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EXPERT CONSULTATION ON DATA FORMATS AND PROCEDURES FOR MONITORING, CONTROL AND SURVEILLANCE

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VMS REPORTING PROCEDURES

1. At the current state of the art, a fishing vessel monitoring system (VMS) is a "cooperative" system where only participating vessels are monitored. It is "cooperative" because each participating vessel must carry an operating VMS unit (transmitter or transceiver) that is capable of fixing a position (in most cases, calculating its own position and, thus, the position of the boat carrying it). An automated reporting system then controls the transmission of the position data and possibly other data via a communication system to a monitoring station.

2. The transmitter or transceiver must have an integrated means of fixing a position and, hence, calculating speed and course. The Global Positioning System (GPS) used so successfully by the fishing industry is the generally preferred method because of its high level of accuracy, availability and relatively low equipment cost. The automated reporting system achieves its purpose through a combination of computerized instructions in the transmitter and functions available in the communication system. The automated reporting system is capable of being programmed to send position reports at specified times or time intervals.

3. The communication system moves data between the shipboard equipment and the monitoring authority. This may involve the use of a satellite, but not necessarily. Many tracking applications for land based vehicles use cellular phone or HF radio. China is trialing a VMS which uses Single Side Band radio as part of the communication system, and a similar system was successfully tested in Hawaii (USA) in the early 1990s. For the monitoring, control and surveillance (MCS) of fishing vessels, however, satellite based communication systems are considered the most suitable since they have the advantages of global coverage and high reliability.

4. In a satellite based communication system, data are transferred from the vessel, to a satellite and then to an earth station. The earth station then forwards the data to the monitoring authority via a secure public data network or the telephone network using an international standard data communications protocol such as X.25 or the Internet's TCP/IP. When using the Internet for such transmissions, employing data encryption is necessary to compensate for security weaknesses.

5. Within a fisheries monitoring agency, there must be a computerized monitoring station to:

   - collect the data received from the earth station;
   - validate the data;
   - store and protect that data so that integrity is maintained;
   - analyze the data to detect and highlight exceptions or other conditions of interest to monitoring officers; and
   - display those data in a meaningful way, typically against a background map.

6. This makes the VMS monitoring station a specialized geographical information system (GIS) for the historical and statistical analysis of positions, and potentially other information such as catch and effort data.

Satellite Communication Systems

Principles

7. Satellite communication systems relevant to fisheries MCS use satellites that are either geostationary or orbiting. With a geostationary system, the satellite remains in a fixed position relative to a given geographical location (the satellite is actually in a fixed orbit and moves in a consistent relationship to the earth). With this type of system, the satellite can receive and transmit messages to any transmitter or transceiver that is within the fixed geographical area visible to the satellite, all of the time.

8. A communication system based on geostationary satellites may have more than one satellite to cover a larger percentage of the earth's surface. An orbiting communication satellite moves in an orbit such that it passes overhead of a given geographical location at periodic time intervals. Such a system means that earthbound transmitters or transceivers come into a satellite's range at these periodic time intervals and transmit or receive only while the satellite is in range or "visible."

9. The transmitter may store messages until the satellite is in range. When messages are transmitted to the satellite, they may also be stored in the satellite until the satellite comes into range of a receiving earth station. Unlike a geostationary system, a single satellite can feasibly cover the whole of the earth's surface. There will, however, be time gaps in coverage when the satellite is not in view of given geographical locations. Increasing the number of satellites will increase the coverage of the system by decreasing the time gaps when a satellite is not in view of a given location.

10. In each type of system, a fixed or mobile transmitter can be used. Such a transmitter is mounted on a vessel, aircraft, building, etc. and uses a radio signal to send a message to the satellite mounted transponder. The message can be stored in the satellite for later forwarding or immediately forwarded to a receiver or transmitter with a receiving capability (transceiver) mounted on another vessel, aircraft, building, etc. In some cases the receiving station will be a large fixed "land earth station," which will link to the normal terrestrial telephone system.

Factors Affecting Performance

11. The performance of a satellite system is primarily related to the type and strength of radio signals used between the vessel-mounted transmitter and the satellite. The power available in the satellite and the extent to which the satellite can focus on a geographical area are interrelated factors, and determine the size and power requirements of the vessel transmitter and receiver.

