Vessel Monitoring Systems (VMS) Commercial Fishing Density
Northeast and Mid-Atlantic Regions

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1. INTRODUCTION

NROC received VMS data for the Northeast Reporting System from the National Marine Fishery Service (NMFS) Office of Law Enforcement (OLE) and delivered them to RPS for processing and analysis. NMFS describes VMS as "a satellite surveillance system primarily used to monitor the location and movement of commercial fishing vessels in the U.S." The system uses satellite based communications from on-board transceiver units, which vessels operating in certain federally managed fisheries are required to carry. VMS data are subject to strict confidentiality and resulting products were created such that identifiable vessel locations which did not conform to criteria mandated by OLE were removed.

These datasets characterize the density of commercial fishing vessel activity for seven fisheries in the northeast and mid-Atlantic regions of the U.S. based on Vessel Monitoring Systems (VMS) from NMFS for the years 2006 to 2016[1]. The fisheries include Multispecies, Monkfish, Herring, Scallop, Surfclam/Ocean Quahog, Pelagics (Herring/Squid/Mackerel), and Squid. Data were available for all fisheries for the entire time date range with the

[1] NROC conducted the first phase of spatial characterization of fisheries in 2012 using VMS data from 2006 to 2010, which resulted in four density products showing broad scale patterns of vessel activity published to Northeast Ocean Data for the multispecies, monkfish, scallop, and surfclam/ocean quahog fisheries. Individually identifiable vessel locations were removed to ensure points that represented unique vessel locations or tracks were not included in the final products. Because speed over ground was not included, these products did not differentiate between transits and fishing. The full report of the spatial characterization of commercial fisheries is on NROC's website at http://northeastoceancouncil.org/2013/09/23/report-describing-first-phase-of-the-commercial-fishing-mapping-project-is-now-available/.

exception of Squid, which were designated specific fishery codes by NMFS in 2014. Along with VMS data analysis, NROC conducted extensive outreach to numerous fishermen, agencies, and organizations across the region to obtain feedback on the patterns reflected in the VMS.

The VMS data contained geographic coordinates of the vessel at the time of transmission, day, and vessel Declaration Code, which signifies fishery plan, programs, and associated geographic or gear type information. Data from 2011 to 2016 also included speed over ground (SOG) information in order to assess the possibility of identifying transit vs. fishing activity based on speed thresholds identified by industry and agency interviews.

The final products show the standardized density of locations for vessels that use VMS for each fishery for three aggregate time periods. Most fisheries used the time frames 2006-2010, 2011-2014 and 2015-2016, however the Surfclam/Ocean Quahog fishery used 2006-2010, 2012-2014 and 2015-2016, since habitat closures implemented by the New England Fishery Management Council in 2102 significantly impacted the spatial use patterns in this fishery when compared with the period before 2012. Squid products are available for 2014 and 2015-2016, and Pelagic products are available for 2014 and 2015-2016 periods only, due to data availability from NMFS. Data were log transformed and standardized, and are best interpreted qualitatively. There are two types of products:

- Density grids that characterize all VMS records for each time period.
- Density grids that characterize VMS records below a speed threshold for the 2011-2014 and 2015-2016 periods only. Speed thresholds were vetted through engagement with fishermen in each fishery.

These products represent efforts to expand on the initial phase of work and to refine the spatial characterization methodology such that speed thresholds could be analyzed and a finer resolution could be used. A full list of the 33 products is below:

- Multispecies 2006-2010
- Multispecies 2011-2014
- Multispecies 2011-2014 (< 4 knots)
- Multispecies 2015-2016
- Multispecies 2015-2016 (< 4 knots)
- Monkfish 2006-2010
- Monkfish 2011-2014
- Monkfish 2011-2014 (<4 knots)
- Monkfish 2015-2016
- Monkfish 2015-2016 (<4 knots)
- Herring 2006-2010
- Herring 2011-2014
- Herring 2011-2014 (< 4 knots)
- Herring 2015-2016
- Herring 2015-2016 (< 4 knots)
- Scallop 2006-2010
- Scallop 2011-2014
- Scallop 2011-2014 (< 5 knots)
- Scallop 2015-2016
- Scallop 2015-2016 (< 5 knots)
- Surfclam/Ocean Quahog 2006-2010
- Surfclam/Ocean Quahog 2012-2014
- Surfclam/Ocean Quahog 2012-2014 (<4 knots)

