OCS Study
BOEM 2021-035

Vessel Risk Calculator: Graphical User Interface User's Manual

U.S. Department of the Interior
Bureau of Ocean Energy Management
Office of Renewable Energy Programs

BOEM
Bureau of Ocean Energy Management

OCS Study
BOEM 2021-035

Vessel Risk Calculator: Graphical User Interface User's Manual

April 2021

Authors:
Amit Malhotra (Geo Horizons)
Mark Fonseca, Ph.D. (CSA)
Mary Jo Barkaszi (CSA)
Kim Olsen (CSA)

Prepared under Task Order 140M0119F0033

By
CSA Ocean Sciences Inc.
8502 SW Kansas Avenue
Stuart, Florida 34997

U.S. Department of the Interior
Bureau of Ocean Energy Management
Office of Renewable Energy Programs

BOEM
Bureau of Ocean Energy Management

DISCLAIMER

Study concept, oversight, and funding were provided by the U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEM), Environmental Studies Program, Washington, D.C., under Contract Number 140M0119F0033. This report has been technically reviewed by BOEM, and it has been approved for publication. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Government, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

REPORT AVAILABILITY

To download a PDF file of this report, go to the U.S. Department of the Interior, Bureau of Ocean Energy Management Data and Information Systems webpage (http://www.boem.gov/Environmental-Studies-EnvData/), click on the link for the Environmental Studies Program Information System (ESPIS), and search on 2021-035. The report is also available at the National Technical Reports Library at https://ntrl.ntis.gov/NTRL/.

CITATION

Malhotra A, Fonseca M., Barkaszi MJ., and Olsen, K. 2021. Vessel Risk Calculator: Graphical User Interface User's Manual. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2021-035. 46 p. + Appendices.

Contents

List of Figures

List of Figures (Continued)

List of Figures (Continued)

List of Tables

List of Abbreviations and Acronyms

AIS	Automatic Identification System
BOEM	Bureau of Ocean Energy Management
CSA	CSA Ocean Sciences Inc.
GUI	graphical user interface
km	kilometer
kn	knot
m	meter
NARW	North Atlantic right whale
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
OCS	outer continental shelf
RAM	random access memory
SAG	surface-active group
U.S.	United States
UME	unusual mortality event
WEA	wind energy areas

1 Introduction

With the development of offshore wind projects, the Bureau of Ocean Energy Management (BOEM) must evaluate the environmental risks of the projects. One risk identified is the potential impacts of vessel operations on marine mammals and sea turtles. Vessel strike has been identified as a source of injury and mortality of both large whales and sea turtles. Current qualitative assessments of expected encounter rates and/or strike numbers are often based on highly localized evaluations and better assessment Calculators are needed to better evaluate the spatial and temporal risks from wind development vessel operations.

An associated report[1], describes a new Vessel Risk Calculator (Calculator) with its underlying encounter prediction and graphical user interface (GUI) was developed to evaluate these risks and visualize the results. This document provides user guidance for the utilization of the Calculator.

1.1 Scope/Goals of Project

The objective of this study was to characterize the risk of a strike on large whales or sea turtles by the different vessel types operating to support of offshore wind energy and develop a model that can account for geospatial, temporal, and species-specific parameters for any wind energy areas on the Outer Continental Shelf (OCS) of the Atlantic.

The study was conducted in four stages, the first characterized the baseline conditions for vessel traffic along the Atlantic OCS and within the "wind farms"[2] and includes selection options for vessel types, operational parameters, and vessel actions during different stages of wind area development (i.e., surveys, construction, operations). Also developed was an analytical framework that utilized existing data to calculate encounter rates based on species' information including behavior, vessel parameters, geographic area, and stage of wind area development. See Section 2.3 of the associated report[1] for further discussion regarding matrices. The second phase assessed and identified the quantitative parameters and developed the model that evaluated the encounter rates and estimation for large whales and sea turtles. See Section 3.0 of the associated report[1] for further discussion regarding the model development. In the third phase, a user-friendly GUI was developed that operates with the Vessel Risk Calculator to allow users to create complex scenarios of vessel activity as it interacts with animal density distributions. The GUI provides the user with text reports of the encounter numbers generated by the users' scenario and produces encounter risk-based heat maps that correspond to the scenario tabular data, displayed in a geographic context. The combined predictive model and GUI is described here as the 'Calculator'. See Section 5 of the associated report[1] for further discussion regarding Calculator application. A fourth stage was added after delivery of a draft version and that was to add a capacity to the GUI to allow aggregation and summation of model results from multiple, user-defined scenarios.

---

[1] Barkaszi MJ, Fonseca M., Foster T, Malhotra A, Olsen, K. 2020. Risk Assessment to Model Encounter Rates Between Large Whales and Vessel Traffic from Offshore Wind Energy on the Atlantic OCS. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2020. 86p.

[2] Here, the term "wind farm" is used generically and includes all the destinations that the user will be able to select in the Calculator. This list is composed of data compiled from BOEM data sources (BOEM_Lease_Areas_4_13_2020 and BOEM_Wind_Planning_Areas_4_13_2020) and includes Wind Planning / Wind Energy Areas, Call Areas, Lease Areas and actual wind farm designations within Lease Areas.

The Calculator can be used to assess the expected encounter[3] numbers and, to some degree by utilizing aversion selections, potential vessel strike numbers for large whales and sea turtles over spatial and temporal scales indicative of the current and future offshore wind energy project development. While project-based assessments of vessel traffic and potential vessel strike impacts are required from the wind energy developers, no comprehensive assessment of the vessel strike risk takes place over all phases of a single development or across multiple projects. While individual project risk to vessel strikes is likely very low, the outlook for development along the eastern seaboard demands that vessel strike risk be assessed on a more comprehensive basis to inform National Environmental Policy Act (NEPA) compliance and the public.

This study has identified sensitive parameters for vessel type, operation, and species activity, including expected animal swim depths, that allow for a robust analytical framework that allows users to assess vessel encounters and animal strikes associated with vessels serving offshore wind development. The aforementioned associated report contains a detailed risk assessment has been conducted to establish critical parameters from both vessels and species that are included in the predictive model.

1.2 Approach and Methods

Assessing the strike risk from vessels operating in support of offshore wind development is necessary under NEPA requirements and assists managers in identifying vessel activities that present risk that could be mitigated, under the purview of agencies that oversee wind development. Through the GUI, the user will set up a series of scenarios[4] of their choice that will provide an expected number of encounters for the input parameters. Scenarios themselves can then be accumulated to provide multi-year or multi-route encounter predictions or compared to one another to assess strike risk against several options.

The risk of a strike has several components. The first-order component of that risk is the frequency of a vessel encountering an animal. Subsequent risk components, including whether or not that encounter becomes an actual strike (e.g., did the animal or vessel detect one or the other and avert and avoid a strike) or the consequences of that strike (e.g., animal mortality) are not explicitly modeled here. However, users of the graphical user interface provided with this encounter model are allowed to create theoretical scenarios that begin to consider actual strike risk. This is accomplished by allowing the user to vary the effectiveness of aversion (by both a vessel and an animal from each other) at the point of encounter within each scenario. Through the creation of these scenarios, built on the first-order issue (encounter frequency), users may begin to assess the overall likelihood of strike risk. See Section 2.4 of the associated report[1] for further discussion regarding encounter factors.

Importantly, this risk assessment, as a predictor of animal-vessel encounters, required a spatial scale of the Atlantic OCS (**Figure 1**). As no large-scale commercial wind farms have yet been constructed in the U.S., it was necessary to identify the factors influencing encounter risk for the Calculator using the best available information but with the flexibility to adapt to changing vessel and biological data as well as ongoing and future wind development activities.

---

[3] An encounter refers to an event during which a vessel and an animal are in close proximity such that a "strike" could occur. An encounter describes a precursor situation that could result in a strike unless either the animal, vessel, or both averts and thus is a measure of strike risk.

[4] A scenario for the GUI is defined as a single set of input parameters that include a single species of interest, a single month, up to seven vessel types, a single transit route to a wind farm area or a wind farm area traversed by the vessels, and user-specified number of transits.

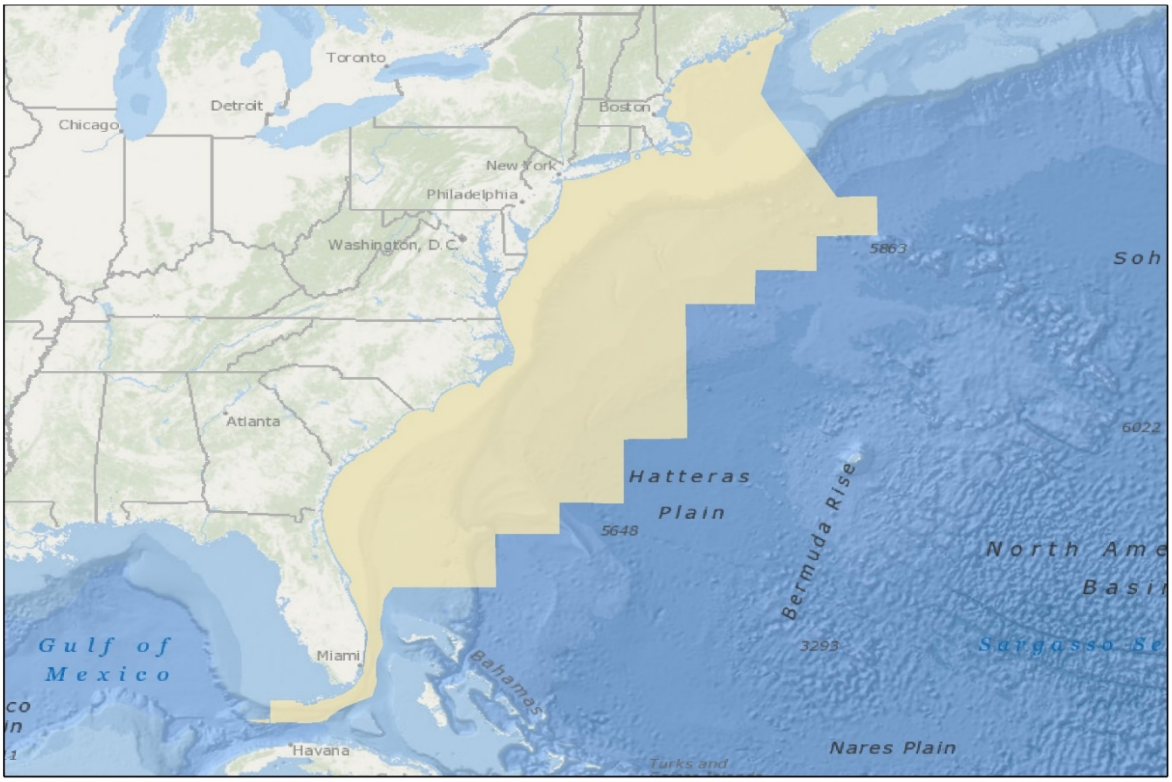


Figure 1. Atlantic outer continental shelf

1.3 Model Basics

The overall methodology for GUI development was to separate vessel encounter computations into two components:

1. Vessel encounters during a transit to and from a wind farm area (round trip); and
2. Vessel encounters within a wind farm area (e.g., lease area).

