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Report of Fishing Industry Science Alliance (FISA) Project 04/12

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This report presents the results of marine and freshwater scientific work carried out for Marine Scotland under external commission.

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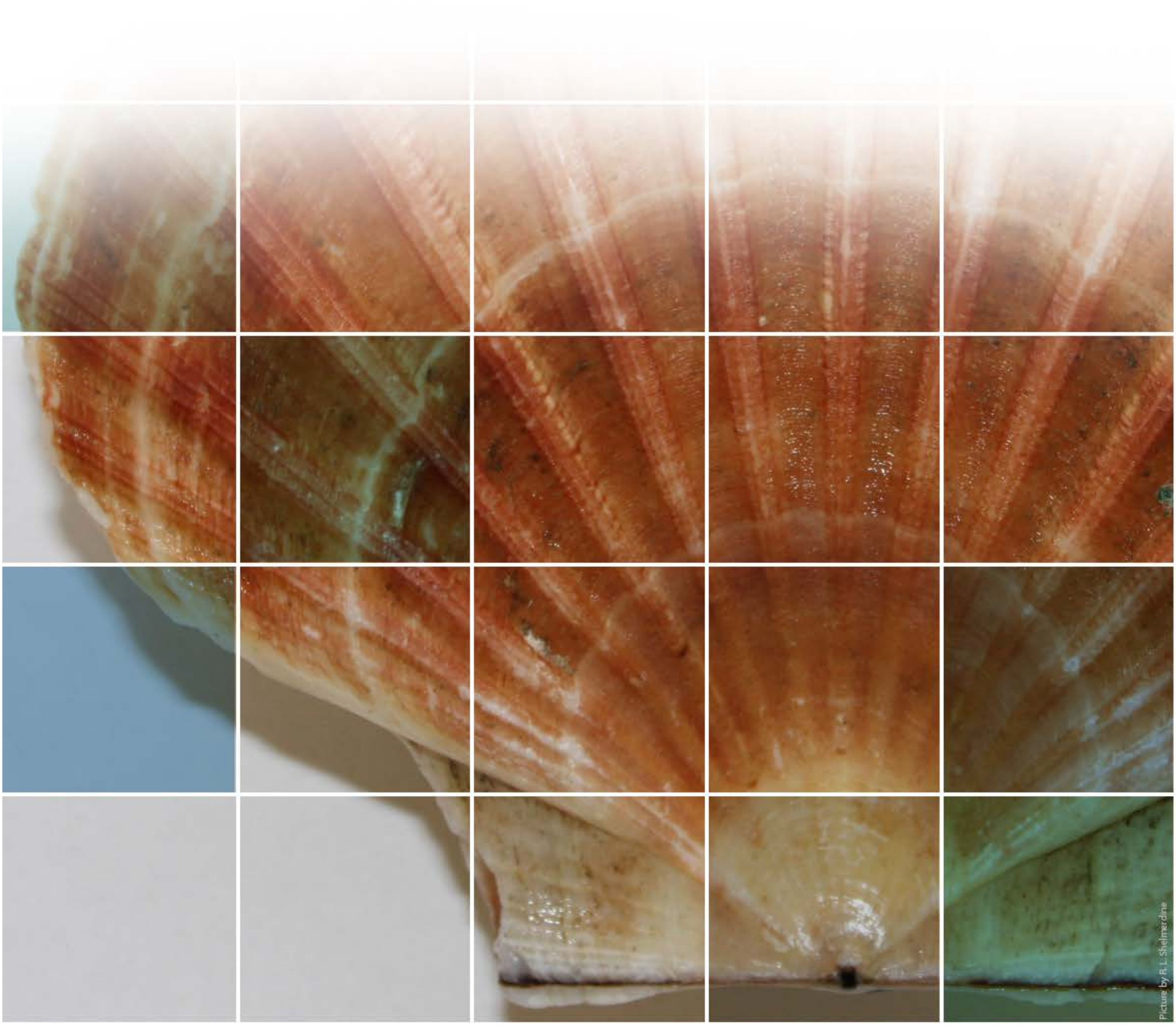

A multidisciplinary approach to collection and use of VMS data from an inshore scallop fishery

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1 Introduction

The Shetland Shellfish Management Organisation (SSMO) manages the shellfish fishery around Shetland, out to the six nautical mile limit, under the Shetland Islands Regulated Fishery (Scotland) Order which has been in operation since 2000. The Regulating Order covers several commercially fished shellfish species including the king scallop (*Pecten maximus*) and includes powers for the SSMO to restrict access to potential fishing grounds on a temporary or permanent basis. Management measures must be approved by Scottish Government ministers depending on the scale and legislative requirements.

During 2010 the SSMO, following consultation with local fishermen, proposed a set of 22 voluntary closed areas to scallop dredging activity to help eliminate any possibility of interaction with protected habitats, namely horse mussel (*Modiolus modiolus*) and maerl beds, found within six nautical miles of Shetland. *Modiolus modiolus* and maerl beds have been identified as being threatened and requiring conservation under the UK Biodiversity Action Plan (UK BAP). They are also listed as OSPAR habitats and as Annex I habitats under the EU Habitats Directive. The location of each proposed closed area was initially based on historical point records and 'predicted species bed' data of *M. modiolus*, maerl, and *Zostera* from various sources and agencies which had been combined and collated in the Shetland Islands' Marine Spatial Plan (NAFC Marine Centre, 2014). Surveys were then carried out at each area in order to determine the presence of any protected habitat, quantify the scale of that habitat, and refine the closed area boundaries (Shelmerdine, *et al.*, 2013; Shelmerdine, *et al.*, 2014). As a result of this work, the refined closed areas were legalised and came into force in 2011. In March 2012, the Shetland scallop dredge fishery was awarded Marine Stewardship Council (MSC) accreditation.