- Surfclam/Ocean Quahog 2015-2016
- Surfclam/Ocean Quahog 2015-2016 (<4 knots)
- Squid 2014
- Squid 2014 (< 4 knots)
- Squid 2015-2016
- Squid 2015-2016 (< 4 knots)
- Pelagics (Herring/Squid/Mackerel) 2014
- Pelagics (Herring/Squid/Mackerel) 2014 (< 4 knots)
- Pelagics (Herring/Squid/Mackerel) 2015-2016
- Pelagics (Herring/Squid/Mackerel) 2015-2016 (< 4 knots)

2. IMPORTANT DATA CONSIDERATIONS

The limitations of these data should be understood prior to use. The density grid products do not necessarily distinguish between fishing activity, vessel transit, and other vessel activities. Some maps show vessel activity below a speed threshold that was determined with industry input to attempt to better highlight fishing areas. Nevertheless, those maps still likely show some non-fishing activities that occur at low speeds, such as processing catch, sorting, drifting, or idling in port. The most accurate interpretation of these products is that they indicate relative levels of vessel presence.

These data are from vessels operating in certain fishery management plans and certain programs within those plans. It is important to note that these data include all trips using the specified VMS code by vessels with these permits, and as such, may include trips that target other fisheries but use a VMS declaration for another fishery as a management and reporting mechanism. There are many New England fisheries not described through any VMS-derived maps.

VMS data is subject to strict confidentiality restrictions. Therefore, the map shows the density of vessel locations following the removal of individually identifiable vessel positions. This process can result in the products showing vessel activity that seems anomalous, e.g. single data points in areas where fishing isn't common. This is usually because of transit lines that overlap while nearby areas contain no data.

In addition to the above data considerations, the following are specific to individual fisheries:

Multispecies

VMS data is included from fisheries with a limited access multispecies permit fishing under a Category A or B Days-at-Sea or catch regulated species or ocean pout while on a sector trip, or those with a limited access NE multispecies small vessel category or Handgear A permit that fish in multiple NE Multispecies Broad Stock Areas (50 CFR 648.10).

Herring, Squid, and Pelagics

Vessels fishing in the herring, squid, and mackerel fisheries can fish under a particular VMS fishery code but fish in another fishery, e.g. herring VMS code but fishing for mackerel. This can make the VMS activity patterns appear to be unusual in one of the three fisheries and requires additional exploration of fishing activity in these three fisheries to best understand what is occurring in a particular fishery.

Scallop

VMS activity in the Gulf of Maine, east of the Western Gulf of Maine closed area, is likely multispecies activity for vessels which also have a scallop permit and VMS requirement.

VMS activity in closed areas in the Mid-Atlantic and off of North Carolina is likely summer flounder, scup, and black seabass activity for vessels which also have a scallop permit and VMS requirement.

Surfclam/Ocean Quahog

VMS activity in deep water areas in the eastern Gulf of Maine are likely fishing activity for vessels in another fishery but that also have a surfclam/ocean quahog VMS reporting requirement.

VMS activity in areas between Georges Bank and the Mid-Atlantic region in the area south of Cape Cod and in areas deeper than surfclam/ocean quahog fishing occurs is likely the result of overlapping transit lines.

3. PURPOSE

In 2014 and 2017 the Northeast Regional Ocean Council (NROC) commissioned with George Lapointe, a fisheries consultant, to undertake a project that describes how New England's commercial fishing industries, utilize the region's ocean space. Datasets were configured to spatially represent specific fisheries and timespans. Subsequently shared with members of those industries, these datasets were refined based on feedback and information gleaned over the course of over 50 meetings with the fishing industry and fishery managers.