Transit speed between the port and the wind farm is assumed constant with the model defaulting to a normal operating speed for the selected vessel that can be adjusted by the user. The constant speed assumption removes the complexity (and inaccuracy) of adjusting the aversion coefficients as a function of speed along a single track line. Within a wind farm area, vessel behavior is more complex and can often not be predicted simply based on its task. Consequently, the vessel behavior (by vessel category) within the wind farm area is represented by the percent time the vessel was at operating speed; there is no spatial representation of a vessel's behavior in a wind farm area given the boundless combinations of movement patterns. Consequently, only one value for encounter risk is returned for a wind farm area.

In order to provide the user with a total number of predicted encounters for a user-defined scenario, a summing operation in the Calculator totals the encounter numbers computed by the underlying model, utilizing the user-defined conditions as well as various parameters such as vessel speed, animal density, etc. to produce a count of animal encounters. This summing operation provides two types of total encounter numbers, one for the total number of encounters during a single transit (round-trip; out and back) from a user-selected port to a wind farm area. The transit is composed of the vessel moving across sequential 1 km^2 blocks within each of which the risk of encounter is computed. All the blocks along the transit route are summed which is called the vessel transit total. The second type of summing operation

provides a total number of encounters within an entire wind farm area over a 24-hour period which is composed of multiple km^2 transit blocks within the wind farm area for any user-defined scenario. Each scenario is computed independently of any other[5]. Both values (transit and wind farm encounter sums) are returned to the user for each scenario. Importantly, these summing operations in the Calculator do not total across scenarios; that function is performed by the Aggregator Module which is discussed in **Section 3.3**.

To review and clarity, several terms are defined in this manual as follows: A **scenario** is the compilation of the individual parameters that the user wants to evaluate and that is submitted for a model run in the Calculator (for example a transit route from 1 port to 1 wind farm for 1 species, for 1 set of vessels for 1 month, with no aversion selected). A **project** is made up of as many scenarios as the user desires that are named the same and filed in the same project folder. For example, a project can be 4 different transit scenarios to a wind farm or multiple wind farms plus the vessels within the wind farm for all species for all months. A project can include any set of scenarios for which a cumulative total risk value is desired. The Aggregator module then allows the user to select which scenarios in a project that may be summed together to gain a larger scale (both in space and time, as defined by the scenarios selected) perspective. Thus, the user is strongly advised to plan a strategy of scenario selection and project building to address a defined question at the outset.

2 Installation

The Calculator has been created as an ArcMap add-in using Python 2.7 and ArcGIS 10 architecture. To run the Calculator, the computer should have ArcGIS 10.5 or higher installed with Python 2.7.

2.1 System Requirements

The operation of the Calculator has not been systematically tested on combinations of platform configurations. Therefore, the Calculator may run faster or slower on different systems and potentially, for substantially older systems, not at all. Other versions of Windows may be suitable but have not been tested. These are the recommended minimum system requirements to run the Calculator on a machine running ArcGIS 10.5:

- Windows 10+
- ArcGIS version 10.5 or higher.
  - Basic License
  - Spatial Analyst
- Processor speed: 2.0 GHz
- Cores: 4
- OS: Windows 10 64 bits
- RAM: 16 GB
- Hard drive: 500 GB

The Calculator can be installed on a stand-alone computer that meets the above requirements or will work from a network-based configuration with a workstation meeting the above system requirements.

[5] Note: given the extreme range in values that can be generated among user scenarios, the color ramps representing the encounter numbers in a scenario are scaled only to that scenario and color ramps are NOT directly comparable with any other scenario.

2.2 Installation Files

The GUI Calculator is distributed using the 'GUI Calculator Installer.exe' file. Click the file to start the installation of the Calculator.

2.3 Installation Steps

The Calculator is distributed as a zip folder with installation files and data folders, which can be downloaded on a local computer for installation.

Installation steps:

1. Download the 'Vessel Risk Calculator Installer.zip' file and un-compress the zipped file and extract to a local folder.
2. Click on Vessel Risk Calculator Installer.exe and follow the installation steps to install Calculator's necessary modules on the computer (**Figure 2**). Either install it as admin status or local user only depending on privileges. Pick a local folder to install the files. The completion of the Vessel Risk Calculator setup screen is illustrated in **Figure 3**.
3. Default installation location is 'C:\Program Files (x86)'.

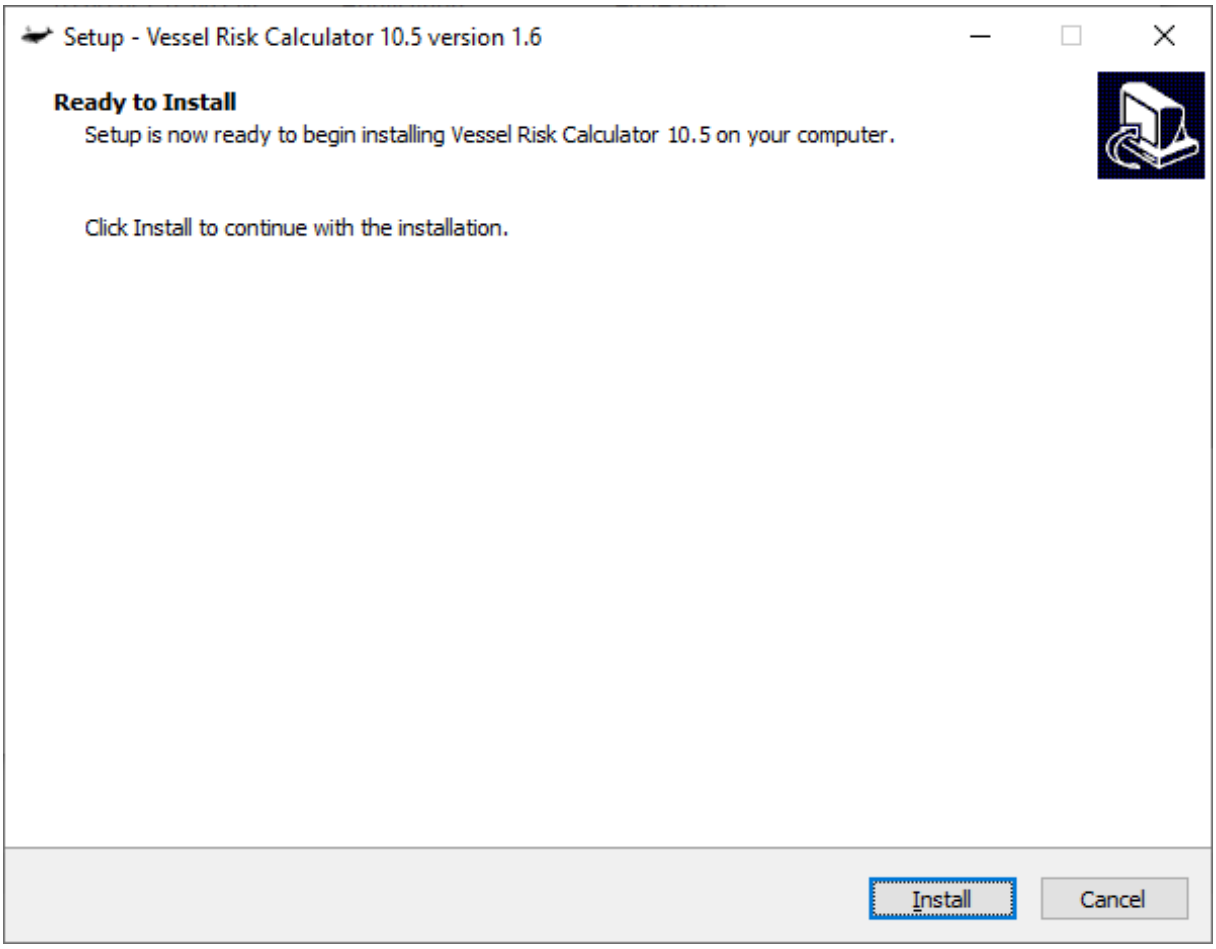


Figure 2. Screenshot of Vessel Risk Calculator Setup

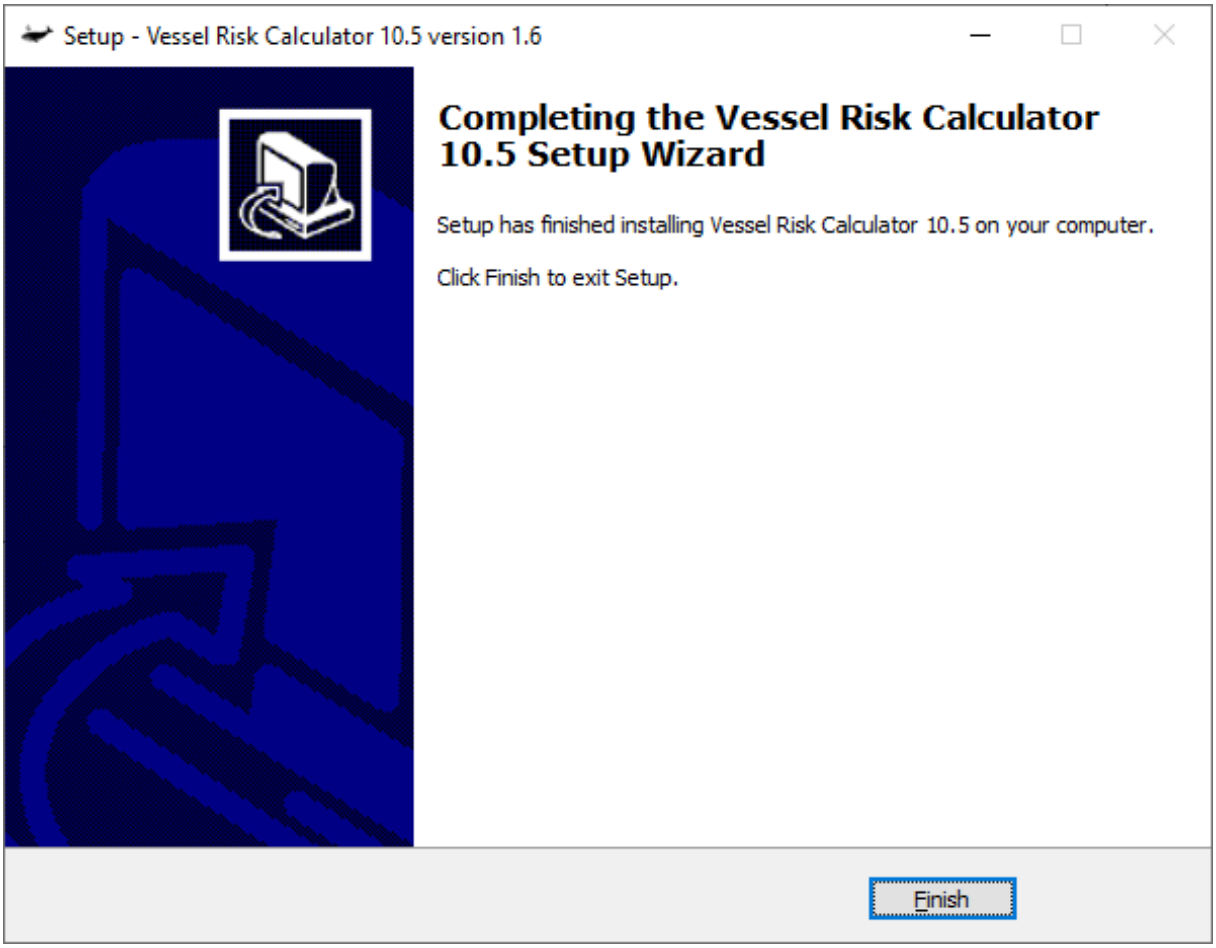


Figure 3. Screenshot of Vessel Risk Calculator Setup completion

4. Once installed navigate to the folder where the user installed the Vessel Risk Calculator. The folder will be named 'Vessel Risk Calculator'
5. Inside the folder 'Vessel Risk Calculator', double click the file 'arcaddin.esriaddin' to install the Calculator on ArcMap (**Figure 4**).