Vessel Monitoring System, or VMS, is the generic name given to a satellite-based monitoring system which provides information on fishing vessels' speed, course, and location. In Scotland, each data package (termed 'ping') is sent to a land-based receiver station via satellite every two hours. It was first used to monitor fisheries by the European Union (EU) in 2000 and is now considered a standard tool to monitor fisheries worldwide. All fishing vessels greater than 12 m in length are legally required, under EC Regulation 2244/2003 and Scottish Statutory Instrument (SI) 392/2004, to have a working VMS unit, of a specific type fitted[1]. This covers a small portion of the inshore shellfish fleet in Shetland but would not provide an adequate resolution, at the current two hour reporting period, to determine for example if a vessel fished within a closed area. Skaar*, et al.* (2011) showed that with a two hour reporting interval, a maximum variation of 8 km was recorded between the actual vessel track and the VMS pings. Such a large variation could have a significant impact when looking at inshore vessel movements which can operate very close to shore with the majority of fishing activity lasting less than the two hour ping period. Using VMS to map fisheries is not a new concept (for examples see Witt and Godley, 2007; Pedersen*, et al.*, 2009; Bastardie*, et al.*, 2010; Campbell*, et al.*, 2014) but all these studies focussed on the offshore fishery using a ping period of one to two hours. A more regular ping rate would be required in the inshore fishery for VMS to be a useful tool for fisheries managers in order for them to effectively maintain sustainable inshore fisheries. Understanding the movements and activity of the inshore fishing fleet in Shetland and Scotland, information which has historically not been present, will provide valuable information on any potential interaction between identified and protected habitats with fishing gear. The information produced could also aid fishery managers in informing spatial management measures for the fishery, could be incorporated into the stock assessment process, and has the potential to feed into marine spatial planning decisions.

1.1 Aims

The main aim of this work was to trial the use of Succorfish's SC2 VMS tracking technology on vessels from the inshore scallop dredge fleet around Shetland and to evaluate its effectiveness as a tool for informing management decisions and protecting the environment, specifically looking at:

- Is the equipment suitable for use in inshore vessels?
- Is reporting via mobile phone signal an appropriate methodology in areas where there is poor mobile coverage?
- Is the quality of data sufficient to support spatial management of shellfish fisheries?
- Will the data outputs be useful for incorporation in shellfish stock assessment?
- What are the potential uses of such data in Marine Spatial Planning?

[1] Thrane & Thrane 3026M (Mini-C) VMS unit is the only approved unit for UK fishing vessels greater than 12 m in length.

2 Materials and Methods

2.1 Units and Installation

The Succorfish SC2 VMS (hereafter referred to as "VMS") unit is a single box with no external antenna which is hard-wired to the vessel. The units incorporate dual Iridium satellite and GPS/GPRS/GSM mobile technology to provide accurate positioning to within two metres. Outputs from the unit for each ping include; vessel name, position, generated date and time of ping, speed, course, whether a satellite was overhead at the time of the ping, and the date and time the ping was received. The unit calculates instantaneous speed for each ping and then assigns a 'speed bin value' in knots starting at 0 knots with incremental increases of 2 knots thereafter. These 'speed bin values' are what is exported by the system.

VMS units were offered to fishermen on a voluntary basis with the most active scallop dredge vessels approached for inclusion in the project. There were 36 SSMO licenced vessels which fished for scallops, all of whom were written to regarding the project and its aims. Of these, 23 make the majority of landings and these vessels were actively approached to have units fitted. The first unit was fitted in Shetland in April 2013 with a total of fifteen VMS units fitted throughout the period of the project. A data sharing agreement (Appendix 1: Data Sharing Agreement) between the NAFC Marine Centre and each SSMO licence holder participating in the study was carried out in order to provide the fishermen with security as to how and when their data would be used. Fishermen were also provided with log in details for the Succorfish online database (see Section 2.2) so that they could view their own activity online.

Initially the units were set to report every three minutes but this was later changed to every ten minutes with locational information stored in a secure database and accessed via the internet. The change in ping frequency from three to ten minutes was an operational decision in order to maximise the quantity of information relevant to the vessel activity and the aims of the project without losing valuable information on fishing activity. Pings were transmitted via satellite but in the event of no satellite coverage, the units stored the information until it was possible to re-transmit the data. This eliminated any information loss due to loss of signal.

2.2 Database

The Succorfish secure online database provided several screens of information with the main screen, the 'Dashboard', summarising events from each VMS unit. Summaries included all vessels not reporting, power and tamper events, and any "Broken Geofences" (a user defined area, e.g. areas closed to fishing). In addition, the database contained information on the 'Assets' (vessel information), 'Monitoring' (the map interface), and an 'Administration' section. Monitoring provided real time map displays of vessel locations which could be back dated by two days. In addition, it was possible to select specific geofences for display providing real-time and short-term historical views on vessel movements and potential interactions with closed areas (geofences).

2.2.1 Data Export

Exporting the data was carried out through the Administration section of the database using a user friendly interface with the ability of selecting specific vessels and time periods. The default export related to each vessels' coordinates and the data was exported as a comma separated (*.csv) file. Each export contained eight fields per ping corresponding with the vessel's name, generated date and time, coordinates, speed, course, whether a satellite was overhead at the time, and a received date and time (see also Section 2.1).

