VMS data received from vessels, and ensure the information is sent to the FMC in a usable format. Airtime costs associated with the use of communication satellites and LES are largely dependent on a combination of: (1) the size of the data report, (2) the overall VMS reporting rate in use, and (3) the number of vessels being monitored.

3. *VMS Service Provider:* Typically, a fisheries authority contracts with a commercial VMS vendor that securely manages and stores processed VMS data from MCSPs, and provides a software solution, or graphical user interface that displays vessel VMS data to enable appropriate geospatial analysis and monitor vessel operations. Some VMS service providers offer management authorities a fully managed service in which the costs for licensing, maintaining and operating the VMS software, maintaining a secure VMS database and IT hardware, managing, storing and processing the VMS data, and costs of airtime are all included in the overall service. In some cases, VMS service providers also serve as the airtime providers and contract directly with MCSPs for bulk data to provide a seamless service and take advantage of economies of scale. This may allow for greater bargaining power with MCSPs on airtime pricing. However, in some cases, in order to meet certain management objectives, authorities may choose to establish and maintain separate MCSP and VMS service provider contracts in managing their VMS as well as allow vessel owners to choose and install their own preferred VMS unit from a list of approved devices. Table 1 provides an outline of typical commercial providers for a range of VMS services.

VMS ELEMENT	PROVIDERS (not inclusive)
Shipboard Hardware (ALC/MTU)	Applied Satellite Technology (AST), Thrane & Thrane, Faria Watchdog, Furuno, Thorium, SatLink
Mobile Communication Service Providers	Vizada, Speedcast, Stratos, Iridium, Inmarsat, Argos
VMS Service Providers	PoleStar, Trackwell, Visma, CLS

Table 1: Vessel Monitoring System Components and Sample Providers

For satellite communications, VMS units typically rely on GPS for position and time information. The VMS unit transmits this data to monitoring systems most often using conventional satellite systems including, but not limited to:

- Inmarsat: Originally founded by governments but now a commercial entity. Inmarsat maintains a constellation of geosynchronous communication satellites;
- Iridium: Uses a constellation of Low Earth Orbit (LEO) satellites to provide global coverage;
- CLS Argos: Uses LEO European and US satellites in polar orbit;
- AST: Uses both mobile phone technology and Iridium communications via polar LEO satellites; and
- Qualcomm: Provides access to Iridium satellite systems.

2.2 Data Reporting

Typically, an MCSP uses a Data Network Identity (DNID) number to address specific groupings of VMS units being monitored. All VMS units within a specific grouping must be configured to belong to a specific unique DNID. Vessels are identified within this grouping by a VMS data report that uses a combination of two unique identifiers; (1) the DNID, and (2) the VMS unit identifier. These groupings may be associated with a fleet of vessels monitored by a national authority licensed for a specific fishery or those authorized vessels required to be monitored under specific RFMO arrangements. A single VMS unit may be configured to belong to and store more than one specific DNID group and therefore a vessel may be monitored directly and simultaneously by more than one entity (which may include a national fisheries authority, RFMO or vessel owner) through separately transmitted data reports; however, this has implications of increased satellite airtime costs.

As indicated, VMS data reports are typically provided to relevant authorities independently of each other, generating their own separate airtime costs. Management authorities can help minimize these higher satellite transmission costs by enabling an MCSP or VMS service provider to establish a "gateway" within a centralized VMS database to allow the simultaneous secure dissemination of VMS data reports to multiple authorized users under strict data confidentiality protocols. This allows a single data report to come from a vessel and be processed through a communication satellite to an LES and MCSP significantly reducing airtime costs.

2.3 Set-Up Options

There are three different approaches to housing the IT hardware, servers and databases needed for a VMS:

1) *In House System*: A client (e.g. flag State) establishes a secure location with limited physical and electronic access, buys the necessary IT hardware and software, maintains the equipment, and obtains VMS data directly from an MCSP. They also set up their own Virtual Private Network (VPN) so that VMS data can be sent directly to authorized users such as their own national FMC to be viewed via software developed in house or, more typically, owned and managed by a VMS service provider;

2) *Hosted System*: The VMS service provider supplies the software by which VMS data can be viewed and also hosts the system in a secure location, with all IT hardware, software and data storage provided and the client (e.g. flag State or RFMO Secretariat) uses secure internet access to view the data. In most cases, this is the preferred system as there are multiple advantages to clients such as:

    - No capital outlay;
    - No ongoing IT costs (maintenance, upgrades, warranties, etc.);
    - Hardware specifically built on which VMS is run;
    - Secure access from anywhere in the world;
    - Highly redundant (power, internet, backup) – while these are achievable via an *In House System*, to achieve the same standard would be extremely expensive; and

- IT costs are amortized over multiple clients which results in lowers costs in the long term for clients.