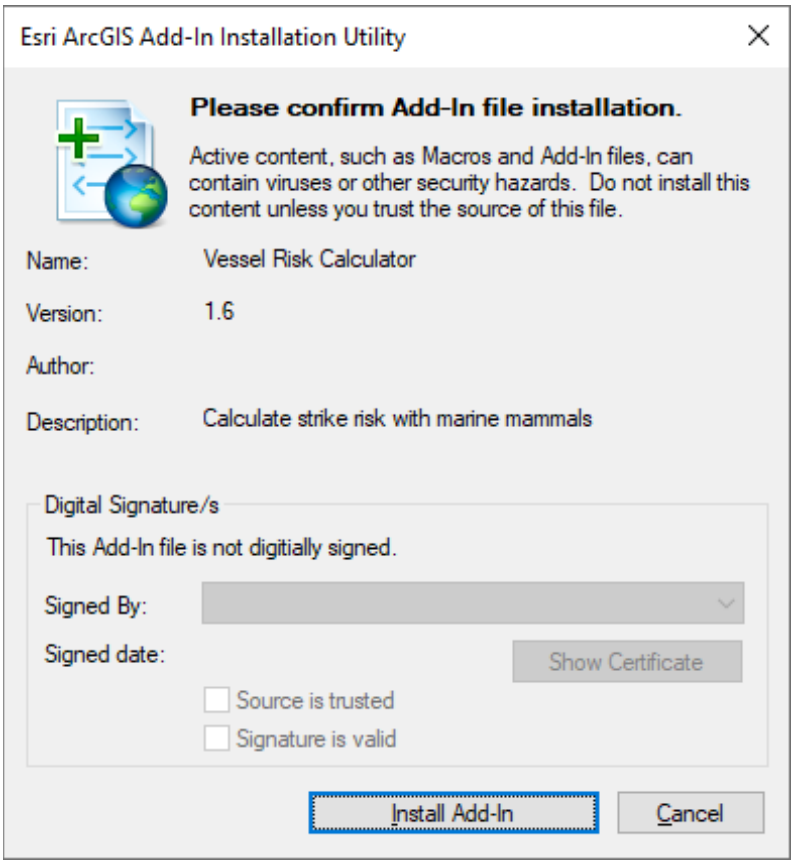


Figure 4. Screenshot of ArcGIS Add-In Installation Utility to install Vessel Risk Calculator add-in

6. Click 'Install Add-In' in the next window. 'Installation succeeded' message should confirm the installation (**Figure 5**).

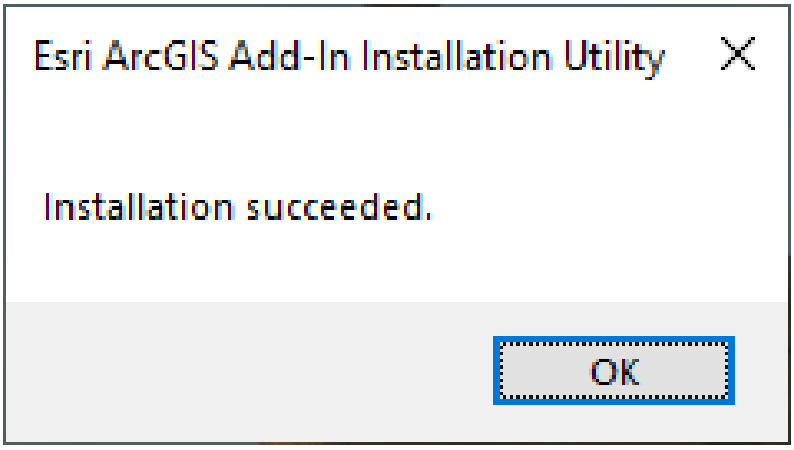


Figure 5. Screenshot showing the 'Installation Succeeded' once the Vessel Risk Calculator successfully installs

7. Open GUI Tool.mxd by navigating to ‘GUI Workspace\data\mxd data’ folder (**Figure 6**).

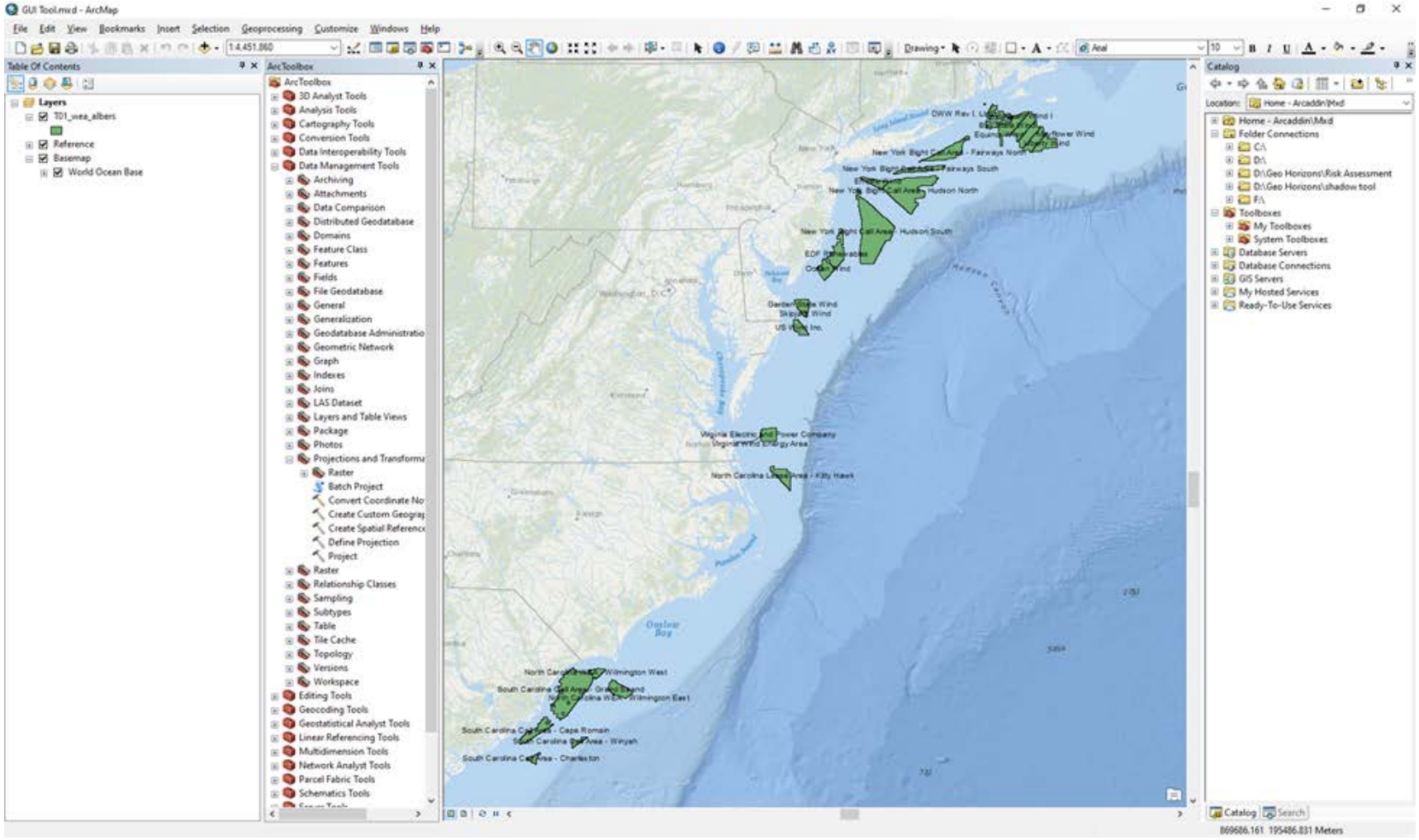


Figure 6. GUI Tool.mxd document

8. Once ArcMap opens as shown in **Figure 7** navigate to 'Customize -> Add-in Manager'.
9. Open Add-in Manager to confirm the installation of Vessel Risk Calculator. Once confirmed, close the Add-in Manager.

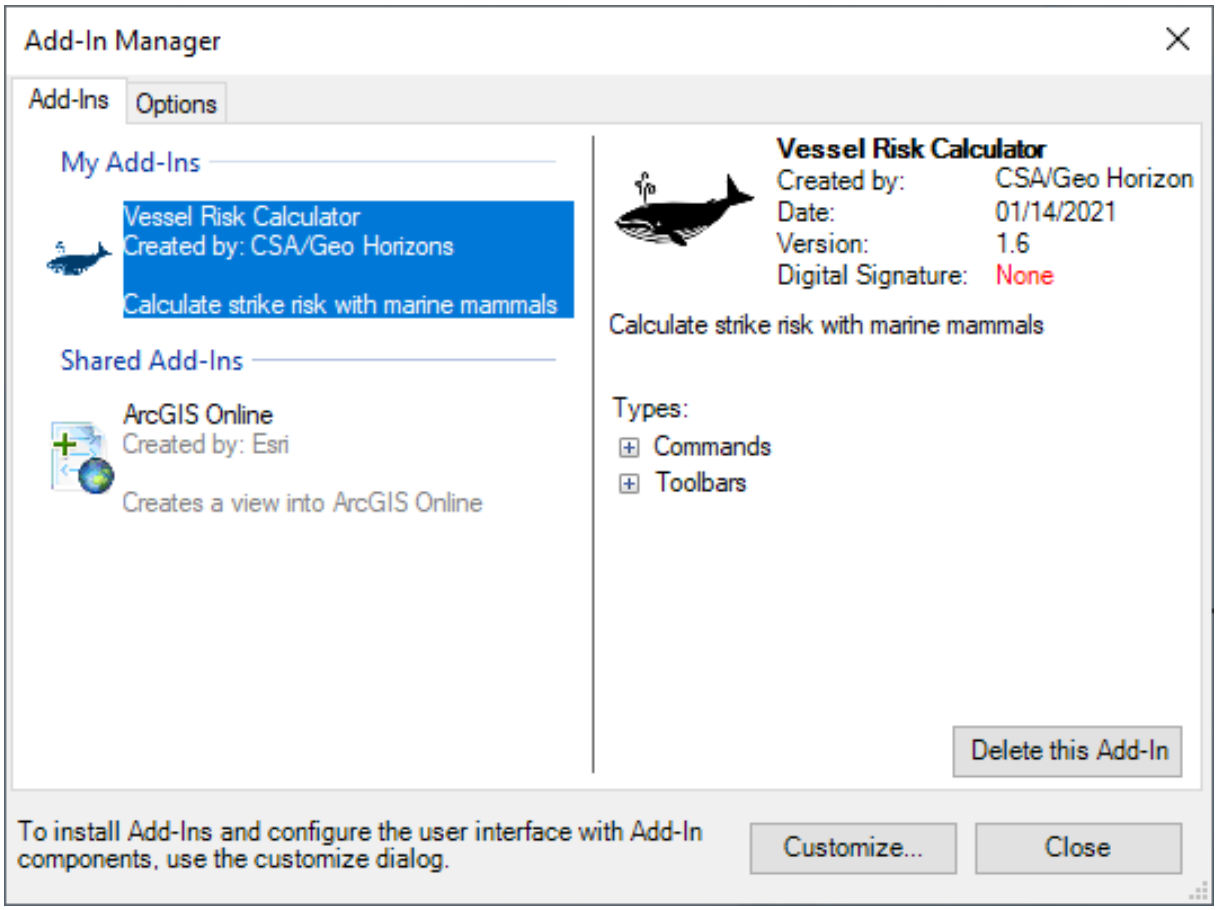


Figure 7. ArcMap Add-In Manager showing GUI Calculator Add-In installed in ArcMap