Additional exports were also possible and included:

- geofence breaches,
- any events listed (e.g. low battery, tamper events, etc),
- instances of units not reporting.

2.3 Data Processing

After the initial database export, a simple transformation could be applied to the csv file allowing a point shapefile to be created and used in ArcGIS. However, this information provided details on the vessels' distribution showing all movements including steaming and dredging, as well as all types of fishing (e.g. scallop dredging, squid or finfish trawling, etc). Although the original export contained information on a vessel's speed, the value exported was assigned a specific number (a data bin which had an incremental increase of two knots per bin, see also Section 2.1) rather than a calculated speed between pings. In order to obtain good quality information on whether a vessel was fishing or not, additional processing was required in Excel and the mapping package ArcGIS. Additional processing increased the reliability of the data and enabled vessel tracks to be incorporated onto a map which added an extra level of quality control and interpretation.

The exported csv file was converted to a point shapefile in ArcCatalog. In order to obtain more detailed information between consecutive pings to better evaluate vessel activity, additional fields were calculated. Using the Tracking Analyst extension and the tool “Track Intervals To Features”, four additional fields were calculated between consecutive pings for distance, duration, speed, and course. The calculations were based on a formatted time stamp and subdivided by vessel name. This data was exported from ArcCatalog and saved as an Excel file.

Two additional columns were created in the Excel file titled “Activity” and “Curfew”. Vessel activity was categorized, based on the above calculated vessel speed as; “Stopped” (≤0.5 knots), “Fishing” (between 0.5 and 2.5 knots), or “Steaming” (>2.5 knots). If the predicted activity was “Fishing” outside the curfew hours of 6 a.m. to 9 p.m., the text “Check” appeared in the Curfew column. These two columns provided a quick reference to the data but still required a quality control via mapping in ArcGIS. The processed information was converted to a shapefile and vessel track lines were created, using the Tracking Analyst extension, which created a straight line between each consecutive ping. By displaying the point data by Activity and combining vessel track information it was easy to identify genuine fishing activity and eliminate any ‘rogue’ values when in port or steaming.

3 Results

3.1 Units and Installation

The length of time taken to fit the units varied depending on the size of the vessel and accessibility within the wheelhouse, however the fitting times were generally in the region of two to three hours. There were often holdups in getting a date for fitting the equipment to the vessel, as this meant that the vessel had to remain ashore, and fishermen prioritised fishing. Organising fitting dates was further compounded by the fact there was only one fitter in Shetland who was very busy. In some cases this lead to a long waiting time for fitting in order to accommodate both the fisher and the fitter. There were several cases where fishermen were in the process of selling their vessel and the units were therefore not fitted until the new vessel was purchased and ready for sea. This process can take several months and in one case was further delayed by damage to a vessel through an engine room fire. A small number of fishermen were unwilling to have the equipment fitted to their vessels as they did not want to share detailed information on their fishing activity. In two cases units were fitted to vessels which had initially responded negatively. In one instance this was due to the licence holder changing their mind and in the other case it was at the request of the SSMO following a replacement vessel application.

Overall the units reported consistently, especially units fitted to the more active vessels. However, after Christmas of the first year (2013) when the vessels remained at the pier for a week or two, many of the units stopped reporting their position. It is believed this was due to low battery power in the units, probably from being installed post isolator, rather than direct to the vessel's battery. By switching everything off aboard the vessel prior to the Christmas break, caused the units to drain their internal battery supply. In response to this, a troubleshooting information leaflet was sent out to all the vessels. However, anecdotal evidence suggested that in one case, where the fitting was direct to the vessels battery, there were issues with excessive battery drain resulting in the vessels battery being replaced.

3.2 Exports and Mapping

Data exported from the database and inputted directly to ArcGIS displayed an instantaneous distribution of vessel activity (Figure 3.1). It was possible to use the speed information from the initial export to give a quick indication of fishing activity based on a speed bin value of two knots (Figure 3.2). When this was compared with the more accurate processed fishing activity (as described in Section 2.3), it was found that the speed calculated by the units and assigned a bin value did slightly overestimate fishing activity in some instances but overall represented scallop dredging activity quite well (Figure 3.3). For the purpose of this report, these maps display a year worth of data but in order to optimise processing efficiency, and to provide management reporting, viewing the data on a monthly basis was found to be more effective.