A hosted system can also be tailored to individual client requirements and provides the basis for an RFMO centralized VMS. A centralized VMS allows for the reporting of vessel positional data, either directly to an RFMO Secretariat or to the RFMO Secretariat through the relevant flag State. In some cases, this reporting is both direct and simultaneous to the RFMO Secretariat and flag State;

3) *"Cloud" System*: The VMS service provider establishes IT services from a "cloud" provider (e.g. Amazon, Google, or Microsoft). The VMS service provider contracts with the "cloud" provider for the needed hardware and data storage based on the size of fleet monitored and range of services offered. This is a variation of the hosted system, with the advantage that capacity can be easily scalable—both higher and lower—to meet the client's needs at a moment's notice, thereby increasing the ability to achieve maximum cost efficiencies.

It is critical to understand that in a centralized hosted or cloud system, VMS data retains existing data ownership protocols and still belongs to the client (flag State, RFMO, or other) as reflected in established flag State and RFMO data rules and procedures. Importantly, centralized systems eliminate redundant, separate and costly satellite transmissions to multiple authorities by instead providing a true copy of the data automatically, securely and in near-real time to both the relevant RFMO member countries and RFMO Secretariat.

2.4 Size and Cost Implications for Data Reports

The size of a VMS data report transmitted from a VMS unit is known as single or two-packet reporting—in some cases even three-packet reporting. Two-packet reporting contains; (1) information on the identity of a vessel and its current position in latitude and longitude within one packet, and (2) the vessel's course and speed within another packet. Older VMS software required two-packet information in order to display both a vessel's position and course and speed together on a graphical user interface. However, given the high costs of airtime where two-packet reporting costs twice as much as single-packet reporting, most VMS service providers developed their own data processing software to calculate the course and speed of a vessel based upon the last two VMS data reports received. This technological advancement has nearly eliminated two-packet reporting requirements and has drastically reduced unnecessary and expensive airtime costs.

2.5 Two-Way Communication

Ideally, VMS units should allow for two-way communication. This enables a fisheries authority to directly change the reporting rate of a VMS unit or send the VMS unit an order to provide an immediate positional update of a vessel—critical operations from both an enforcement and management perspective—and where necessary, alert the vessel if it is nearing or entering a closed area. In addition, a duplex VMS unit can provide a means for a fisheries authority to communicate directly, via text or email, when desired, allow for the near real-time transmission of electronic logbook and catch data through the VMS unit, as well as facilitate information flow supporting quota monitoring or product traceability if required by management regulation or licensing condition. Newer duplex technology is also much better suited to smaller vessels than older VMS units, thereby reducing the need to restrict VMS to larger vessels and countering arguments against VMS units being installed on smaller vessels.

2.6 Reporting Rates

In order for fisheries authorities to have confidence in VMS data, it is better to have shorter time periods between data reports. Increased VMS reporting rates allow authorities to determine with

greater accuracy the location, direction and speed of the vessel which correspondingly provides greater confidence in understanding vessel movement patterns consistent with fishing activity. Additionally, higher temporal resolution is beneficial for scientific assessments. Higher reporting rates are particularly useful when vessels operate adjacent to known or disputed maritime boundary lines or in areas where a vessel is not authorized to fish. Duplex capability allows authorities to automatically increase the VMS reporting rate for specific vessels as they approach or operate in close proximity to these known boundaries. Importantly, it also allows authorities to send alerts to these vessels as they approach boundaries or closed areas; thereby providing proactive notification that may act as an effective deterrence to non-compliant activity. However, increased VMS reporting rates are directly proportional to increased airtime costs. As such, the management authority should determine optimum reporting rates to strike a balance between effective monitoring and cost effectiveness.