10. Click ‘Customize -> Toolbars -> Vessel Risk Calculator Toolbar’ to initialize the Calculator (**Figure 8**).

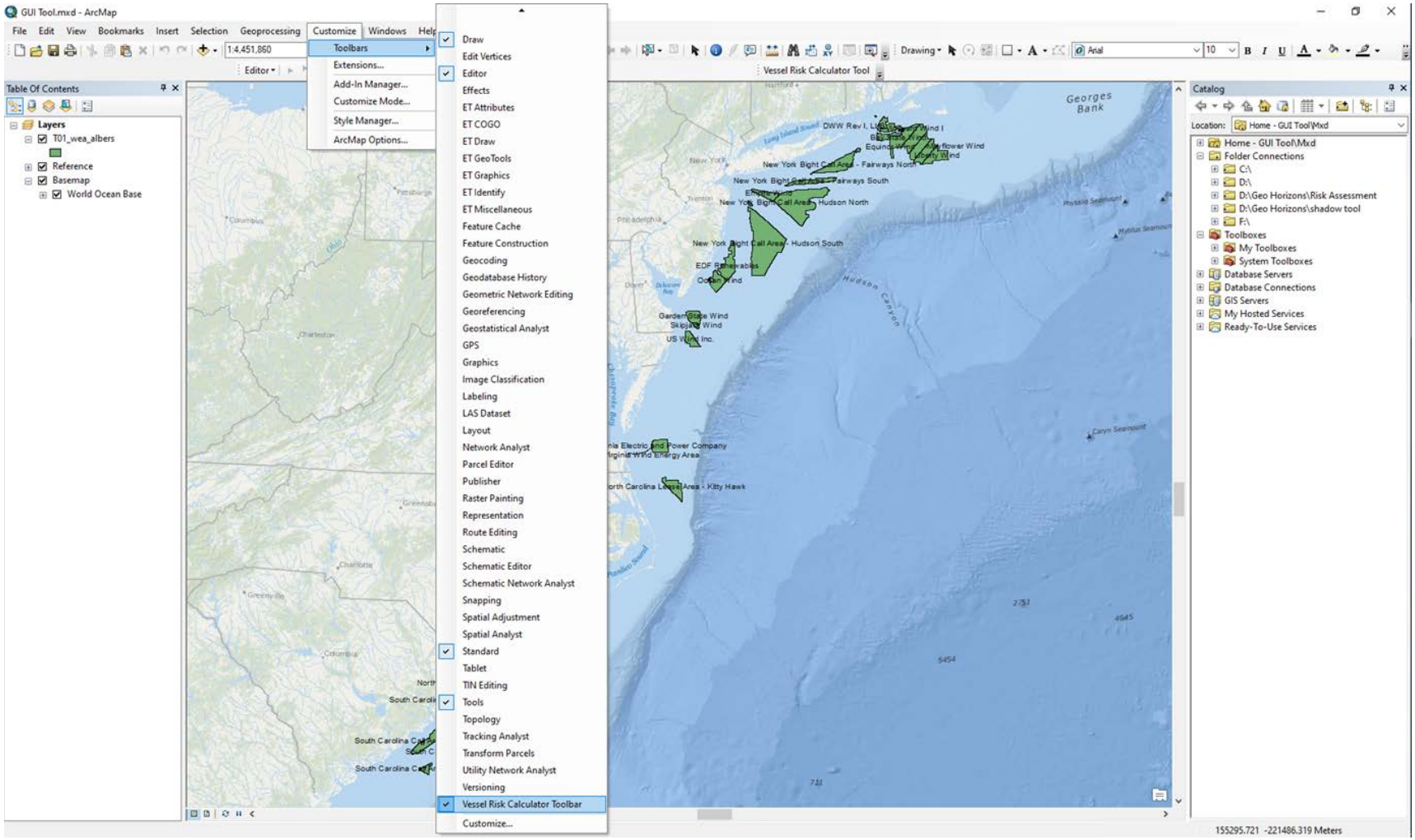


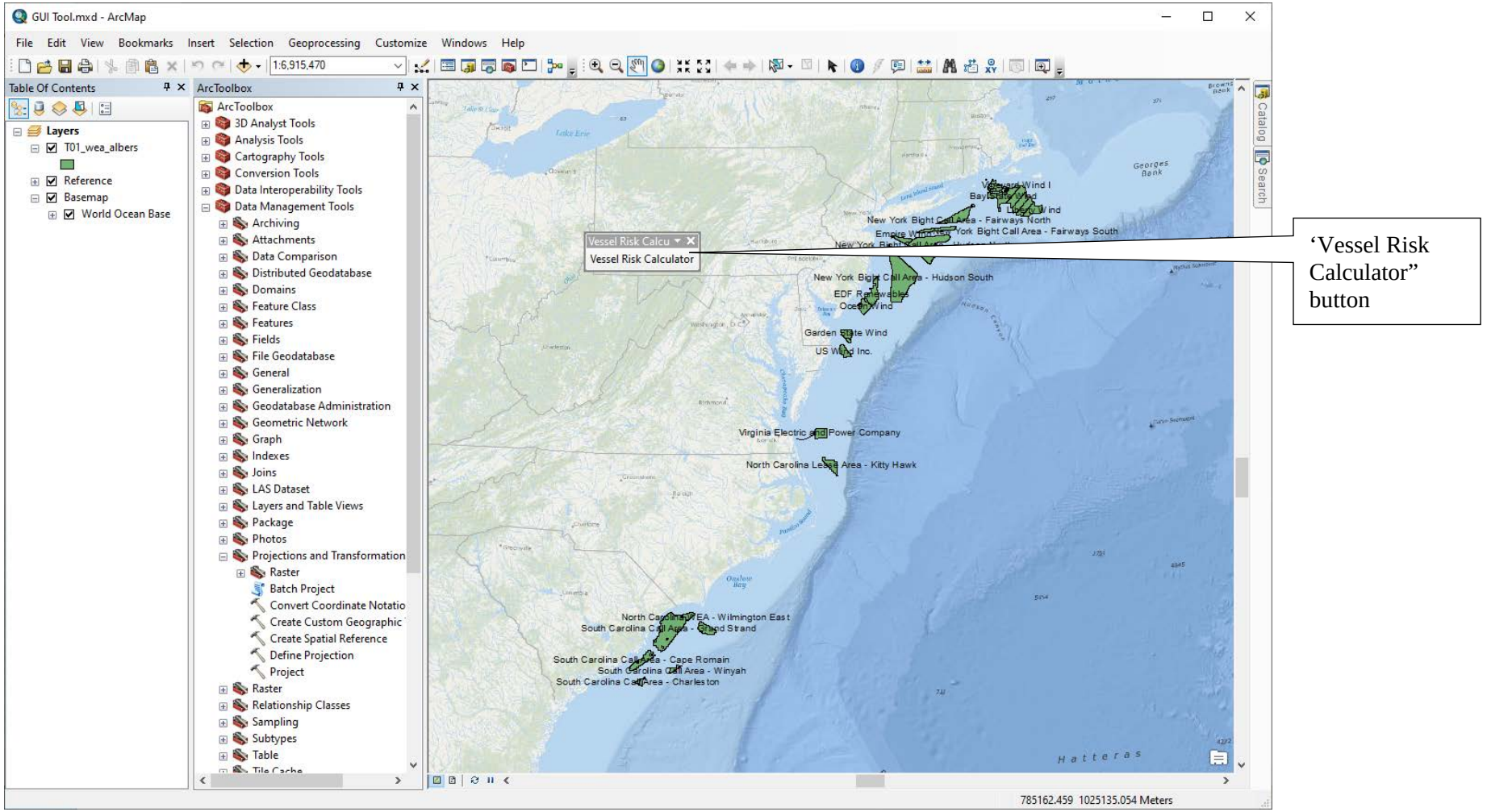
Figure 8. ArcMap Calculator bar menu showing how to access the Vessel Risk Calculator toolbar

11. Open GUI Tool.mxd ArcGIS document file in the folder (**Figure 9**).

Next **note** that the overall methodology for the Calculator development was to decompose vessel encounter computations into two separate components:

- During vessel transit to and from a wind farm area
- During vessel movement within a wind farm area

The GUI's initial screen shows the 'Vessel Risk Calculator 'button to calculate the vessel encounter numbers as shown in **Figure 9**.



‘Vessel Risk Calculator” button

Figure 9. Vessel Risk Calculator toolbar initiated in ArcMap

ArcMap needs to be restarted every time the Vessel Risk Calculator Add-in is installed or removed using the Add-In Manager.

3 Getting Started

Before utilizing the GUI, the user should first begin to identify a scenario. For example, the user should be considering a scenario organized by the month, ports and wind farms, marine species of interest and operational phase. The selection and file naming of scenarios is important for using the Aggregator Module (**Section 3.3**) to aggregate the desired scenario total risk. Remember to open the .mxd in the 'GUI workspace\data\mxd data' folder called GUI Tool.mxd. The Vessel Risk Calculator toolbar will open automatically when the mxd opens, but it be turned off manually by clicking 'Customize -> Toolbars -> Vessel Risk Calculator Toolbar' as shown in **Figure 8**.

3.1 Calculator File Structure

The Calculator is built as an ArcGIS add-in and all the supporting files, data, and output folders are installed during the initial installation. Critical files are installed in the system folder. All files can be viewed and accessed using Esri Desktop Software (e.g., ArcMap or ArcCatalog) and file names should not be modified, or files deleted.

The GUI workspace (**Figure 10**) is where all the input and output data will be stored on the computer. This is the directory where the GUI interacts with the data folder and creates the output. These data folders provide the essential data on the risk factor matrix that help to forecast an encounter and ultimately helps to determine the vulnerability of an animal to a vessel strike.

The GUI workspace is divided into two folders:

1. Data

The data folder is in turn divided into four separate data subfolders:

1. Wind Farm area: The wind farm data folder holds all the files about the wind farms and their location.
2. Species data: All risk factor matrices related to species characteristics and behavior is stored in this data folder.
3. Track line: Track line geodatabase stores all the track line datasets.
4. Vessel data: Data about vessel categories, characteristics, and their activities are stored in this folder.

2. Output

This directory holds two the output geodatabase and the output text files from both the Transit and Wind Farm area scenarios distinguished by prefix T and WF respectively. The user will develop scenarios for each transit which provides a monthly risk value and a wind farm area which provides a 24-hr risk value.

