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 and Southeast 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 fisheries in the northeast and mid-Atlantic regions of the U.S. based on Vessel Monitoring Systems (VMS) from NMFS for the years 2015 to 2019[1, 2]. The fisheries include Multispecies, Monkfish, Herring, Scallop, Surfclam, Ocean Quahog, and Squid/Mackerel/Butterfish. Along

[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/.

[2] NROC conducted a second and third phase of VMS data processing based on data covering 2011 to 2016, which resulted in a range of density products including differentiating activity for likely transiting vs. fishing activity, based on vessel speed. Data products for 2015 to 2016 cover the same time period as some of these new products described in this document, however, they were based on different source VMS data and were processed differently.

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 and the potential uses and limitations of these products.

The VMS data contained geographic coordinates of the vessel at the time of transmission, date and time of transmission, vessel identification number, speed over ground (SOG), and vessel Declaration Code, which signifies fishery plan, programs, and associated geographic or gear type information. Vessel identification number (DOC_Num) was used to distinguish vessel activity from unique vessels only (described in more detail in the Data Processing section).

The final products show the standardized density of locations for vessels that use VMS for each fishery as well as those declared out of any fishery and for all activity regardless of declaration for different aggregated time periods. The time periods assessed were either from January 2015 to December 2019 or for monkfish, multispecies and scallop, by their fishing season (April 2015 to March 2019 or May 2015 to April 2019). Data were log transformed and standardized and are best interpreted qualitatively as density grids that characterize all VMS records for each fishery over that time period.

These products represent efforts to expand on the initial phases of work and to refine the confidentiality filtering approach to account for activity by unique vessels. A full list of the current products is below:

- All VMS Vessels 2015 - 2019
- Declared Out of Fishery 2015 - 2019
- Herring 2015 -2019
- Multispecies May 2015 – April 2019
- Surfclam 2015 – 2019
- Ocean Quahog 2015 – 2019
- Scallops April 2015 – March 2019
- Squid/Mackerel/Butterfish – 2015 – 2019
- Monkfish May 2015 – April 2019
- Transit Density 2015-2019 (see Appendix A)

2. IMPORTANT DATA CONSIDERATIONS

The limitations of these data should be understood prior to use. Most of the density grid products do not distinguish between fishing activity, vessel transit (see Appendix A), and other vessel activities. The most accurate interpretation of these products is that they indicate relative levels of vessel presence for each fishery.

These data are from vessels operating in certain fishery management plans and certain programs within those plans (except for the data showing all vessel activity). 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 northeast 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.

3. PURPOSE

From 2019-2021, the Northeast Regional Ocean Council (NROC) and the Mid-Atlantic Council on the Ocean (MARCO) collaborated with the Responsible Offshore Development Alliance (RODA) to obtain feedback from the fishing industry on the data products that are currently available via the Portals, how to improve those products, and on other datasets that could be developed to characterize fishing activity. These products incorporate many of the recommendations that resulted from that project and are documented in the final report. These products were also reviewed by many fishing industry interests and fishery management agencies before public release.

4. SOURCES AND AUTHORITIES

- Vessel Monitoring Systems (VMS) – National Oceanographic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS)
- Responsible Offshore Development Alliance
- Stakeholder Fisherman, Agencies, and Organizations in the Northeast region
- VMS Activity Declaration Code Glossary for the Greater Atlantic Region, NMFS (November 2019)
- VMS Activity Code Declaration Glossary for the Southeast Region, NMFS (September 2013)

5. DATABASE DESIGN AND CONTENT

Database Name: VMSCommercialFishingDensity

Dataset Status: Complete

Multispecies May 2015 – April 2019:

(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: 6453, 13092
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: -1.509
Maximum: 4.962
Mean: 0.00000004
Standard Deviation: 1.00

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: 1638514.64911 to 2262014.64911, -461744.203189 to 825155.796811

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: 1:250000 to 5,000,000

7. DATA PROCESSING

Processing environment: ArcGIS Pro 2.5.1, Windows 10 Enterprise, Intel(R) Xeon(R) E-2276M CPU

Processing Steps:

Background

NROC submitted a data request to NMFS to obtain VMS data. 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 unique vessel 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 Preparation

VMS data were received from NMFS OLE in 2020 for the time period 2015-2019. Raw data files for each year were organized in text or comma-separated-values (csv) files, each covering a third of a month, 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
- UTC Date and Time
- Speed Over Ground (SOG)
- Doc# (vessel ID)
- Average Speed

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/time, Doc#, 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, and program code, which occupies the second set of 3 characters in the declaration code. A sample declaration code is below, and the first three characters indicate it belongs to the Surfclam, Ocean Quahog, and Mussel plan, the second three characters indicate it was part of the Ocean Quahog program.

SCO-OQU-XXXXXX

The following plan and program combinations to select VMS points into specific fishery level products.

Fishery Product	Plan Code	Program Code
All VMS	*all*	*all*
Declared Out of Fishery	DOF	*all*
Herring	HER	*all*
Monkfish	MNK	*all*
Multispecies	NMS	*all*
Ocean Quahog	SCO	OQU
Scallop	SES	*all*
Squid/Mackerel/Butterfish	SMB	*all*
Surfclam	SCO	SFC
Transit Density	*See Appendix A*	

More information on declaration codes can be found in the VMS Activity Declaration Code Glossary for the Greater Atlantic Region (NMFS, 2019) and VMS Activity Code Declaration Glossary for the Southeast Region (NMFS 2013). Attribute queries were performed on the VMS points to identify which records belonged to each of the fisheries listed above by year, years, or approximate annual fishing season.