12. The type of radio signals used by transmitters relevant to fisheries MCS is usually within the microwave band and, as such, are reliable and relatively low-powered. The signal is not greatly affected by atmospheric conditions.

System Descriptions

13. The communication systems used for fisheries MCS are primarily Inmarsat and Argos. Detailed system descriptions are available from the suppliers and will not be documented here other than in the very broadest terms.

Inmarsat

14. Inmarsat is a communication system that has four operational geostationary satellites. One each is mounted over the Pacific and Indian Oceans and a further two cover the Atlantic Ocean. This provides almost universal coverage because the satellites are all close to the equator and have overlapping regions of coverage around the globe. Coverage of the polar regions is not possible because the satellites' altitude above the earth's surface means that the polar regions are not visible. The area of non-coverage is south of 75 degrees South latitude and north of 75 degrees North latitude.

15. Inmarsat offers a number of different types of service formats using the same satellites. Many large vessels use Inmarsat-A or its digital successor, Inmarsat-B, and Inmarsat has recently inaugurated a new service called Inmarsat Fleet. These formats include voice, facsimile and high speed data transmission in both send and receive modes. Inmarsat-A or B effectively provide an "end to end," or duplex, communications medium similar to a telephone connection where the sender and receiver are in almost immediate real time contact. Inmarsat Fleet provides access to broadband communication services, including Internet access.

16. Inmarsat-M is a smaller and lower speed format but essentially provides similar services to A and B. Inmarsat-A, B and M do not have automated position reporting systems. They provide the equivalent of a telephone line and therefore an "end to end" type of service on which it is possible to build a position reporting system.

17. Inmarsat-C is substantially different from the other formats offered. Inmarsat-C is not an "end to end" system, rather it is a "store and forward" system where the data are not immediately sent all of the way from the sender to the receiver. The message is stored in intermediary locations such as an Inmarsat Land Earth Station (LES) before forwarding to the final recipient. Typically, the transmission time will be less than five minutes. This is inappropriate for voice communications, but it is most appropriate and less costly for Email, fax and telex messages.

18. Free-format messages are sent in a mode called the message reporting mode. Inmarsat-C goes further and offers a very inexpensive mode for very small messages. This is called the data-reporting mode and allows for transmission of 16-bit packets of data.

19. Inmarsat-C, by definition of the Inmarsat organization, includes an automatic reporting system making it highly suitable as an off-the-shelf monitoring system in both land and maritime applications. The transceiver can be programmed to report at set time intervals. Programming of the time intervals can be done remotely from a monitoring station via the satellite communication system. The transceiver can receive and process other commands such as a request to send the current position of the vessel immediately. Position fixing is done using a GPS receiver integrated into the Inmarsat-C transceiver.

Argos

20. The Argos system is based on the use of dedicated communication subsystems carried aboard two National Oceanic and Atmospheric Administration (NOAA, USA) satellites that are in polar orbits. A variety of transmitters are available for use with Argos in mobile tracking applications. The system normally operates in send only mode, that is from ship to shore. Shore-to-ship mode is now available on one of the Argos satellites.

21. Argos is a store-and-forward system with messages being sent from the ship-based transmitter stored in the satellite until an Argos ground station is in view. Messages are also stored in various Argos processing centres for convenient distribution around the world.

22. Argos is GPS-capable and has an automated position reporting system. GPS positions are fixed at predetermined time intervals within the equipment on board the vessel and are transmitted when the satellite comes into view. The satellite is also capable of fixing a position using a Doppler shift method based on a signal sent from the Argos transmitter on board the vessel.

Security

23. Security is a factor when selecting a satellite service provider and equipment types. The issue of security is not covered here other than to say that the satellite systems offer varying levels of security and none is immune from possible security breaches. The level of security available, however, is reasonable and in most systems breaching security would require a high level of expenditure and/or technical knowledge. Each user agency should make its own assessment of its security requirements. In some circumstances, it may be wise to add data encryption to achieve a higher level of protection.