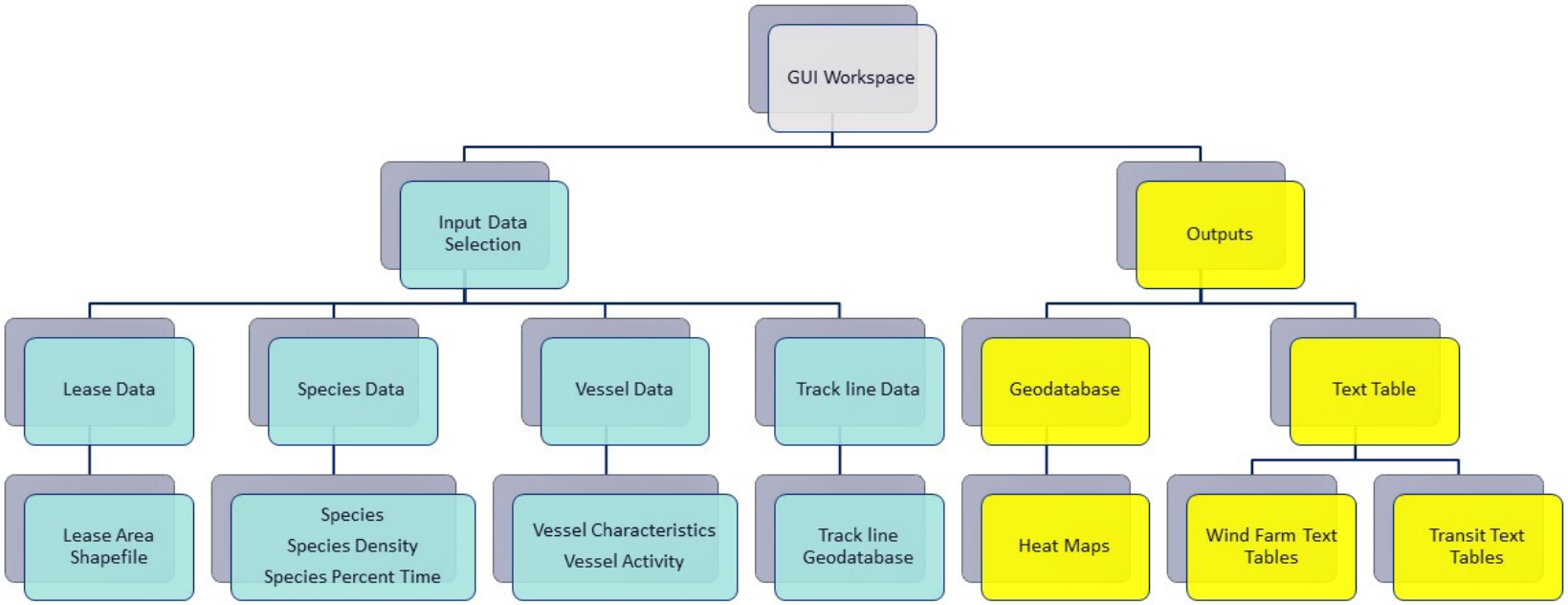


Figure 10. Calculator file structure

Important Note: The Importance of File Structure

The project (see **Section 1.3**) can be thought of as a folder in which related scenarios are stored to help the user to organize related output data and ensure proper filing of each scenario. In the event no project name is assigned output file will have a 'temp' attached to the filename instead of the project name and is stored in a default location. However, **note** that temp files are replaced with similarly named files upon a new run; therefore, it is always recommended to enter a project name when prompted to aid in saving and not overwriting Calculator-derived scenarios. When choosing a project name, do not include an underscore (_) in the name or the characters after the underscore will not be recognized in the Aggregator Module (**Section 3.3**).

It is recommended that for housekeeping purposes, like any 'folder' the project name provide clues to its content and purpose of that particular compilation of scenarios.

If the user desired to ultimately have the sum of encounters for every month in, for example, a 3 year period, scenarios would need to be run for each month of the 3 year period and saved under the project name, especially to allow subsequent summarization by the Aggregator module (**Section 3.3**).

The assembly of scenarios under a project then allows for application of the Aggregator module to compute the total number of encounters (and to some degree, risk, if aversion had been applied in scenarios) across all the scenarios assembled in the project. However, the user is of course free to manually sum up encounters among any individual scenarios at any time.

Note that both transit and wind farm scenarios can be placed under the same project name. The user is prompted to choose either transit or wind farm data to sum across scenarios and the Aggregator module automatically differentiates among transit and wind farm scenarios in its aggregation process. The Aggregator module does not combine data from both transits and wind farms.

3.2 Calculator Steps

Before running the Calculator, the users are required to select the GUI workspace in the 'Project Folder Settings' tab (**Figure 11**). It is recommended that a new project subfolder be created that contains no other files. If multiple scenarios will be modeled and risk probabilities later aggregated, each scenario under this subfolder should be assigned a unique name to avoid overwriting of scenarios. The GUI workspace is the location that all the input and output data will be stored on the computer; this will be the location to which the user will navigate to obtain reports on their scenarios from the Calculator. The user selects the output location in the 'Project Folder Settings' tab shown below. This will consist of 'Data' folder that contains the data used to run the Calculator, and an 'Output' folder that will contain the output products of the Calculator. **Figure 10** provides a diagram of the full file structure.

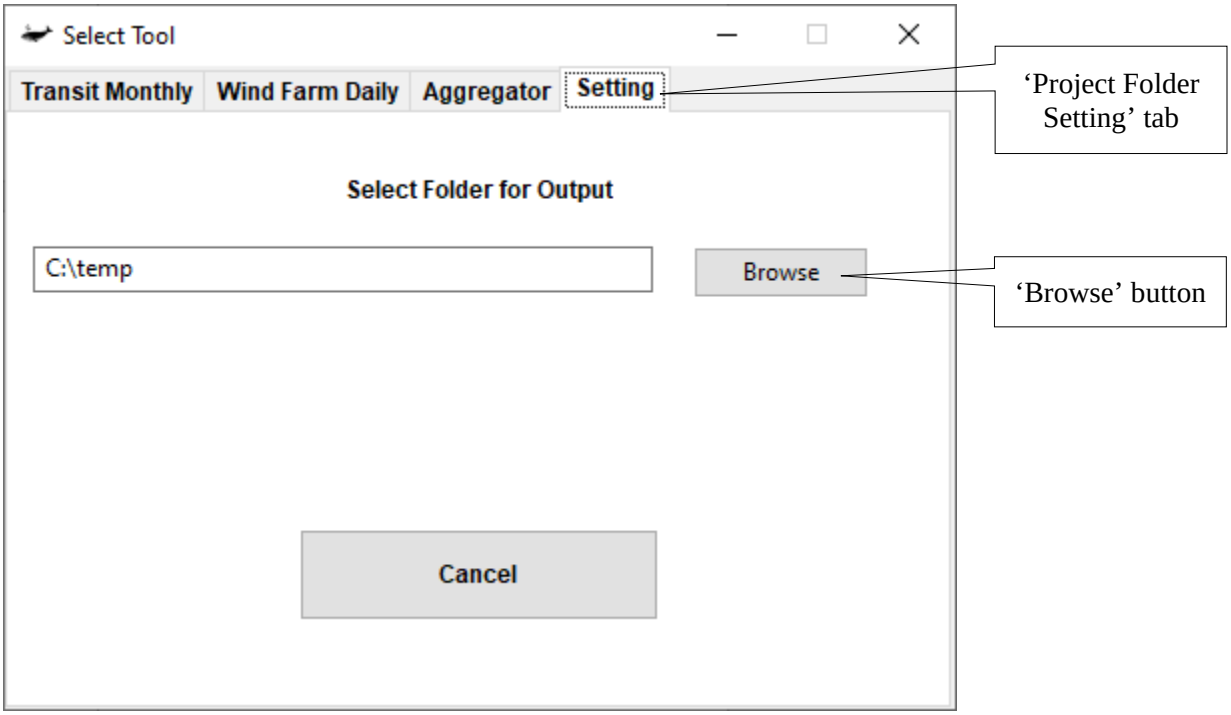


Figure 11. Calculator 'Project Folder Setting' tab for selecting the GUI Workspace folder

Click on the 'Project Folder Setting' tab, then click on the 'Browse' button and select the GUI Workspace on the machine where the data folder and output folder will be created (**Figure 11**).

Note: Make sure the folder selected for the GUI Workspace is empty and the user has permission of read and write in the folder.

Note: Make sure the folder location is NOT in the same folder where the tool was installed.

Before every run make sure to check that the GUI Workspace folder is selected; when selected that should be displayed in the text control box.

3.2.1 Inputs for Vessel Transit Total

The Vessel Transit Total integrates the modeled number of encounters calculated for each 1 km^2 block along the vessel transit from a selected port to a wind farm area into a combined number of predicted encounters along the entire vessel transit track. See Section 4.1 of the associated report[1] for further discussion regarding GUI inputs and model formulas.

Note that the Calculator determines the expected values along only one round-trip (out and back) vessel transit track to a wind farm area per run although this track may be composed of multiple vessels using that track. If the user needs to calculate for more than one vessel transit track, the track should be run separately and then the user aggregates the values either manually by summing up the output from individual scenarios or through use of the Aggregator module (**See Section 3.3**).

After selection the output folder, proceed to set the parameters for the scenario:

1. The project name (**Figure 12**) helps in aggregating the scenarios together with similar parameters. The project name is optional but highly recommended. In case no project name is assigned an output file will have a 'temp' attached to the filename instead of the project name and temp files are replaced with similar name files from previous scenarios; therefore, it is always recommended to use a unique Project Name to ensure files are not overwritten. When choosing a project name, do not include an underscore (_) in the name or the characters after the underscore will not be recognized in the Aggregator Module (**Section 3.3**).

2. Select the desired wind farm area that the vessels will transit to from the drop-down list under the 'Transit Monthly' tab (**Figure 12**). Selecting the wind farm (i.e., Wind Energy / Planning Area, Call Area, Lease Area, actual wind farm, etc.) destination narrows down the list of pre-programmed tracks available.

   Note: the wind farm areas available for selection are data from the BOEM Renewable Energy GIS Data (*BOEM_Lease_Areas_4_13_2020* and *BOEM_Wind_Planning_Areas_4_13_2020*). **Appendix A** provides a table with the project names and lease numbers that is included in the GIS data used. Additional project boundaries may be included within an existing lease boundary.

   Note however, the user can also draw their own vessel transit track to model specific vessel transit scenarios (See **Section 3.4**).

3. Once the wind farm destination is selected, in the same dialog box, click the 'Select Track Line' button to get to the pre-drawn 'Track Line' selection screen (**Figure 12**). Figures illustrating the various pre-drawn Track Lines are included in **Appendix B**.