"Rule of Three" Filtering

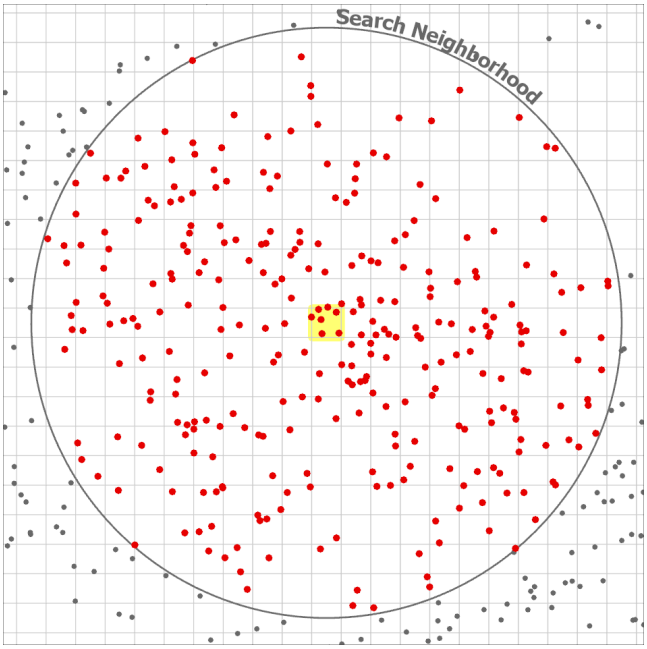
VMS data are subject to strict confidentiality and resulting products need to be created such that identifiable vessel locations which do not conform to criteria mandated are removed. This criterion is referred to as the "Rule of Three" where locations with less than three vessels fishing are excluded (filtered) from the data prior to creating density products. This rule has been interpreted based on using a search distance of 1,000 meters and requiring three unique vessels to be fishing in that area. For more details on this process, please refer to Vessel Monitoring Systems (VMS) "Rule of Three" Confidentiality Filtering Process Details.

Density Analysis

To further maintain confidentiality, by generalizing the output and not showing exact vessel positions, data was presented as a density grid. These grids can then be used to summarize the level of fishing vessel activity in a general area. Density was plotted onto a raster grid with a resolution of 100 meters and using a 1,000 meter radius circular neighborhood. For each cell in the grid, the count of VMS positions within the 1,000 meter circular radius neighborhood (not cell) was determined. Density was then calculated for that cell, based on the VMS count and the area of the search neighborhood. Density values were then normalized to show a relative density.

The figure below shows how this density processing was performed. The grid represents the density processing grid with 100 meter cells. The yellow highlighted cell represents the cell being analyzed. The large circle represents the 1,000 meter radius circular search neighborhood. Red dots are VMS positions within the search neighborhood and grey dots are

VMS positions outside of that. The density of the highlighted cell would be based on the count of the red VMS positions and the total area of the search neighborhood.



A list of steps below outlines the processing:

	Process Steps Description
1	Format the raw data from NMFS 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/time, Declaration Code, speed, Doc#, Latitude, and Longitude. Invalid records in the CSV data were reviewed and/or removed in a parallel quality control process.
3	Annual, seasonal, or multi-year feature classes were extracted from the master database for the selected fishery and time period, based on declaration codes and date/time attributes.
4	Create a 1400 meter polygon screening grid for the Atlantic Coast: 1. CREATE FISHNET in the coordinate system North American Albers Equal Area Conic for the extent 1290000, -1650000, 2450600, 955400
5	Performed "Rule of Three" Filtering (see more information in Vessel Monitoring Systems (VMS) "Rule of Three" Confidentiality Filtering Process Details)
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)
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, mid-Atlantic, and southeastern 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 (except it the All Vessels and Declared Out of Fishery products)*. 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. Due to the high number 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 expand 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: 2015 to 2019

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.

Appendix A - VMS Transit Data

Additional data products were prepared to show likely vessel transit activity from 2015 to 2019 and exclude active fishing activity. Various SOG filters were used to attempt to most accurately isolate transit activity. These speed thresholds varied for different types of fisheries that use variable fishing methods.

Data were processed for the same extent as other VMS products in most cases. Some products (as noted below) were isolated to only included activity in the Gulf of Maine. This area was defined by the initial BOEM Gulf of Maine offshore wind Planning Area, and all coastal areas adjacent to it.

Data is displayed differently then the other VMS data products. Instead of classified visualization, data is displayed using a stretch render, where higher density is shown by reds, lower density is shown as blue.

All other processing was the same as the other VMS products described above.

The following data products are available, using the filtering logic outlined here:

Product Description	Speed Filter	Plan Code	Program Code
All VMS Transit Density	> 5 knots	*all*	*all*
All VMS Transit Density	> 6 knots	*all*	*all*
Gulf of Maine Transit Density	> 5 knots	NMS, MNK, HER, SES, DOF	*all*
Gulf of Maine Transit Density	> 6 knots	NMS, MNK, HER, SES, DOF	*all*
Multispecies / Monkfish	> 4 knots	NMS, MNK	*all*
Multispecies / Monkfish	> 5 knots	NMS, MNK	*all*