User Friendliness

24. Installation of transmitters and transceivers is relatively simple, but is best done by trained technicians such as may be found in many commercial shipping supply businesses. Professional installation is often required by fishery management authorities. Operation of the equipment is relatively simple with guidance from the user manuals and the equipment supplier representatives. It should be noted, however, that operator language skills and computer literacy can be obstacles in some fisheries and regions.

25. The position-reporting function of a VMS unit usually requires no input from the vessel operator, but a catch and effort reporting function, or other ancillary requirements for data input, require significant training and documentation for operators.

26. Competent instruction will be required where equipment is also used for safety purposes such as part of the Global Maritime Distress and Safety System (GMDSS).

27. On the monitoring station end of the system, the level of user friendliness will be determined by the system interface provided by the satellite service provider and the facilities provided by the software used in the monitoring station. Both are increasing in ease of use and are within the capability of most fisheries monitoring agencies given some guidance from supplier representatives.

Message Formats and Protocols

Position Reports

28. Each satellite communication system has its own established standard for transporting position information to a monitoring agency. The particular format may be necessitated by the need to minimize the size of the message during transit. Given that the number of communication systems relevant to VMS remains small, it will not be a major problem for monitoring agencies to receive all of the different formats and decode them to a common format for analysis and storage.

29. The situation is similar in regard to the communications protocol used to deliver position reports to a monitoring agency. Most satellite communication systems provide a variety of interfaces to terrestrial transmission systems.

International Data Exchange Formats and Protocols

30. Exchanging VMS data between national monitoring agencies is foreshadowed in international agreements and is currently operational within the European Union. A standard format, generally referred to as the North Atlantic Format, has been agreed for this purpose. The data are transmitted using the X.25 network (though the more general tendency for terrestrial data transmission is to use the Internet, counteracting its security weaknesses with encryption). Such agreed standards enable monitoring station software providers to develop software that would provide the ability to exchange position data more easily between agencies.

31. The alternative would be that each national or regional system would decide its own format and protocol and every other agency exchanging data with that agency would likely have to support that format and protocol.

Positioning Systems

Principles of Operation

32. Radio navigation systems have been in place for many years. These use intersection techniques. In a radio direction-finding system, the user tunes to two radio stations of known locations and takes a bearing of each using a directional antenna. The point of intersection of the bearings gives the user's position. In a hyperbolic system, a pair of radio stations transmits signals such that the points where the difference between the signals is constant, forms a hyperbola. Using radio equipment, a user can then identify his or her location as somewhere on a particular hyperbola. Repeating this process with a second pair of radio stations, the user can then determine his or her position accurately as the point where the two hyperbolae intersect.

33. These systems are of limited use for global navigation, as their coverage is generally limited to coastal areas where chains of radio stations exist. Satellite systems have

emerged to provide accurate worldwide positioning. The most common system is the USA's NAVSTAR system. Russia has a similar system called GLONASS, and the European Union is in the process of developing a system called Galileo. These systems work using similar principles to other radio navigation systems, but because the radio stations are satellite mounted, global coverage can be achieved.

34. The NAVSTAR and GLONASS system use the principle of triangulation. A satellite transmits a signal that a user's receiver can use to determine how far the receiver is from the satellite. This places the receiver as somewhere on a sphere (all points equidistant from the satellite). With two satellites the receiver can be placed on the circle formed by the intersection of the two spheres. With three satellites the receiver can be placed at two points formed by the intersection of the three spheres. Usually one of these points will be impossible or ridiculous, so a conclusion about position can be made accurately. A fourth satellite completely assures a specific single location fix in three dimensions: latitude, longitude and altitude. Of course, the position of the satellite must be known to the receiver. Details of satellite orbits are programmed into the receiver (its almanac) and the satellite itself transmits its own position and status data that the receiver can use.

35. Another common satellite position method is based on measuring the Doppler shift in the frequency of a radio signal from or to an orbiting satellite as it moves past the user. Small movements in the frequency of the radio signal will be apparent to the receiver resulting from relative movement towards or away from the transmitter. So long as the position of the satellite is known then a position can be fixed.