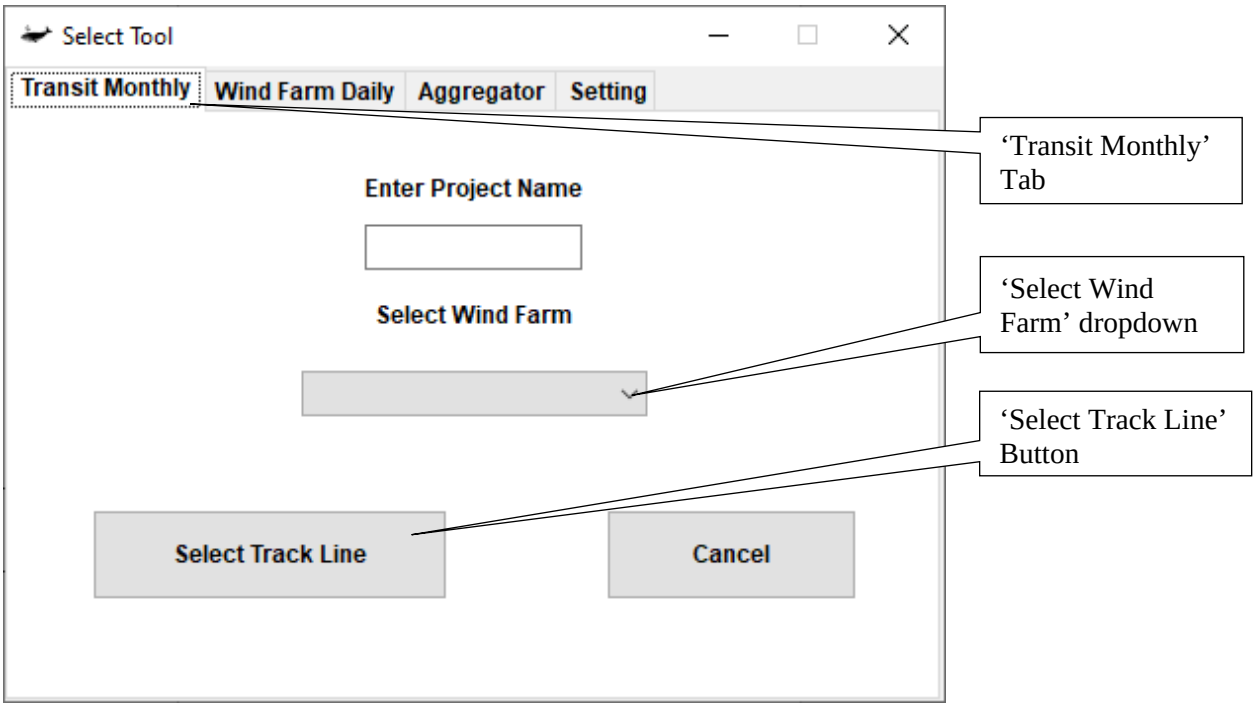


Figure 12. Calculator GUI 'Transit Monthly' tab for starting vessel transit total. Enter the wind farm destination area, then select the available track line for the destination area chosen.

4. Select a pre-drawn Track line from the drop-down and select the ‘Select Vessel Parameters’ button (**Figure 13**).

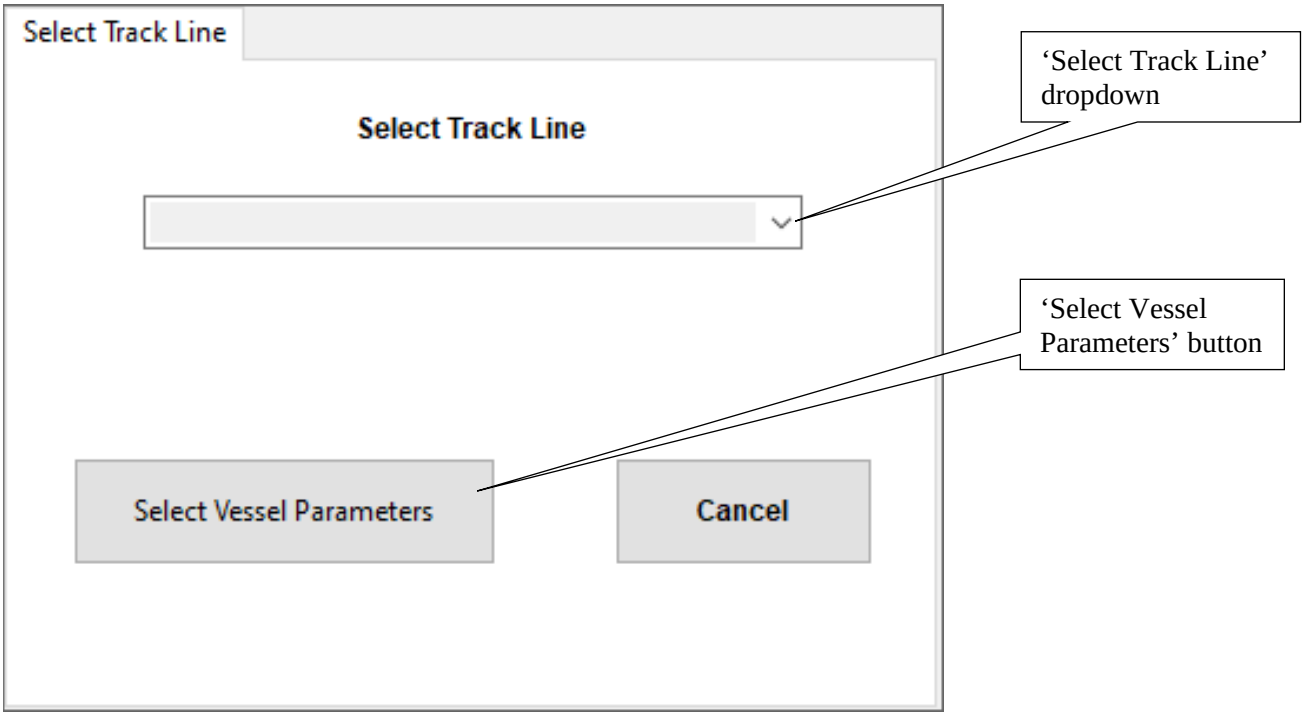


Figure 13. Track line select tab in vessel transit total

Vessel Parameters

Once the transit route is selected, the vessel parameters screen (**Figure 14**) lets users select the vessel types to model, vessel speeds, and month of operation. Variable vessel speeds and months cannot be selected but can be modeled independently under different scenarios for aggregation using the Aggregator module (**Section 3.3**). To use this screen:

1. Select the month from the drop-down list (**Figure 14**).
2. Select the vessel categories from the drop-down list (**Figure 14**). Users need to select at least one vessel category to calculate the encounter risk; multiple vessels may be run simultaneously but the encounter numbers are pooled among all vessels selected. The typical scenario could range from a single vessel run to a large number of vessels run in all the categories within the selected month to get the aggregate strike risk of all vessels selected for that month.
3. Vessel speeds is same for the whole transit. All the speeds are initially filled by default values based on each vessel category, though the Calculator lets users change these values accordingly for running various scenarios.
4. Users can select the aversion coefficient for each vessel category by sliding the slider for each vessel category to incorporate in the strike risk calculations (**Figure 14**), from aversion 0% of the time to 100% of the time.

Important Note: Vessel Speed and Encounter Rate Relationship

Reduction in vessel speed automatically results in an increased encounter number because the vessel will now be spending more time in any unit (1 km^2) area, creating more encounters. However, it is recognized and supported in the literature that reduction in speed can mitigate vessel strikes because of increased opportunity for aversions. Consequently, it is strongly recommended that the User employ their best professional judgement and utilize, as desired, to modify aversion using controls in the GUI to revise a given scenario to account for the real-world possibility of aversion success (both by vessel and animal) especially when reducing vessel speed.

5. The number of trips can be representative of the number of trips within any time period of interest within the month chosen. Users are required to select at least one trip in either vessel category to calculate strike risk. Users may select the number of trips in each vessel category chosen that transits between a port and a wind farm area, transits within the wind farm area, and returns to port. One trip within a route from a port is counted as one complete round trip.
6. After entering the desired Vessel Parameters, click the 'Select Animal Parameters' button (**Figure 14**).

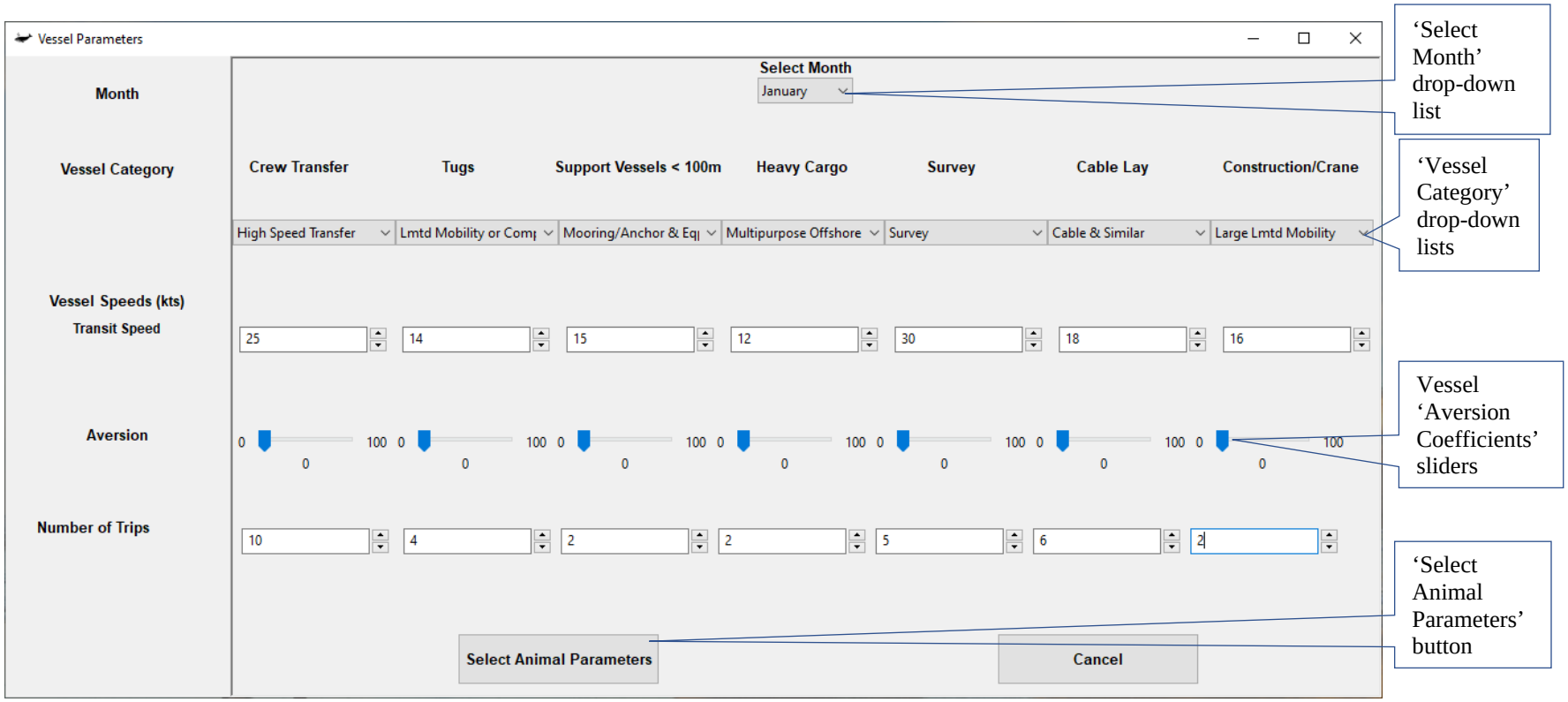


Figure 14. Vessel parameter screen to enter vessel parameters and their number of trips in the vessel transit total

The animal Parameters screen (**Figure 15**) lets users select the animal species and their activity category in that region; to use this screen:

1. Select the desired species from the drop-down list (**Figure 15**). Based on the selected species the other parameters get default values. Only one species may be used at a time. To assess the combined risk of multiple species, different scenarios, each with the desired species, must be run separately and then those encounter risks summed manually or the scenarios organized under a common project name for summation by the Aggregator module.
2. The animal population parameter lets users select the percentage of the population within each activity category (**Figure 15**).
    a) Foraging: the percentage of the marine mammal population in foraging activity can be adjusted using the slider bar, though the foraging and migrating population sums to 100 minus population of calf rearing and surface-active groups (SAG). The foraging percent for sea turtle species is set to 100.
    b) Migrating: the percentage of the population in migrating activity can be adjusted using and slider bar and like foraging. The slider moves automatically to adjust the other values and always sums up to 100.
    c) Calf rearing: The population percentage is fixed and is displayed in the text box based on the species. This can, however, be changed by going in the data file and replacing the number. More detail in **Section 3.3**.
    d) SAG (Surface Active Group): SAG activity only applies to North Atlantic right whale species in the Northeast and Mid-Atlantic zones and the population percentage number is fixed. Here again, the population percentage can be changed by going into the data file and replacing the number. More detail in **Section 3.3**.
3. Users can select the animal aversion coefficient for the species by sliding the slider (**Figure 15**) to incorporate in the strike risk calculations (0 = no aversion [strike occurs]; 100 = full aversion [no possibility of a strike]).
4. After entering the desired information, click the 'Calculate Expected Encounter' button (**Figure 15**). This provides the round-trip expected number of animal strikes for that scenario, adjusted by the aversion factor selection.