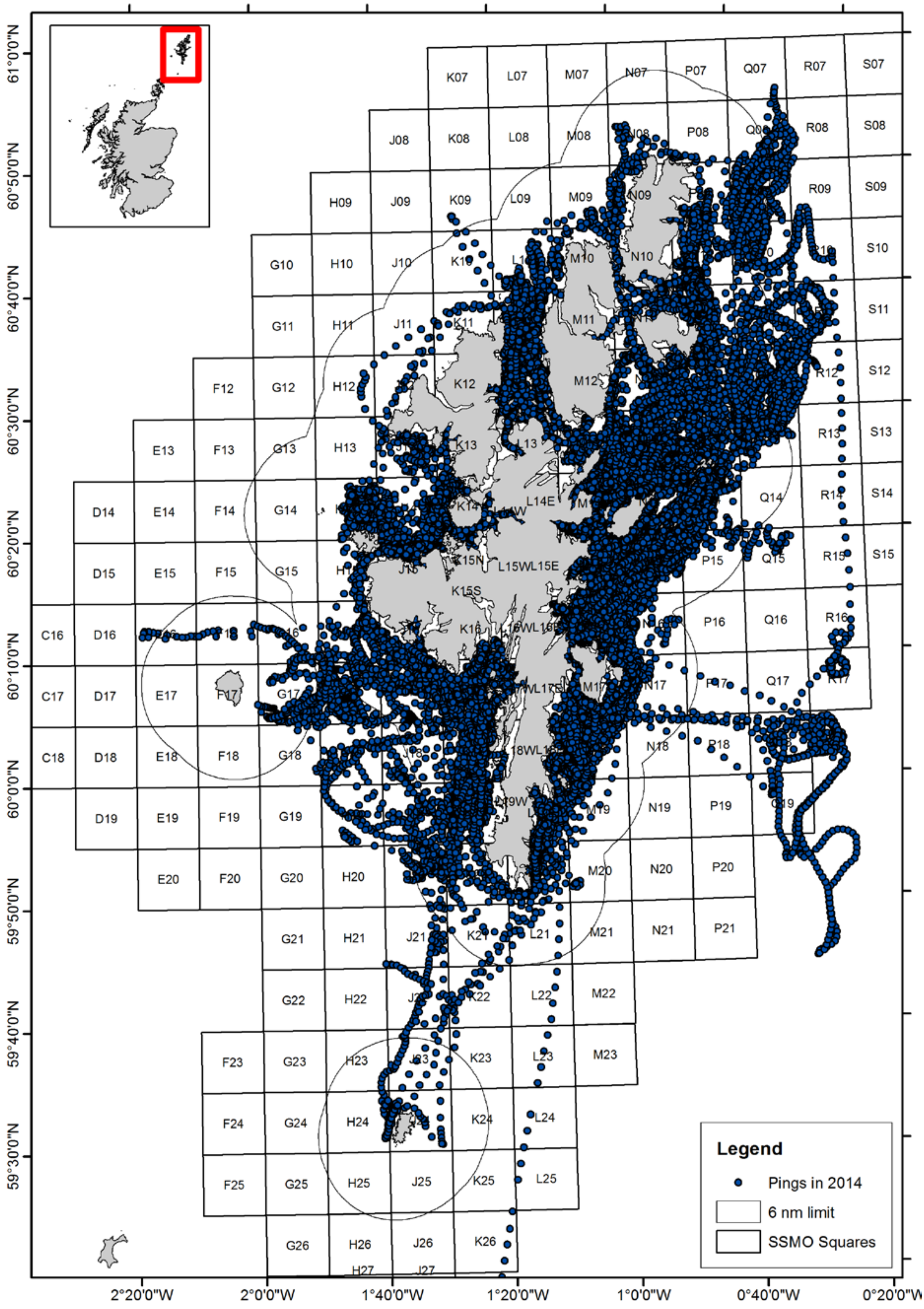

Figure 3.1 Distribution of vessel activity for all VMS pings in 2014.