2.7 Type Approval

For VMS units to operate consistently and effectively and for fisheries authorities to have confidence in the transmitted VMS data, the VMS unit must be fit for purpose and tamperproof. In order to ensure this, fisheries authorities generally require a make and model of a VMS unit to undergo an established "type approval" process. Type approval is a process designed to ensure that the quality of VMS data received from a specific VMS unit make and model is sound and meets specific operational and technical standards. Generally, this involves having an independent authority, approved by either the national or regional fisheries management regime, assess the VMS unit hardware via technical and environmental trials. Following testing, fisheries authorities prepare a list of "approved" VMS unit types from which operators can choose. Approved VMS hardware installers then install VMS units on-board whereupon fisheries authorities can ensure they receive VMS data from that specific vessel consistent with management requirements.

2.8 Data Sharing Agreements

VMS data is considered commercially sensitive and is not publically available unless vessel identity and track history information is removed. However, when subject to strict confidentiality arrangements, it can and is, shared between appropriate fisheries management authorities of neighboring States or other States for both cooperative EEZ and high seas fisheries enforcement purposes. An example of an established VMS data sharing agreement is the one established between the 17 members of the FFA. VMS data regarding nearly 1,500 foreign fishing vessels listed on the FFA Vessel Register that are licensed to fish within FFA members' waters is shared between the fisheries authorities of each member according to established, strict data-sharing policies and procedures. Sometimes, VMS data is also shared between inter-governmental agencies such as a State's Coast Guard, Navy or other maritime authority via a Memorandum of Understanding (MOU) to assist in broader maritime domain awareness, allowing these authorities to filter legitimate fishing vessels from possible unwarranted surveillance and enforcement actions.

2.9 New Technologies

The cost of operating and maintaining a VMS will vary according to the functionality requirements of the specific system. In general, the higher the functionality, the more expensive the equipment and required airtime costs. Some VMS, such as those operated by the United States and European Union require more expensive onboard equipment and large amounts of data to be transmitted over the communication satellite link. Although this results in higher airtime charges, it also provides a high level of functionality. It is important to note, however, that the basic cost for VMS hardware continues to decrease as technology advances. In most cases, a standard VMS unit for a vessel can be purchased for approximately $1,000 USD or less depending on the type of functionalities that come with a specific make or model.

There are a number of emerging VMS options available for fisheries managers to consider. While all the systems available use GPS to monitor vessels movements, they differ with respect to the method and ability of transmitting VMS data to a MCSP. Some emerging lower-cost systems include:

- **General Packet Radio Services (GPRS)** which is mobile phone technology. This system utilizes coverage from land-based mobile phone masts which, as with mobile phones, can be "patchy" in coverage in some areas and have limited range. To optimize performance many systems use marine quality antennas. During periods of signal loss this system has the capacity to continue logging vessel positions to transmit when the signal returns. However, given mobile phone coverage limitations, this system is more applicable to nearshore fisheries and smaller or artisanal vessels.

- **Very High Frequency (VHF) Time Division Multiple Access (TDMA)** which involves radio frequency transmissions using a dedicated radio frequency to transmit data. Depending on the height of antennas installed on vessels and shore towers, transmissions are possible up to 40 nautical miles. There are no transmission costs once the system is set up, other than a VHF license cost. However, much like GPRS technology this type of VMS configuration is limited in range and is more applicable to nearshore fisheries.

3.0 Primary Uses of Vessel Monitoring Systems

To date, the primary use of VMS is as an MCS tool, to assist fisheries managers and enforcement authorities to monitor the activities of licensed vessels. In addition to increasing the efficiency and effectiveness of conventional aerial and surface assets and associated costly enforcement responses involving their deployment, VMS has been particularly useful where fisheries management arrangements have included area (spatial) or time (temporal) restrictions or limitations. Where management arrangements involve closed areas for fisheries purposes (i.e. nursery grounds) or broader closures (i.e. marine protected areas) or a fixed period of time that a fishery is open (i.e. seasonal closures) the use of VMS can immediately tell authorities where and when vessels are operating.

3.1 What Vessel Monitoring Systems Can Do

When properly configured and subject to appropriate operating procedures and penalties, VMS is also useful in benchmarking fisheries management objectives. It provides highly accurate positional data that can prove useful in supporting the development of improved stock assessments by allowing scientists to crosscheck VMS data with other established fisheries management tools such as vessel logbooks, catch data and observer reports. With recent technological advances, VMS functionalities have evolved to the point where their capabilities allow fisheries managers to consider the requirement for vessels to provide electronic submission of fisheries data to facilitate near-real time access by fisheries managers to catch reports and observer data. This eliminates considerable delays associated with paper reporting methods and greatly reduces the potential for false or intentionally manipulated and inaccurate data.