IMPORTANT NOTE:

To obtain just the expected number of encounters in the transit to and from the selected wind farm area the aversion factors for BOTH vessels and animal (below) must be set to zero. Otherwise, aversion can reduce the number of encounters and the returned value from the Calculator and becomes more of a risk assessment than simply a count of encounters. While setting aversion to 0 can be taken to simply mean the expected number of encounters it also represents the highest potential estimate of strikes because with 0 aversion, every encounter could be considered a strike.

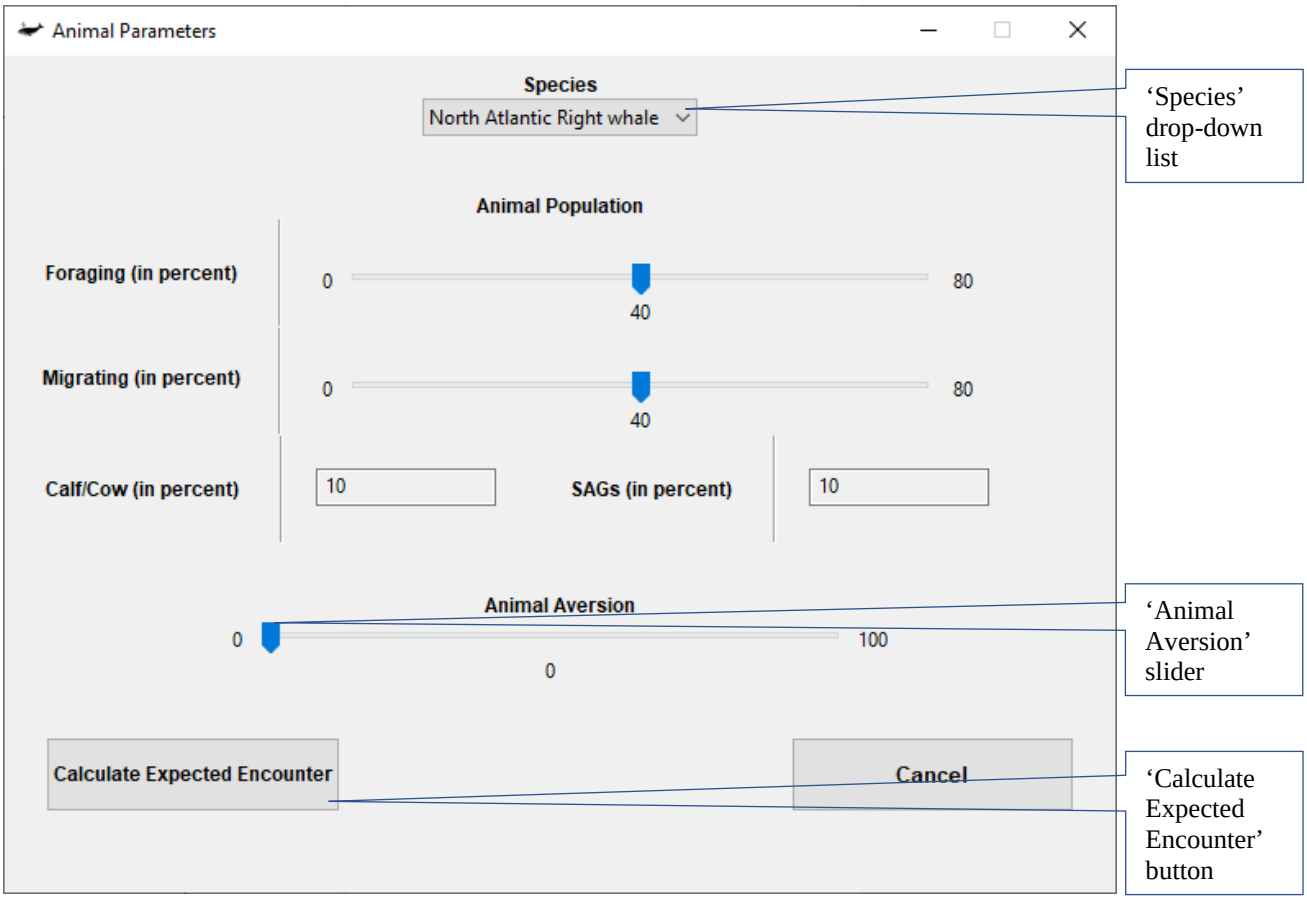


Figure 15. Animal parameters screen to enter foraging, migration, SAGs and calf/cow percentages, along with likelihood of animal aversion

The Calculator will go through the calculations of the strike risk with the selected species along the selected vessel transit track for all the vessels selected by the user recursively and provide the output, expected number of animal strikes along the route as a message box.

Figure 16 is an example screenshot of the total expected number of animal encounters; which with aversions all set to zero, is also the number in which there is a likelihood of a strike. The number of encounters for the user-defined scenario is displayed in this output box once computations are complete. Setting all aversion (vessels and animal) to zero results in the most conservative (highest) strike estimation.

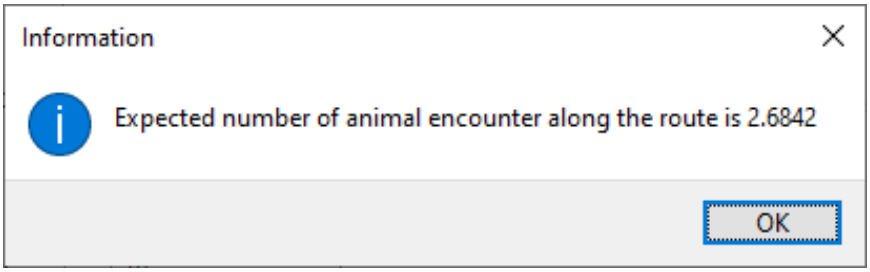


Figure 16. Message box showing the output for vessel transit total

The Calculator provides detailed output in two formats:

1. Table format: The Calculator creates a table output as a text file (**Table 1**). The file contains the expected encounter values for each 1 km block of the track starting from port to the wind farm. The file shows the contribution of each vessel category in expected encounter and also provides cumulative expected encounter value for each 1 km^2 block. The expected number of strikes during the whole transit is shown at the bottom of the file. This text file can easily be formatted into an Excel table by using the import wizard as shown in **Table 2**.
2. Heat map (**Figure 17**): The Calculator produces encounter risk-based heat maps that correspond to the scenario tabular data, displayed in a geographic context that is color-scaled for the range of expected encounter values for each 1 km block of the track starting from port to the wind farm. These values are stored in the geodatabase located in GUI workspace output folder.

The Calculator-generated naming convention used for storing geospatial files where T stands for Transit is structured as follows to keep it segregated from wind farm solutions:

T_Project Name_Port_Wind Farm_route#_Species_month.txt[6]

[6] The operator's Windows operating system must be set up to show the file name extension to show the .txt portion of the file name or no .txt will be shown in the file name; either way, the file type will be shown as text file.

Table 1. Monthly Vessel transit total example table format output text file

Project Name = solotest_20201227
Track Route = NewHaven_BayStateWind_route50
Month = February
Species = Humpback whale
Foraging percentage = 10, Migrating percentage = 85, Cow/Calf percentage = 5.0, SAG percentage = 0.0
Animal Aversion = 0
High Speed Transfer,Lmtd Mobility or Companion,Mooring/Anchor & Eqpmt Handler,Multipurpose Offshore,Survey,Cable & Similar,Large Lmtd Mobility,
number of trips:10,10,5,5,5,5,0,
Inshore Speed: 25,14,15,12,30,18,0,
Open Ocean Speed: 25,14,15,12,30,18,0,
Wind Farm Speed: 25,14,15,12,30,18,0,
Vessel Aversion: 0,0,0,0,0,0,0,
0.00118,0.00174,0.00243,0.00297,0.00223,0.00408,0.0,0.08781,
0.00118,0.00174,0.00243,0.00297,0.00223,0.00408,0.0,0.08781,
0.00118,0.00174,0.00243,0.00297,0.00223,0.00408,0.0,0.08781,
0.00118,0.00174,0.00243,0.00297,0.00223,0.00408,0.0,0.08781,
0.00118,0.00174,0.00243,0.00297,0.00223,0.00408,0.0,0.08781,
0.00118,0.00174,0.00243,0.00297,0.00223,0.00408,0.0,0.08781,
0.00118,0.00174,0.00243,0.00297,0.00223,0.00408,0.0,0.08781,
0.00118,0.00174,0.00243,0.00297,0.00223,0.00408,0.0,0.08781,
0.00118,0.00174,0.00243,0.00297,0.00223,0.00408,0.0,0.08781,
0.00118,0.00174,0.00243,0.00297,0.00223,0.00408,0.0,0.08781,
0.00101,0.0015,0.00209,0.00256,0.00191,0.00351,0.0,0.07545,
0.00101,0.0015,0.00209,0.00256,0.00191,0.00351,0.0,0.07545,
0.00101,0.0015,0.00209,0.00256,0.00191,0.00351,0.0,0.07545,
0.00101,0.0015,0.00209,0.00256,0.00191,0.00351,0.0,0.07545,
0.00101,0.0015,0.00209,0.00256,0.00191,0.00351,0.0,0.07545,
0.00101,0.0015,0.00209,0.00256,0.00191,0.00351,0.0,0.07545,
0.00101,0.0015,0.00209,0.00256,0.00191,0.00351,0.0,0.07545,
0.00101,0.0015,0.00209,0.00256,0.00191,0.00351,0.0,0.07545,
0.00101,0.0015,0.00209,0.00256,0.00191,0.00351,0.0,0.07545,
0.00101,0.0015,0.00209,0.00256,0.00191,0.00351,0.0,0.07545,
0.00053,0.00078,0.00109,0.00134,0.001,0.00183,0.0,0.03942,
0.00072,0.00107,0.00149,0.00182,0.00137,0.0025,0.0,0.05387,
0.00072,0.00107,0.00149,0.00182,0.00137,0.0025,0.0,0.05387,
0.00072,0.00107,0.00149,0.00182,0.00137,0.0025,0.0,0.05387,
0.00072,0.00107,0.00149,0.00182,0.00137,0.0025,0.0,0.05387,
0.00072,0.00107,0.00149,0.00182,0.00137,0.0025,0.0,0.05387,
0.00072,0.00107,0.00149,0.00182,0.00137,0.0025,0.0,0.05387,
0.00072,0.00107,0.00149,0.00182,0.00137,0.0025,0.0,0.05387,
0.00072,0.00107,0.00149,0.00182,0.00137,0.0025,0.0,0.05387,
0.00072,0.00107,0.00149,0.00182,0.00137,0.0025,0.0,0.05387,
0.00072,0.00107,0.00149,0.00182,0.00137,0.0025,0.0,0.05387,
0.00074,0.00109,0.00153,0.00187,0.0014,0.00256,0.0,0.05515,
0.00074,0.00109,0.00153,0.00187,0.0014,0.00256,0.0,0.05515,
0.00074,0.00109,0.00153,0.00187,0.0014,0.00256,0.0,0.05515,
0.00074,0.00109,0.00153,0.00187,0.0014,0.00256,0.0,0.05515,
0.00074,0.00109,0.00153,0.00187,0.0014,0.00256,0.0,0.05515,