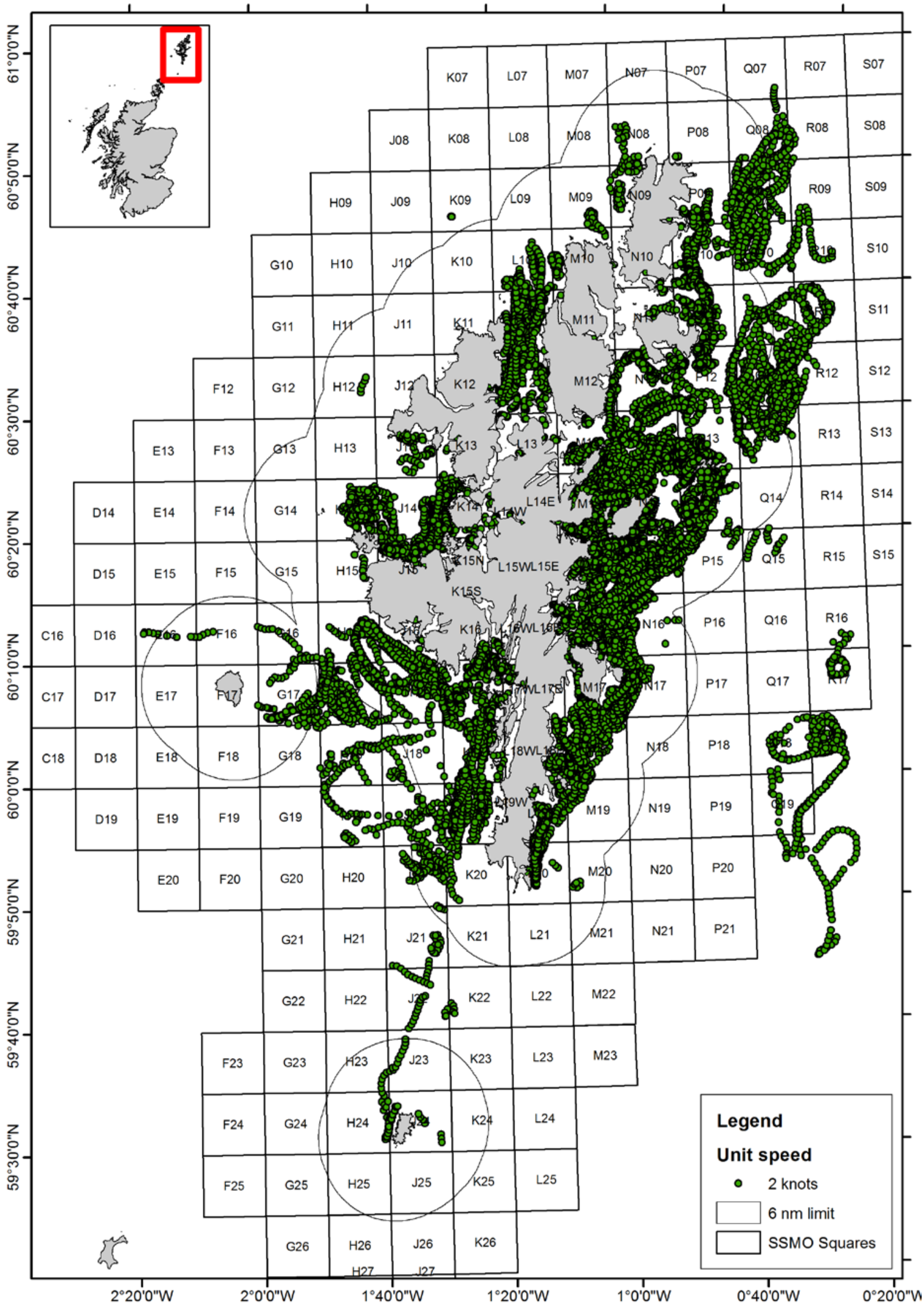

Figure 3.2 An indication of potential fishing activity from the initial data export based on the speed bin of two knots. Information shown is for all fishing types, not just scallop dredging for the whole of 2014.

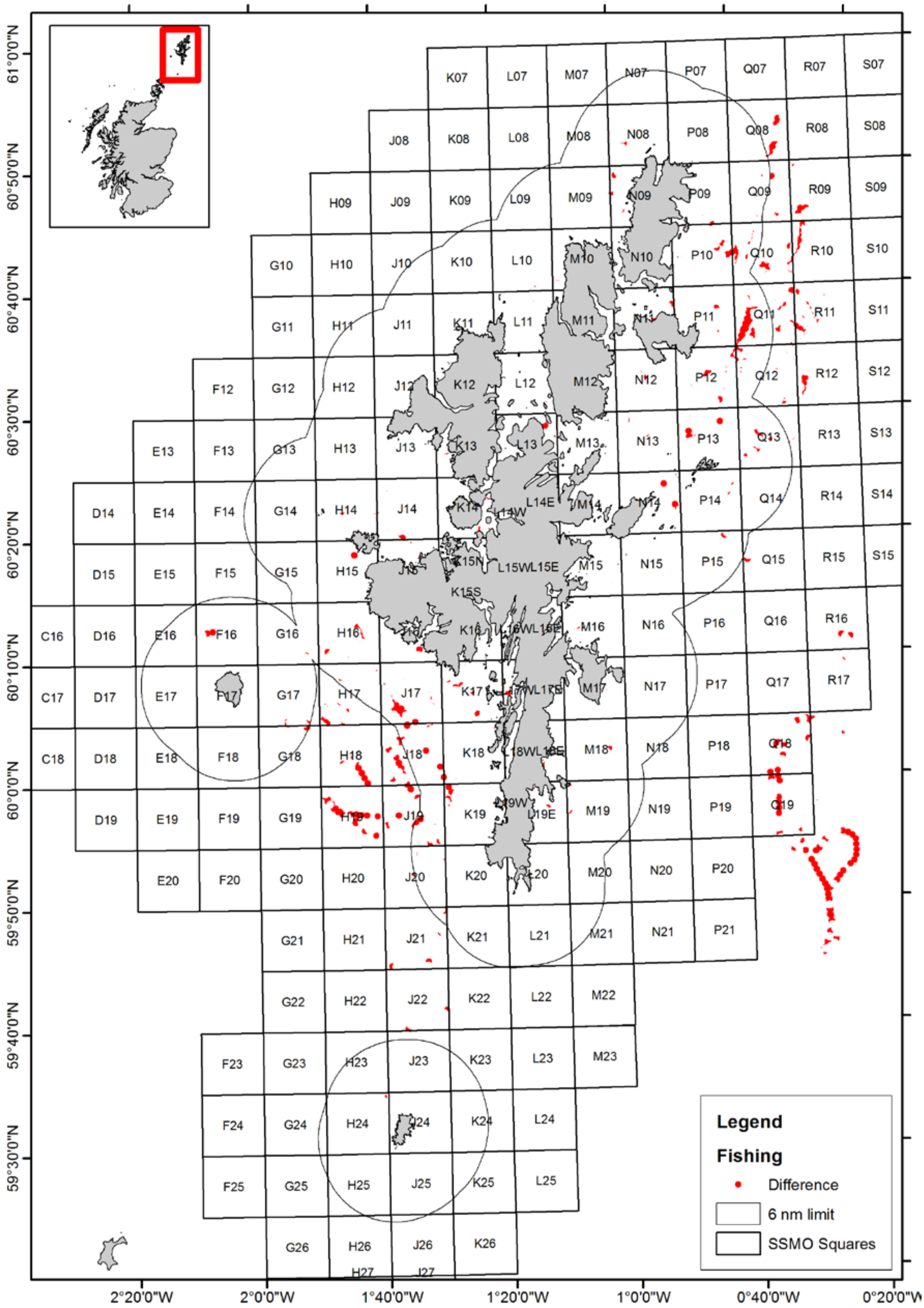

Figure 3.3 Difference in fishing activity between the speed calculated by the VMS unit and the processed speed calculation. Red areas show where the VMS units predicted fishing but the processed data did not.

3.3 Activity Outside Curfew Hours

Post processing in Excel provided a quick and easy way to view any predicted fishing activity outside the curfew hours. The information was displayed as “CHECK” as the curfew only applies to vessels dredging for scallops within the 6 nm limit. All this identified activity needs to be checked against logsheet information in order to determine if the vessel was potentially fishing illegally. This is important since most scallop vessels fish for species other than scallops which do not have restrictions on fishing times. The information is also needed to be mapped in context with vessel track information. This helped eliminate any false positive fishing activity due to slow steaming. Without vessel track information identifying slow steaming, with any confidence, would be nearly impossible.