NAVSTAR GPS

36. The most commonly used positioning system in all maritime usage is the NAVSTAR Global Position System usually referred to simply as GPS. This system uses a constellation of 24 satellites maintained and operated by the US Department of Defense. With this number of satellites, the required three or four will be visible to a user anywhere on the globe. While GPS does have military purposes, it is freely available for use by anyone who purchases a GPS receiver. Such receivers come in many different forms, even hand-held units, and are inexpensive.

37. Land, sea and airborne users can determine their three dimensional position accurately. In regard to latitude and longitude it is possible to determine a position to within a few meters most of the time. Accuracy to within one meter can be achieved using differential GPS where errors inherent in the system can be accounted for and compensations made if the user's GPS receiver has access to a current GPS position fix from a known fixed reference point which is in the same general vicinity of the user GPS receiver. Differential GPS accuracy is not usually required for fisheries MCS.

Argos

38. Aside from GPS, the Argos system is currently the only other positioning system of global significance for fisheries MCS. The Argos system has both a satellite communications and a positioning-fixing capability. The latest versions of Argos transmitters contain a GPS receiver that allows GPS positions to be fixed, stored and transmitted. The Argos system can, however, also fix a position using the Doppler shift method. The Argos transmitter on board the fishing vessel transmits a constant radio signal which one of the two orbiting satellites can use to fix the position of the transmitter as the satellite moves relative to the transmitter.

39. The Doppler shift method of position fixing is inherently less accurate than GPS. The Argos Doppler shift system can provide accuracy to within 500 m most of the time. As the Argos Doppler positions are calculated at an earth station, rather than aboard the vessel, they are essentially tamper-proof. Furthermore, taken together with GPS positions, they provide a useful verification tool.

Positioning System Usage

40. The use of positioning systems is inherent in the VMS application. The positioning system must be outside of the control of the vessel operator, and its operation should be fully automated.

41. For a monitoring agency, there are certain issues to bear in mind with respect to positioning systems. One is to understand that there is some small error in the position fixing system as outlined above, and that further error is possible through the degree of precision of each communication system's position report format. These factors combine to reduce the accuracy of most systems. For example, Inmarsat-C position reports are accurate to about 70 m.

42. A further issue for monitoring agencies is in correlating positions to charts. Firstly, it is important to recognize that charts may be inaccurate. Secondly, some inaccuracy may be introduced if the chart is not based on the same geodetic datum as the positions supplied from VMS position fixing system. A geodetic datum is a standard reference system for defining geographical positions on the earth's surface. The current datum used for GPS is the World Geodetic System 1984 (WGS 84), but charts worldwide commonly use different datum systems, potentially resulting in differences in surface distances of up to several hundred metres.

Other Uses of Satellite Communication Systems

43. The primary purpose of a satellite communication system used in a VMS is to enable the activities of fishing vessels to be monitored. The presence of the VMS equipment on board the vessel, however, can offer other benefits arising from use of the equipment for purposes other than monitoring fishing activity. The beneficiary of these uses is mostly the vessel operator. This is important because it may help to justify the cost of VMS for the operators (if the operator is required to pay for the system). The main uses of the equipment other than for VMS are the ability to use it for communications and safety.

Messaging

44. The master of a vessel may use a VMS transmitter to send messages to a fisheries monitoring agency, the fishing company, family, and just about anyone else with access to the terrestrial telephone network. The purpose of such communication will be widely varied and may be related to fishing, the weather, safety or simply a personal matter.

45. In systems with transceivers that offer the capability to receive as well as send, it will be possible to exchange messages in both directions with other vessels and shore- based organizations and people.

46. Prior to fitting a VMS unit, most fishing vessels will already have one or more communication systems on board. The VMS transmitter or transceiver adds an additional system that is probably more reliable and secure than existing systems. It will also offer

the wider range inherent with a global satellite system and may be less expensive to operate in some circumstances.

Safety

47. The tracking of a fishing vessel to monitor fishing activity is in itself a safety advantage as it may facilitate finding the vessel or survivors in an emergency search and rescue operation. It can also identify vessels close to distress sites and allow them to be directed to such sites to render assistance.