VMS is able to assist in monitoring and facilitating enforcement action in response to a range of fisheries management measures:

1) *Area restrictions and closures:* A near-real time VMS track allows fisheries authorities to accurately monitor which vessels are fishing in designated areas. In addition, if an area is subject to a management regulation involving catch or time limits, VMS can be used to ensure vessels leave the area as required;

2) *Time management:* Similar to an area restriction or closure, fisheries authorities can monitor in near-real time vessels which are subject to a seasonal or time closure so that they leave fishery grounds and return to port as appropriate;

3) *Catch restrictions:* VMS combined with additional catch reporting software can provide notification to a vessel when it has reached a catch limit and then be used to monitor vessels to ensure they depart the fishery grounds and return to port. This can be used in conjunction with area restrictions and time management;

4) *Quota tracking:* When combined with electronic catch reporting, VMS can provide near-real time information on catches against established quota limits; and

5) *Tracking seafood product along the supply chain and market assurance:* When combined with a catch documentation scheme, VMS can provide fisheries authorities information that can validate vessel movements and activities which may assist in providing chain of custody information up to the point of landing or transshipment.

3.2 What Vessel Monitoring Systems Cannot Do

While a properly configured VMS can provide a range of useful fisheries management and enforcement information, there are limits to what it can do. Some of these limitations include:

1) *VMS cannot conclusively tell authorities if a vessel is fishing:* On its own, VMS cannot indicate if a vessel is fishing unless the VMS unit is linked to gear sensors or cameras that may provide verification of activity. However, VMS does provide enough information that, through analysis, can indicate with a high degree of confidence that a vessel's movement is consistent with fishing activity which may then elicit an enforcement response to confirm the activity or lead to a follow up investigation to verify potential non-compliant action;

2) *VMS generally cannot be used in prosecutions as the sole evidence of IUU fishing unless specifically allowed by legislation:* Increasingly, fisheries authorities seek to use VMS data in prosecutions; however, the number of successful prosecutions using VMS data is dependent on how thorough the framework for VMS use is addressed within a country's regulatory and legislative framework. As domestic legislation continues to be updated and specific provisions inserted to allow for VMS use in courts of law as evidence documenting non-compliance, the success in using VMS data in fisheries prosecution cases will improve. This will, in part, be determined by the legal system in place (common or civil law) and the nature of the offense; and

3) *VMS generally is not allowed to be accessed and used by third parties (i.e. RFMOs or coastal States) to confirm non-compliance:* The ability of a party other than the vessel's flag State to use VMS data to definitively prove non-compliance with management measures established through regional fisheries management arrangements while a vessel was operating on the high seas remains problematic. Such data would require forthcoming action from the responsible flag State to investigate the alleged offense and negotiate an appropriate penalty for these potential instances of non-compliance. Currently, at best, VMS use by third parties is as a surveillance tool to assist in directing the activities of more conventional aerial and surface enforcement assets to document potential non-compliance. In these cases, this may provide an impetus for a responsible flag State to take follow up investigation and possible enforcement action on one of their flagged vessels.

4.0 Relevant Vessel Monitoring System Models

The type of VMS that a flag State, coastal State or competent RFMO may choose to adopt will very much depend on the management arrangements in place and the desire to vary these or make use of the increased functionalities now being provided by contemporary VMS. Likewise, the usefulness of VMS in an overall compliance regime will vary depending on the fisheries management arrangements. VMS is most useful in areas where there are spatial or temporal management measures, tracking vessels on the high seas in order to meet a flag State's international obligations, enhancing general maritime domain awareness, and improving the effectiveness and efficiency of law enforcement activities. This can be done by providing data to operational enforcement assets which help target the vessels and areas that hold the highest risk for non-compliance.

In selecting and implementing a VMS, some important initial questions policy makers may wish to consider include:

- Why is VMS being implemented?
- Which vessels will be required to report?
- What purpose will the information be used for?
- Who will be able to view and use VMS information?
- Is additional functionality—electronic logs, observer reporting, catch documentation—desired or needed?

Once these overarching questions have been answered, it is then possible to decide other variables such as what VMS units should be considered for "type approval", whether a duplex communication system be adopted, and in the case of an RFMO, the best way to share VMS information between the flag State, Secretariat and coastal State members. Regardless of the VMS adopted, decisions will also need to be made to set out standards, specifications and procedures, operating requirements, data confidentiality rules as well as what manual reporting process is required if a vessel's VMS unit fails.