3.4 Satellite Coverage

During 2014, a total of 243 504 pings (92%) were recorded which were not transmitted immediately, due to no satellite coverage (Figure 3.4). On average, these generated signals were re-transmitted and received two hours 49 minutes later with the greatest difference recorded as 13 hours and 43 minutes between generated and received signals. When a satellite was located overhead, the average time to receive a ping was recorded as two seconds with a maximum receive time of 57 minutes. No information was lost during this process as the units were capable of storing the information during a delayed send.

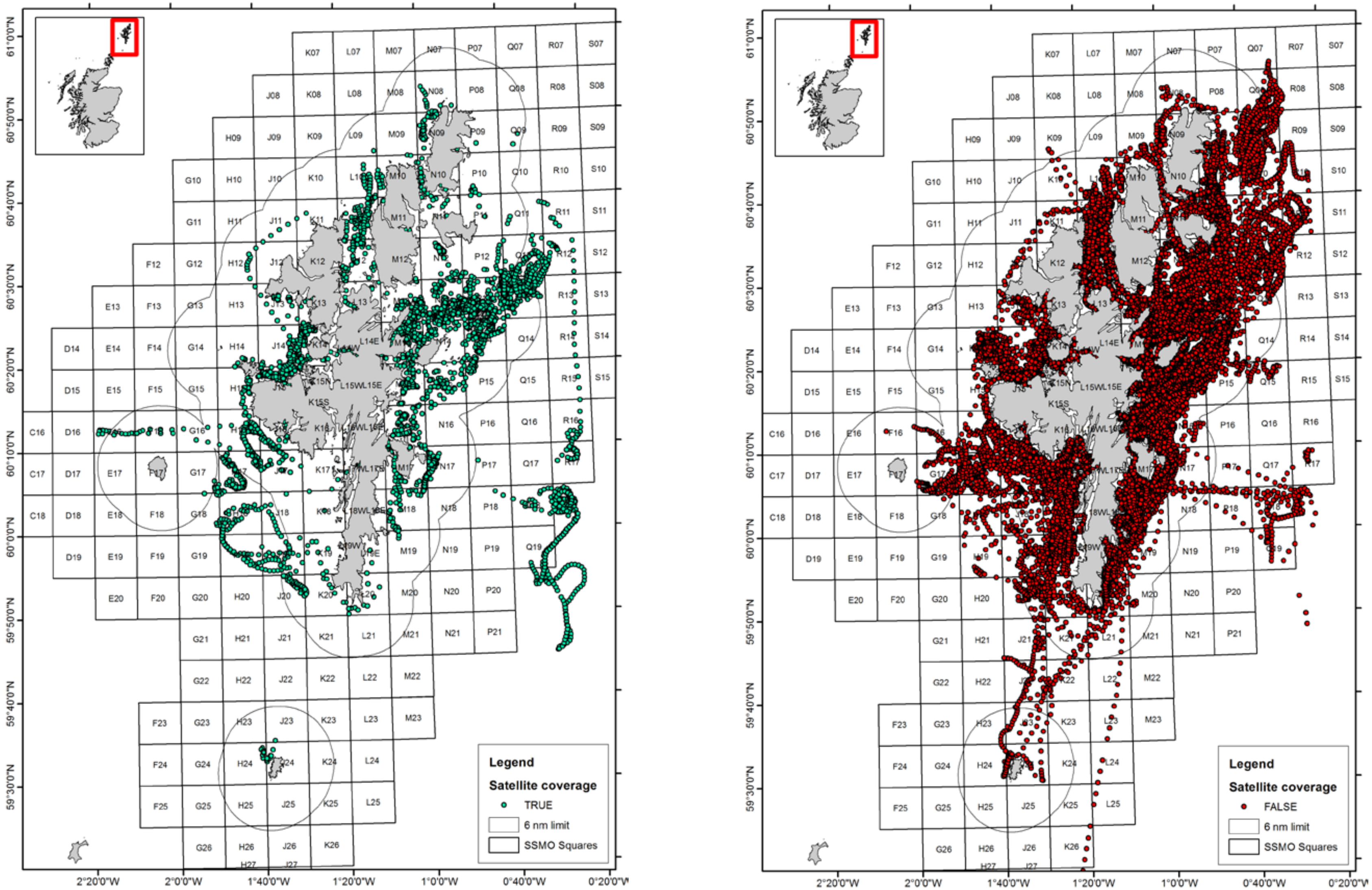

Figure 3.4 Locations of pings sent when a satellite was overhead at the time of the ping (true, green dots) or if the data was delayed due to no satellite coverage (false, red dots).

3.5 Incorporating in Vessel Tracks

Incorporating in vessel tracks to the point data adds an additional level of quality control and clarity to the data (Figure 3.5). Vessel tracks enable easy definition of fishing start and end times in order to assess any curfew infringements as well as differentiating fishing areas and, in some cases, the type of fishing (e.g. scallop dredging or towing for finfish etc.). Without vessel track lines, it would be very time consuming, and in some cases nearly impossible, to determine activity such as when fishing stopped or whether fishing activity occurred within a closed area.