4. SOURCES AND AUTHORITIES

- Vessel Monitoring Systems (VMS) – National Oceanographic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS)
- George Lapointe, NROC Fisheries Consultant
- Stakeholder Fisherman, Agencies, and Organizations in the Northeast region

- VMS Activity Declaration Code Format For the Greater Atlantic Region, NMFS (March 2014) https://www.greateratlantic.fisheries.noaa.gov/vms/doc/vms-declaration-code-glossary-march-2014.pdf

5. DATABASE DESIGN AND CONTENT

Database Name: VMSCommercialFishingDensity

Dataset Status: Complete

Multispecies 2011-2014:
(This example represents data details specific to a select fishery density grid; other products have similar information.)
Native storage format: ArcGIS File Geodatabase Raster
Columns and Rows: 6814, 13332
Number of Bands: 1
Cell Size: 100
Pixel Type: 32 Bit floating point
Linear Unit: Meter (1.000000)
Angular Unit: Degree (0.0174532925199433)
Statistics:
Minimum: -1.961158633232117
Maximum: 4.61347246170044
Mean: 6.158711055485074e-009
Standard Deviation: 1.000000088819612

6. SPATIAL REPRESENTATION

Reference System: North American Albers Equal Area Conic
Horizontal Datum: North American Datum 1983
Ellipsoid: Geodetic Reference System 1980
False Easting: 0
False Northing: 0
Central Meridian: -96
Standard Parallel 1: 20
Standard Parallel 2: 60
Latitude of Origin: 40

Geographic extent: 1322410.62061 to 2324110.62061, -1352818.02339 to 895381.976606

IS0 19115 Topic Category: economy, environment, oceans

Place Names:

Atlantic Ocean, Cape Cod Bay, Cape May, Chesapeake Bay, Connecticut, Delaware, Delaware Bay, Georges Bank, Gulf of Maine, Hudson River, Long Island Sound, Maine, Maryland, Massachusetts, Massachusetts Bay, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Rhode Island Sound, United States, Virginia

Recommended Cartographic Properties:

(Using ArcGIS ArcMap nomenclature)

Classification, 5 classes, color mode: HSV

Low (<-1):	blue (222-91-48)
Medium-Low (-1 - 0):	green (154-85-79)
Medium-High (0 - 1):	yellow (60-100-100)
High (1 - 2):	orange (40-100-100)
Very High (>2):	red (20-100-66)

Scale range for optimal visualization: 1,000,000 to 4,000,000

7. DATA PROCESSING

Processing environment: ArcGIS 10.3, Windows 7 Professional, Intel Core i5 CPU

Processing Steps:

Background

NROC submitted a series of data request to NMFS to obtain VMS data in four separate deliveries. NROC contractors working with the data signed a Non-Disclosure Agreement (NDA) before receiving the data due to strict data confidentiality. The end products generated from the raw data had identifiable vessel locations removed such that the aggregate VMS products adhered to the "Rule of Three," where no fewer than three VMS points were represented in any location across the suite of maps. Data were secured on a password protected hard drive connected to a vetted contractor's computer.

Data Processing

VMS data were received from NMFS OLE in 2012, 2014, 2015, and 2017 for the time periods 2006-2010, 2011-2013, 2014 and 2015-2016, respectively. Raw data files for each year were organized in monthly text or comma-separated-values (csv) files and required some pre-processing to make the information fit for importing into a GIS. Each record in the VMS files included:

- Latitude
- Longitude

- Declaration code
- Date
- Speed (2011-2016 only)
- Home Port (2015-2016 only)

VMS files dated after 2010 included speed over ground (SOG) in knots, which was requested after the first phase of the project to aid in identifying areas where vessels were engaged in fishing or in transit.

Once formatting of the raw data was complete, Python scripting was used to import the information into point feature classes and incorporate latitude, longitude, declaration code, date, and SOG into attribute fields. Feature classes were organized into databases based on fishery plan code, which occupies the first three characters of the declaration code. A sample declaration code is below and the first three characters indicate it belongs to the herring plan.

HER-HER-XXXXXX

The following plans were used to select VMS points into specific fishery level products; Squid codes were identified by fishery program for declaration codes within the Squid/Mackerel/Butterfish (SMB) plan.