5.0 Best Practices for RFMOs

While it is difficult to generalize, a review of current VMS requirements in many RFMOs point to some of the "best practices" in VMS. The following should be taken as a guide and will depend to some extent on the factors outlined immediately above.

VMS should be required for authorized vessels of any size and type: VMS should be required for all fishing vessels in order to monitor compliance with fisheries management measures and support scientific stock assessments, especially for those vessels that are authorized to fish in areas beyond national jurisdiction such as the high seas or in another State's EEZ. This should be applied to all vessels defined as fishing vessels or fishing support vessels, including reefers and carriers, or are otherwise authorized to engage in fishing-related operations, such as transshipment. When first introduced, VMS was used to monitor larger industrial fishing vessels due to high costs and technical requirements. As technology advanced, VMS is now suited for even the smallest vessels due to newer, compact hardware, reduction in overall costs, as well as the use of battery-powered units and cellular technology.

VMS should be type-approved and tamper-proof: VMS units should be "type approved", sealed, fully automatic and provided with adequate backup and recovery procedures. Type approval is essential to establish and maintain uniformly high system integrity whereby an authority retains the ability to approve reliable, robust, and secure VMS units and thereby create and maintain a VMS

that meets high system standards. Type approval requirements include, but are not limited to, demonstration and certification of the following functionalities:

- Transmit mandatory, automatically generated position reports that contain the unique identification of the VMS unit;
- Include visible and/or audible alarms for malfunctioning of the VMS unit;
- Provide comprehensive and transparent communications, which function uniformly within the entire geographic coverage area;
- Provide two-way communications between an MCSP and VMS unit, such as manual polling;
- The ability to send and receive free-form Internet e-mail or text messages;
- Accuracy of the reported position within 100 meters, unless otherwise indicated by an existing regulation or VMS requirement;
- Store a pre-determined number (100 or more) position fixes in local, non-volatile memory when the VMS unit is either unable to transmit or configured to a ''store and retrieve'' mode;
- Allow for variable reporting intervals between five minutes and 24 hours; and
- Capable of having its reporting intervals changed remotely by an authorized user.

Communications between the VMS unit and MCSP should also demonstrate they are secure from tampering or interception, including the reading of passwords and data. Therefore, VMS units should have mechanisms to prevent, to the extent possible: (1) interception during transmission from the VMS unit to MCSP via either wireless or terrestrial facilities; (2) spoofing, whereby one MTU is fraudulently identifying itself as another VMS unit; (3) modification of VMS unit identification; and (4) introduction of viruses that may corrupt the messages, transmission, or the VMS system. In addition, specially identified position reports should be generated upon:

- Antenna disconnection;
- Loss of the positioning reference signals;
- Loss of the mobile communications signals;
- Security events, power-up, power-down, and other status data; and
- The vessel crossing predefined geographic boundaries.

VMS should operate continually at all times with backup systems in place. VMS units should remain in continuous operation at all times at sea and in all areas – in essence, "port-to-port" tracking, which means from the moment a vessel leaves port until the time it returns to port and all times in between. VMS units are capable of providing management authorities with such "port-to-port" tracking though management arrangements should be developed and implemented to capitalize on this and to ensure the elimination of gaps or loopholes in VMS monitoring by the most appropriate authority (flag State, coastal State, competent RFMO) dependent on the geographic position of a vessel. Likewise, in case of VMS failure, rules should ensure that vessels operate without a functioning VMS for the shortest possible time and that they report manually at sufficiently frequent intervals, ideally no less than every four hours. Importantly, manual reporting should not be considered an automatic right; it should be considered a backup plan if a VMS unit malfunctions and fails to automatically report along with the condition that a vessel must follow established manual reporting rules. If a VMS unit remains non-functional for a set period of time, vessels should be required to return to port, make immediate arrangements to have the unit repaired or replaced, and remain in port until the VMS unit is once again operational. Fortunately, the improved reliability of modern VMS units has greatly reduced the number of VMS failures and need for manual reporting.