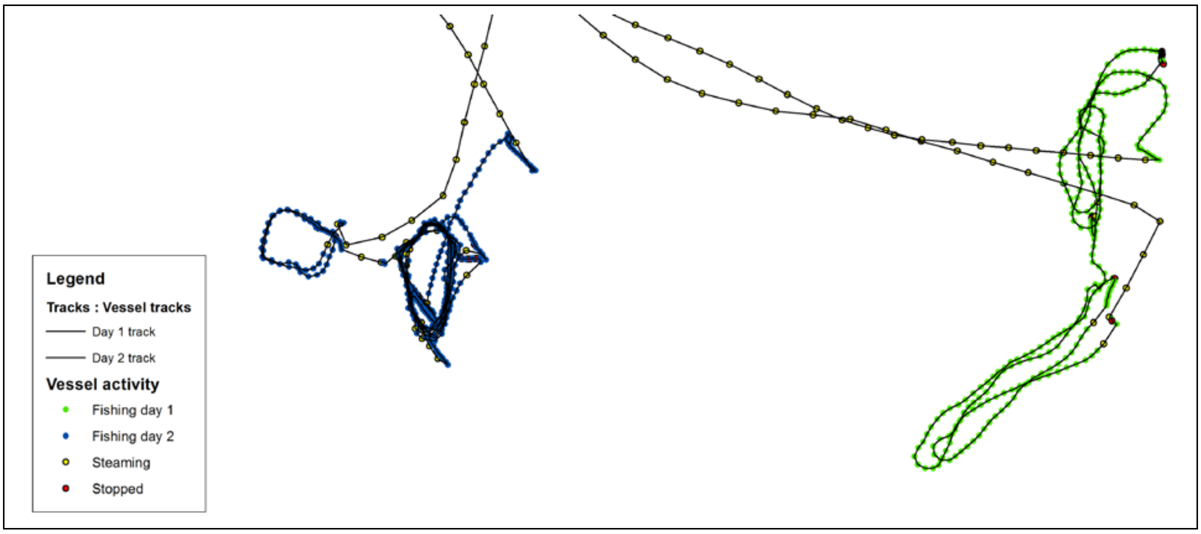

Figure 3.5 Vessel activity over two days showing steaming routes (yellow dots) and fishing (green and blue dots) with the vessel tracks overlaid. Land and sea references were removed to ensure anonymity.

3.6 Broken Geofences

During the course of the study six geofences were reported broken. On investigating the breaches further, one was broken by a vessel fishing for another species (most probably either whitefish or squid), and the rest were broken by vessels in transit through the areas. No closed area had a report of scallop dredge fishing within it by any vessel fitted with a VMS unit.

4 Discussion

This study has clearly demonstrated that Succorfish SC2 VMS units have the potential to operate and deliver high quality data within the inshore environment in remote areas of Shetland. Fishermen were largely positive about the scheme and its benefits both in terms of improved fisheries data for inclusion in stock assessments and marine spatial planning, but also in terms of enforcement of the SSMO regulations.

Entering into a data sharing agreement with fishermen was a valuable exercise as it not only provides them with confidence that their data will only be used for the agreed purpose but also because it sets up a line of communication for any future use of the data. This means that the value of collecting, analysing, and retaining such data can be communicated to fishermen each time they are approached for its future use. This is particularly pertinent in the marine spatial planning context.

4.1 Units

The use of the mobile phone network did not compromise the quality of the data received as the units were found to be able to store and re-send data at a later date without any loss of information (see Section 3.4). In 2014, this applied to 92% of all pings with information being stored on average for nearly three hours before re-sending. The ability to be able to store information for prolonged periods without losing any data is essential in remote locations and when operating close to shore where a signal (satellite or mobile phone) may be obstructed by the local terrain. The use of mobile phone technology is also an important consideration should the fishermen ever be asked to bear the cost of reporting, with mobile phone reporting costing less than a third of the satellite and mobile combination.

Unit reliability was a major initial issue with many units failing to report positional information. The problem was identified as most likely due to the units being installed post isolator causing the internal battery to drain when the main power was switched off for long periods. Succorfish recommend the units are connected direct to the battery but in many cases the fisher did not want this in case the unit drained the vessel's power supply. Each unit is rated as drawing on average 1 Amp hour a day from the vessel's battery. At this rate, the units would drain a 12 V battery if left for more than three months. As this study relied on volunteers, it was not possible to enforce how units were wired up to the power supply of the vessels. The dashboard of the online database was the quickest way of determining if a vessel was reporting or not. This was hugely advantageous as it meant that any power issues could be addressed quickly however, it also relied on someone logging on and checking the database on a frequent basis.

4.2 Data Processing

A ping period of ten minutes provided high quality data outputs enabling easy interpretation and subsequent mapping of fishing areas. The initial export from the database, and subsequent import to ArcGIS, displayed vessel movements at different speeds and was relatively straight forward to do. It gave a good indication of fishing location, based on the defined speed bins, and it would be possible to extract information on any vessels fishing outside of the curfew, although this would be quite time consuming without further processing steps.

Further data processing in Excel and ArcGIS added an extra confidence in the outputs and provided additional capabilities as well as added value to the data. Most importantly, it allowed the information to be differentiated into fishing methods, focussing attention on scallop dredge activity only. In addition, further processing enabled vessel tracks to be created which helped to differentiate between fishing activity and natural slow vessel movements. Without vessel tracking information, an increase in false fishing areas or activity would be reported. This would have a knock on effect on management and compliance of curfew periods or closed areas with an increased number of investigations having to be carried out into legitimate activity. Without carrying out further processing, it would not be possible to use the information in spatial management plans for fisheries, stock assessments, or in marine spatial planning. We would recommend that the data is processed fully, separating out fishing types, creating vessel tracks, and identifying fishing activity. This reduces the demand on managers and compliance but increase the reliability of the information and correspondingly increases the level of trust and 'by-in' from the fishers.