48. In some equipment, such as Inmarsat-C transceivers, further safety advantages are available. Information on weather and sea conditions can be received. The transceivers may also provide emergency distress alerting so that an emergency can be signalled to a search and rescue organization along with an accurate position of the distress site. Such transceivers may be compliant with the requirements of the Global Maritime Distress and Safety System (GMDSS), a specification set out under the auspices of the International Maritime Organization (IMO).

49. The GMDSS specifies the requirements of an international sea safety system including the type of equipment carried, procedures for use, and the responsibilities of vessel operators and national safety authorities. Some requirements of GMDSS may be met by carrying transceivers that can also be used for fisheries monitoring, although this is not guaranteed unless GMDSS installation standards and configurations are used.

50. The Safety of Life at Sea Convention (SOLAS) is an agreement that also relates to sea safety. Since 1999, SOLAS has increased the level of safety requirements that apply to fishing vessels of more than 300 gross registered tonnes. The SOLAS Convention requires the presence of GMDSS compliant transceivers on board such vessels.

Monitoring Control Centres and Facilities

51. Within a fishery management agency, a monitoring control centre may already exist or should be established to provide a secure environment for the VMS monitoring station. The VMS monitoring station will consist of a at least computer with a suitable colour display screen and adequate disk space, a connection (e.g., Internet connection, telephone modem or X.25 PAD) for accessing data from a communication service provider, and a printer. Supporting hardware and software applications must operate at an acceptable performance level.

52. Monitoring station capabilities vary with the communications, data handling and analysis requirements of each fishery management agency.

Communications

53. The monitoring station must be capable of receiving position reports from the communication service provider, or providers if more than one is permitted. Typically, data will be transferred across this link using X.25, voice band data or Internet protocols such as TCP/IP. Other protocols are possible.

54. The monitoring station may optionally have the capability of distributing data. For example, in some circumstances it may be necessary to send position data to remote monitoring stations in another country, another region, or on board a patrol aircraft or vessel. Communication requirements for this function will depend on the nature or the

recipient and the amount of data. Many communication protocols and systems are available for these purposes.

55. Encryption of data may be required for data both entering and leaving a monitoring station, depending on the security requirements of the agency.

Hardware Requirements

56. The size and capability of the monitoring station computer will vary depending upon the requirements of the monitoring agency and the monitoring software being used. There are a number of commercial off-the-shelf fisheries monitoring packages available internationally. Many of these are capable of being run on small computers such as PCs running Microsoft Windows. Nonetheless, most recent installations tend to use more powerful servers to manage the growing software requirements of VMS and to assure sufficient headroom for a system to evolve.

Data Storage

57. VMS position data are useful for analyses of vessel activities in an historical sense. The data should be stored for this purpose preferably in an organized manner such as in a database management system. The data should be available for display or for other analysis or cross-referencing against data from other sources. Commercially available Geographical Information System (GIS) software packages may be useful for this purpose. It is essential that, if VMS data are to be used in a legal context such as the prosecution of the vessel, strict measures be taken to assure integrity against inadvertent or intentional modifications.

User Interface and Data Display

58. Monitoring personnel need to interpret the activities of vessels through observation of positions, usually against a background map. Thus, it is important to provide a user-friendly interface to the functions of the display station and for the general management of the monitoring station. This will usually be done with a graphical user interface, e.g. Microsoft Windows. A GIS capability may be useful as many of the functions will relate to geographical areas.

59. Many display features and user functions are provided in commercial monitoring software packages. Demonstration and evaluation are the best means of establishing the most suitable set of features.

Analyses

60. The monitoring station should facilitate the analysis of incoming VMS data, and monitor the data in comparison with the authority’s expectations. There will be a substantial amount of data received even when monitoring a small number of vessels, so it is desirable for the computer to identify “events” which may be of interest to a monitoring officer. The types of events include, but are not limited to:

- vessel failing to report on schedule;
- vessel reporting a position which is not consistent or credible, compared to expectations or to previously received reports;
- vessel entering or leaving a defined geographical area;

- vessel travelling at, above or below a given speed;
- VMS transmitter power down, power up or power interruption; or
- detected interference with the operation of the unit (e.g. antenna obstructed).

61. Sophisticated VMS software may be capable of detecting complex events which might be a combination of those referred to above, e.g. a vessel of a particular type, travelling below a given speed in a defined geographical area.