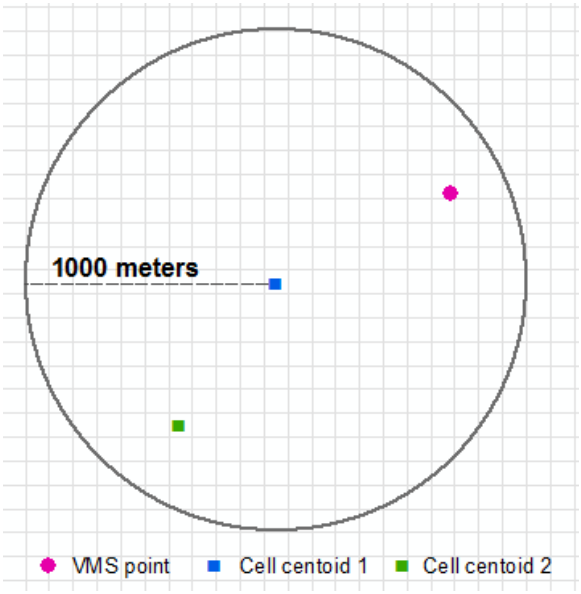
- Multispecies (NMS)
- Monkfish (MNK)
- Scallop (SES)
- Surfclam/Ocean Quahog (SCO)
- Pelagics (Herring/Mackerel/Squid) (HER, SMB) – 2014 and 2015-216 only
- Herring (HER)
- Squid (SMB-SHM, SMB-SQL, SMB-SQM) - 2014 and 2015-216 only

More information on declaration codes can be found in the VMS Activity Declaration Code Format for the Greater Atlantic Region (NMFS, 2014). Attribute queries were performed on the VMS points to identify which records belonged to each of the fisheries listed above by year. The Squid product was only available for 2014, since beginning in 2014 NMFS implemented the new plan code for SMB for those species. Annual fishery products were further aggregated into three time periods for 2006-2010 (five years), 2011-2014 (four years), and 2015-2016 (two years).

Density Analysis

Density was plotted onto a raster grid with a resolution of 100 meters. Values were generated for each 100 meter grid cell based on a search radius of 1000 meters. A grid cell within 1000 meters of a VMS point would be assigned a density value. Cells within 1000 meters of multiple VMS points would be assigned higher density values.

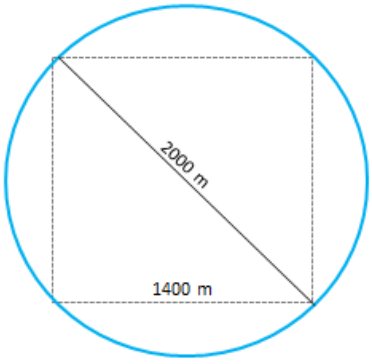
The figure below shows a grid with 100 meter cells. The central blue cell has a single VMS point (pink) within its 1000 meter search neighborhood, and would therefore be assigned a density value. Based on this example the green cell would be assigned a value of zero since there is no VMS point within the search radius.



Screening Analysis

In order to preserve data confidentiality using the Rule of Three, a screening grid of 1400 by 1400 meters was used to remove VMS points from the analysis if fewer than three points occurred within a screening grid cell. A 1400 meter square is the largest square that fits entirely within a 1000m radius (2000 meter diameter) circle.

The figure below shows a 1000 meter radius circle with a nested 1400 meter square inside. The diameter of the circle and the diagonal of the square have the same length. The screening analysis identified grid squares with fewer than three VMS points; VMS points within cells that did not meet the Rule of Three were removed from the data analysis.



This screening step was performed prior to any density analysis and creation of density grids.

A list of steps below outlines the processing:

	Process Steps Description
1	Modify raw data from NMFS in text or csv files as needed to import them into a GIS
2	Import data as points into ArcGIS using Python based on the latitude and longitude coordinates and incorporate information into fields for Date, Declaration Code, Latitude, and Longitude. For data after 2010, an additional field included Speed Over Ground (SOG). Invalid points were reviewed and removed in a parallel quality control process. Annual features classes were created for each fishery based on plan code within the Declaration Code.
3	MERGE annual feature classes into aggregate products for the appropriate time periods. Herring, Monkfish, Multispecies, and Scallop time periods used the time frames 2006-2010 2011-2014 and 2015-2016. Surfclam/Ocean Quahog used 2006-2010, 2012-2014, and 2015-2016. Pelagics (Herring/Mackerel/Squid) used the time period of 2011-2014 and 2015-2016. A single period for 2014 was used for the Squid and Mackerel fisheries.
4	Create a 1400 meter polygon grid for the Atlantic Coast within the Exclusive Economic Zone (EEZ): 1. CREATE FISHNET in the coordinate system North American Albers Equal Area Conic for the extent 1302620, -1586945, 2382020, 944255 (-82.676, 25.545, -63.509, 44.503) 2. CLIP fishnet grid to U.S. waters within the EEZ
5	Join VMS point feature classes with the 1400 meter grid and identify grid cells with three or more VMS points: 1. SELET BY LOCATION the 1400 meter grid with the VMS points using “intersect the source layer feature” and EXPORT to a new gridded dataset that only contains grid cells that overlay VMS points. This step eliminates unnecessary data to save processing time. 2. JOIN the 1400 meter grid from Step 1 with VMS data using the “Join data from another layer based on spatial location” option to determine the count of VMS points in each cell. The output contains a new attribute field with the number of VMS points in each cell. 3. SELECT BY ATTRIBUTE to identify grid cells with three or more VMS points (“Count_” >=3) 4. SELET BY LOCATION using “select from the currently selected features” to identify VMS points that occur within grid cells that have at least three points. 5. EXPORT selected VMS point features to new dataset
6	Run POINT DENSITY under Spatial Analyst to create a density surface using the selected and exported VMS points (Cell Size = 100, Neighborhood = Circle, Radius = 1000, Area units = Square Kilometers) Note: A 1000 meter search radius results in a 2000 meter diameter circle. The largest square which fits inside a 2000 meter circle has 1400 meter dimensions. Therefore, a 1400 meter grid was used to screen out VMS points if fewer than three occurred within a grid cell. This was necessary to adhere to the Rule of Three mandated by NMFS OLE to preserve data confidentiality.
7	Standardize output density grids using a log transformation technique: 1. RASTER CALCULATOR expression using the LN() function 2. ZONAL STATISTICS to determine the standard deviation (stdev) and mean (mean) of the transformed product (ln) 3. RASTER CALCULATOR expression to produce standardized products (ln – mean)/stdev

8. QUALITY PROCESS

Attribute Accuracy: VMS data are considered authoritative and no testing was performed.

Logical Consistency: Point data used to generate the raster densities were represented by a set of coordinate pairs and were processed with the assumption that no duplication was present in the raw data.

Completeness: These products represent VMS records in the northeastern and mid-Atlantic in coastal and offshore waters within the EEZ. Products represent the standardized density of VMS records within each fishery that conformed to the Rule of Three applied in this analysis and therefore characterize the important geography and main scope of each fishery. Since fishery plans were used to group the data, plan codes not represented by the seven fisheries discussed above are not included, nor are vessels whose declaration code was characterized as *Power Off, Power On, Antenna Blockage, Normal, GPS Off,* or *Invalid*. Other records with declaration codes such as *Null* or *Declared out of Fishery* are also not represented. Records in the scallop fishery that indicated a vessel had a powered down status were also removed. Multispecies and monkfish may have overlap due to the nature of reporting and permitting within those fisheries. Incorrect coordinates which indicated a vessel was inland or outside the study area were removed. In cases where records appeared to have reversed latitude and longitude, the coordinates were corrected and included. Due to the high amount of signals sent from VMS transmitters in port areas, ports show up as high density however they should not necessarily be understood as important fishing locations. A review investigated whether standardized values changed substantially if ports were screened out of the datasets, however that did not have an effect on values.

Positional Accuracy: Horizontal accuracy is dependent on the location of the transmitted VMS locations from GPS and includes errors associated with this technology. The density grids represent a smoothed heat map of the VMS vessel activity. While the original data had accurate and precise coordinate information, the density surfaces expands the fine scale footprint of the VMS points by assigning information to 100 meter cells and using a 1000 meter search neighborhood to smooth the data. While this affects positional accuracy at a fine scale, it provides visually informative results at a regional and sub-regional level.

Timeliness: 2006 to 2016

Use restrictions: This dataset is part of a broad effort to spatially characterize commercial fisheries in the northeast. Any interpretations or conclusions based on this data are the responsibility of the user. Users are expected to read through this documentation and understand its contents. Any use of these products must cite NROC and RPS as the source. It is highly recommended to read the full report available on NROC's website.

Distribution Liability: Data are not for download. These products are available online through ArcGIS tile cache services, which are accessible from the data download page on Northeast Ocean Data (http://www.northeastoceandata.org/data/data-download/). The information should not be used for legally binding purposes. NROC and RPS are not responsible for any interpretations, assumptions, or conclusions based on these data. Any redistribution of these data shall reference NROC and RPS as the creator and any derived products must have documented process steps. Users must assume responsibility to determine the appropriate use of these data.