4.3 Data Applications

The quantity and complexity of VMS information incorporated into a stock assessment can vary widely depending on the underlying data available on vessel landings, activity, the resolution of the information, and how that is reported. Shetland operates a logbook system based on a 5×5 nm grid (this equates to, 36 Shetland squares within one ICES square). Information reported in the logbooks includes vessel information, the square fished, hours towed, number of dredges used, and the quantity landed for each trip. By carrying out post processing of the VMS data, as discussed above, it would be possible to incorporate logbook information with the VMS. By incorporating the two datasets, it would be possible to provide ground-specific information on landings, effort, and landings per unit effort

(LPUE), rather than square-specific information. Combining the data provides an increased level of accuracy as the VMS provides high quality information on both the areas fished and the time spent fishing those areas. This may not always correspond with what the fishers report in their logbooks. The data produced by the VMS units has already been used to more accurately define the scallop grounds around Shetland and this is being incorporated into the design of a scallop survey. The expected outcome of the survey is a biomass estimate for the fished population of scallops in Shetland. This will then be able to feed into the management process through the setting of reference points.

The data collected can also effectively support spatial management of scallop fisheries. Incorporated into the database is the ability to define no-go areas, termed geofences, which, when 'broken' (when a vessel moves into the geofence area) by the vessel, the database registers a message on the dashboard. Broken geofences can also be downloaded as a specific export from the database. Geofences do not rely on any speed information so a broken geofence occurs every time a vessel passes through the designated area, irrespective of the vessels' activity. If vessels are permitted to pass through the specified area, as is the case for the scallop dredge closed areas in Shetland, a potentially high instance of broken geofences may occur, depending on their location, and each report of a break would have to be investigated. This tool would be highly beneficial in vessel exclusion areas where a total ban on all vessel movement within an area is in place. In areas which permit vessel through traffic but no dredging, the tool provides a quick way of identifying vessels that may be breaching a ban on fishing in specific areas. By carrying out further processing and displaying the fishing pings and vessel track information in ArcGIS, any illegal fishing within a closed area is easily identifiable.

The data collected through the VMS units has been integrated into the SSMO Management Plan and decision making process and ongoing monitoring of their Spatial Management Plan and Code of Conduct. Examination of the VMS data is a standing agenda item for the SSMO Advisory Group which provides recommendations to the SSMO Board. Should there be any evidence of fishing activity within the closed areas or during the scallop curfew hours within the six nautical mile limit this will be discussed and reported to the board for action.

4.4 Future Considerations

Vessels which participated in the study have retained the VMS units aboard with data still being transmitted and logged. Information obtained from the VMS units will be used for compliance, fisheries spatial management, stock assessments, marine spatial planning, and scallop survey design. The SSMO have paid for an initial years-worth of air time while they finalise their management measures for VMS units and the NAFC Marine Centre have continued to manage and process the data providing the SSMO with regular updates.

5 Summary

The Succorfish SC2 VMS units were found to provide high quality data on inshore scallop dredging activity around Shetland. Information was easily downloaded and viewed through a secure online database with the ability to use the initial exports to indicate the extent of fishing activity. Units were capable of storing data for a prolonged time during periods of no signal without any loss of information. This is critical in and around coastal areas where a signal is not always possible. Unit reliability was an initial concern with many units failing to send any data after prolonged periods of being switched off. This was mostly overcome by talking with the fishers and providing a troubleshooting guide; however, by fitting the units as per the manufacturer’s guidelines direct to the vessel’s battery, this problem should be eliminated.

The data produced was of a high quality and is already being incorporated into the stock assessment of scallops and spatial management of the dredge fishery around Shetland. Should there be any requirement to access the data for use in marine spatial planning, there is a defined mechanism in place via the Shetland Marine Spatial Plan and the data sharing agreement and this type of data could be crucial in planning decisions about aquaculture developments, oil pipelines or other seabed infrastructure, and also marine renewables. The integration of data into both fisheries management and marine spatial planning is aided by additional processing of the data. Although the initial exports of the data provided good quality information, further processing added an element of quality control, increased the potential outputs of the data, and refined the final maps. This acts as a quality control mechanism and enhances any interpretation of the mapped data. There are also significant potential gains in combining the data with logbook information which can then be incorporated into stock assessments, spatial management plans for fisheries, and further mapping for inclusion in Marine Spatial Planning. In addition, further processing of the VMS data provides an effective monitoring tool in protecting the environment with regards protected habitats and closed areas.

It is clear from the results of this study that the VMS technology trialled here is a successful method for gaining high quality data on fishing activity in remote rural areas. What the study has also shown is that further processing of this data can greatly enhance its value for use in fisheries management, marine spatial planning, and in protecting the marine environment.

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8 Appendix 1: Data Sharing Agreement

NAFC Marine Centre
University of the
Highlands and Islands

Shetland Shellfish Management Organisation

Scallop VMS Project

Data Use Agreement

Boat: ____________________

Skipper: ____________________

SSMO Licence No __________ **Home Port:** __________

I understand that NAFC Marine Centre & SSMO will hold this information as confidential, will not release it to any other party and will not publish them in any form that would reveal the activities of my vessel.

I understand that NAFC Marine Centre will use this information, along with similar data from other vessels, to inform the management of scallop fisheries, in stock assessments and to map the distribution of fishing activity in the waters around Shetland. The data may also be used to measure the importance of fishing to Shetland communities. The resulting maps of fishing activity and related information will be published (but only in forms that do not reveal the activities of individual vessels).

Signed: ____________________ **Date:** __________

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