VMS transmissions should be provided to authorities in near-real time. Vessels should transmit VMS data at the highest possible frequency, ideally at hourly intervals, with adjustments for certain fishing vessels as appropriate. Higher reporting rates permit more accurate monitoring of fishing or transshipment operations and, when correlated with catch data, helps improve scientific stock assessments. It should be recognized that there will be a degree of data latency between the time a VMS data report is transmitted from a vessel to the point it is displayed on a user interface within an FMC. Latency is defined as the delay from time of GPS acquisition (calculated onboard a vessel) until insertion of the VMS data report into the VMS service provider database and display to an authorized user via appropriate software. This includes all aspects of the VMS data path, performance of the VMS hardware onboard a vessel, MCSPs, client infrastructure, servers, and software application processes. In most cases, when a VMS is performing correctly, data latency should be less than one hour for at least 90% of the position data.

VMS data should be sent to all relevant coastal States and the competent RFMO. VMS data should be provided simultaneously and in near-real time to the flag State and to all other relevant authorities, including any concerned coastal State and the competent RFMO. Simultaneous and direct reporting to authorities can either be accomplished directly from the vessel via multiple transmissions (through appropriately assigned DNIDs) or after the data is received within a centralized hosted or "cloud-based" VMS. The centralized method is not only more cost efficient, but also limits opportunities for potential tampering, deliberate manipulation or altering of the VMS data as secure landlines and HTTPS protocols (e.g. such as internet banking) can provide the data directly to all relevant authorities in near-real time. If management arrangements are such that VMS data is transmitted solely to the flag State authority in the first instance, measures should be established to facilitate the secure transfer of this data to a relevant coastal State and competent RFMO as close to near-real time as possible in an agreed and standardized data exchange format. Relevant VMS data should also be provided for use by RFMO scientific committees to cross-check the accuracy of fisheries management data provided via other data collection means to improve overall stock assessments (although this does not need to be in near-real time), and also to assist in inspection and at-sea enforcement actions in accordance with pre-established procedures and applicable confidentiality rules.

VMS should provide for two-way reporting. VMS units should allow for communication (duplexing) between a management authority and the VMS unit. This enables the authority to adjust the reporting rate to increased intervals, such as when a vessel nears an environmentally sensitive or closed area, and to poll the VMS unit for an updated position of the vessel. Alerts can also be sent where there might be a need for additional inquiry or real time communication with the vessel operator. There are costs associated with two-way communications which include sending polls to and from VMS units with text or with no text and likewise with status requests. These costs can be mitigated through the establishment of strict protocols and procedures that identify situations and circumstances that warrant an increase in reporting intervals.

Viable penalties should be in place in case of VMS reporting non-compliance. Flag States as well as relevant coastal States and RFMOs should have mechanisms in place to control the effective implementation of applicable VMS regulations, and apply appropriate penalties in the case of non-compliance, up to and including revocation of the authorization to fish. These penalties should include not only prosecution and fines, but also the ability for a relevant enforcement authority, such as an enforcement aircraft on a surveillance patrol, to order a vessel to port for non-reporting on VMS or failure to manual report in case of a malfunctioning VMS unit.

Conclusion

VMS is an essential tool for fisheries MCS increasingly used by maritime authorities to help combat IUU fishing. It is also a very important tool for effective fisheries management. With the adoption and implementation of effective rules and data-sharing amongst appropriate authorities, vessel monitoring systems can help to detect, deter, and eliminate illegal fishing in the world's oceans. They also can provide fishery managers with information critical to the formation and implementation of effective management measures designed to ensure the long-term sustainability of important fisheries.

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[i] FAO Fishing Technology Service, Fishing operations. 1. Vessel monitoring systems, FAO Technical Guidelines for Responsible Fisheries, No. 1, Suppl. 1. Rome, FAO (1998), ftp://ftp.fao.org/docrep/fao/003/w9633e/w9633e00.pdf

[ii] Article 18.3(e) requires "recording and timely reporting of vessel position, catch of target and non-target species, fishing effort and other relevant fisheries data in accordance with sub-regional, regional and global standards for collection of such data" pursuant to Article 18(e). Article 18.3(g)(iii) mandates flag states to conduct monitoring, control and surveillance (MCS) of their vessels by, inter alia, "the development and implementation of vessel monitoring systems [VMS], including, as appropriate, satellite transmitter systems, in accordance with any national programmes and those which have been sub-regionally, regionally or globally agreed among the States concerned." Annex I provides standard requirements for the collection of provision of data, including on vessel positioning and fishing activity.