0.00074,0.00109,0.00153,0.00187,0.0014,0.00256,0.0,0.05515,
0.00074,0.00109,0.00153,0.00187,0.0014,0.00256,0.0,0.05515,
0.00074,0.00109,0.00153,0.00187,0.0014,0.00256,0.0,0.05515,
0.00074,0.00109,0.00153,0.00187,0.0014,0.00256,0.0,0.05515,
0.00074,0.00109,0.00153,0.00187,0.0014,0.00256,0.0,0.05515,
0.00086,0.00127,0.00177,0.00217,0.00162,0.00298,0.0,0.06403,
0.00086,0.00127,0.00177,0.00217,0.00162,0.00298,0.0,0.06403,
0.00086,0.00127,0.00177,0.00217,0.00162,0.00298,0.0,0.06403,
0.00086,0.00127,0.00177,0.00217,0.00162,0.00298,0.0,0.06403,
0.00086,0.00127,0.00177,0.00217,0.00162,0.00298,0.0,0.06403,
0.00086,0.00127,0.00177,0.00217,0.00162,0.00298,0.0,0.06403,
0.00086,0.00127,0.00177,0.00217,0.00162,0.00298,0.0,0.06403,
0.00086,0.00127,0.00177,0.00217,0.00162,0.00298,0.0,0.06403,
0.00086,0.00127,0.00177,0.00217,0.00162,0.00298,0.0,0.06403,
0.00106,0.00156,0.00218,0.00266,0.00199,0.00365,0.0,0.07862,
0.00106,0.00156,0.00218,0.00266,0.00199,0.00365,0.0,0.07862,
0.00106,0.00156,0.00218,0.00266,0.00199,0.00365,0.0,0.07862,
0.00106,0.00156,0.00218,0.00266,0.00199,0.00365,0.0,0.07862,
0.00106,0.00156,0.00218,0.00266,0.00199,0.00365,0.0,0.07862,
0.00106,0.00156,0.00218,0.00266,0.00199,0.00365,0.0,0.07862,
0.00106,0.00156,0.00218,0.00266,0.00199,0.00365,0.0,0.07862,
0.00106,0.00156,0.00218,0.00266,0.00199,0.00365,0.0,0.07862,
0.00106,0.00156,0.00218,0.00266,0.00199,0.00365,0.0,0.07862,
0.00106,0.00156,0.00218,0.00266,0.00199,0.00365,0.0,0.07862,
0.00112,0.00165,0.0023,0.00281,0.00211,0.00386,0.0,0.08306,
0.00112,0.00165,0.0023,0.00281,0.00211,0.00386,0.0,0.08306,
0.00112,0.00165,0.0023,0.00281,0.00211,0.00386,0.0,0.08306,
0.00112,0.00165,0.0023,0.00281,0.00211,0.00386,0.0,0.08306,
0.00112,0.00165,0.0023,0.00281,0.00211,0.00386,0.0,0.08306,
0.00112,0.00165,0.0023,0.00281,0.00211,0.00386,0.0,0.08306,
0.00112,0.00165,0.0023,0.00281,0.00211,0.00386,0.0,0.08306,
0.00112,0.00165,0.0023,0.00281,0.00211,0.00386,0.0,0.08306,
0.00112,0.00165,0.0023,0.00281,0.00211,0.00386,0.0,0.08306,
0.00112,0.00165,0.0023,0.00281,0.00211,0.00386,0.0,0.08306,
0.00118,0.00174,0.00243,0.00298,0.00223,0.00408,0.0,0.08783,
0.00118,0.00174,0.00243,0.00298,0.00223,0.00408,0.0,0.08783,
0.00118,0.00174,0.00243,0.00298,0.00223,0.00408,0.0,0.08783,
0.00118,0.00174,0.00243,0.00298,0.00223,0.00408,0.0,0.08783,
0.00118,0.00174,0.00243,0.00298,0.00223,0.00408,0.0,0.08783,
0.00118,0.00174,0.00243,0.00298,0.00223,0.00408,0.0,0.08783,
0.00118,0.00174,0.00243,0.00298,0.00223,0.00408,0.0,0.08783,
0.00118,0.00174,0.00243,0.00298,0.00223,0.00408,0.0,0.08783,
0.00118,0.00174,0.00243,0.00298,0.00223,0.00408,0.0,0.08783,
0.00118,0.00174,0.00243,0.00298,0.00223,0.00408,0.0,0.08783,
0.00106,0.00156,0.00218,0.00267,0.002,0.00366,0.0,0.07871,
0.00106,0.00156,0.00218,0.00267,0.002,0.00366,0.0,0.07871,
0.00106,0.00156,0.00218,0.00267,0.002,0.00366,0.0,0.07871,
0.00106,0.00156,0.00218,0.00267,0.002,0.00366,0.0,0.07871,
0.00106,0.00156,0.00218,0.00267,0.002,0.00366,0.0,0.07871,
0.00106,0.00156,0.00218,0.00267,0.002,0.00366,0.0,0.07871,

0.00106,0.00156,0.00218,0.00267,0.002,0.00366,0.0,0.07871,
0.00106,0.00156,0.00218,0.00267,0.002,0.00366,0.0,0.07871,
0.00106,0.00156,0.00218,0.00267,0.002,0.00366,0.0,0.07871,
0.00106,0.00156,0.00218,0.00267,0.002,0.00366,0.0,0.07871,
0.00108,0.0016,0.00223,0.00273,0.00204,0.00374,0.0,0.08048,

Table 2. Monthly Vessel transit total example table converted using Excel Import Wizard

Project Name = solotest_20201227	Column1	_1	_2	_3	_4	_5	_6
Track Route = NewHaven_BayStateWind_route50							
Month = February							
Species = Humpback whale							
Foraging percentage = 10	Migrating percentage = 85	Cow/Calf percentage = 5.0	SAG percentage = 0.0				
Animal Aversion = 0							
High Speed Transfer	Lmtd Mobility or Companion	Mooring/Anchor & Eqpmt Handler	Multipurpose Offshore	Survey	Cable & Similar	Large Lmtd Mobility	
Number of trips:10	10	5	5	5	5	0	
Inshore Speed: 25	14	15	12	30	18	0	
Open Ocean Speed: 25	14	15	12	30	18	0	
Wind Farm Speed: 25	14	15	12	30	18	0	
Vessel Aversion: 0	0	0	0	0	0	0	
0.00118	0.00174	0.00243	0.00297	0.00223	0.00408	0	0.08781
0.00118	0.00174	0.00243	0.00297	0.00223	0.00408	0	0.08781
0.00118	0.00174	0.00243	0.00297	0.00223	0.00408	0	0.08781
0.00118	0.00174	0.00243	0.00297	0.00223	0.00408	0	0.08781
0.00118	0.00174	0.00243	0.00297	0.00223	0.00408	0	0.08781
0.00118	0.00174	0.00243	0.00297	0.00223	0.00408	0	0.08781
0.00118	0.00174	0.00243	0.00297	0.00223	0.00408	0	0.08781
0.00118	0.00174	0.00243	0.00297	0.00223	0.00408	0	0.08781
0.00118	0.00174	0.00243	0.00297	0.00223	0.00408	0	0.08781
0.00118	0.00174	0.00243	0.00297	0.00223	0.00408	0	0.08781
0.00101	0.0015	0.00209	0.00256	0.00191	0.00351	0	0.07545
0.00101	0.0015	0.00209	0.00256	0.00191	0.00351	0	0.07545
0.00101	0.0015	0.00209	0.00256	0.00191	0.00351	0	0.07545
0.00101	0.0015	0.00209	0.00256	0.00191	0.00351	0	0.07545
0.00101	0.0015	0.00209	0.00256	0.00191	0.00351	0	0.07545
0.00101	0.0015	0.00209	0.00256	0.00191	0.00351	0	0.07545
0.00101	0.0015	0.00209	0.00256	0.00191	0.00351	0	0.07545
0.00101	0.0015	0.00209	0.00256	0.00191	0.00351	0	0.07545

Project Name = solotest_20201227	Column1	_1	_2	_3	_4	_5	_6
0.00101	0.0015	0.00209	0.00256	0.00191	0.00351	0	0.07545
0.00101	0.0015	0.00209	0.00256	0.00191	0.00351	0	0.07545
0.00053	0.00078	0.00109	0.00134	0.001	0.00183	0	0.03942
0.00072	0.00107	0.00149	0.00182	0.00137	0.0025	0	0.05387
0.00072	0.00107	0.00149	0.00182	0.00137	0.0025	0	0.05387
0.00072	0.00107	0.00149	0.00182	0.00137	0.0025	0	0.05387
0.00072	0.00107	0.00149	0.00182	0.00137	0.0025	0	0.05387
0.00072	0.00107	0.00149	0.00182	0.00137	0.0025	0	0.05387
0.00072	0.00107	0.00149	0.00182	0.00137	0.0025	0	0.05387
0.00072	0.00107	0.00149	0.00182	0.00137	0.0025	0	0.05387
0.00072	0.00107	0.00149	0.00182	0.00137	0.0025	0	0.05387
0.00072	0.00107	0.00149	0.00182	0.00137	0.0025	0	0.05387
0.00072	0.00107	0.00149	0.00182	0.00137	0.0025	0	0.05387
0.00074	0.00109	0.00153	0.00187	0.0014	0.00256	0	0.05515
0.00074	0.00109	0.00153	0.00187	0.0014	0.00256	0	0.05515
0.00074	0.00109	0.00153	0.00187	0.0014	0.00256	0	0.05515
0.00074	0.00109	0.00153	0.00187	0.0014	0.00256	0	0.05515
0.00074	0.00109	0.00153	0.00187	0.0014	0.00256	0	0.05515
0.00074	0.00109	0.00153	0.00187	0.0014	0.00256	0	0.05515
0.00074	0.00109	0.00153	0.00187	0.0014	0.00256	0	0.05515
0.00074	0.00109	0.00153	0.00187	0.0014	0.00256	0	0.05515
0.00074	0.00109	0.00153	0.00187	0.0014	0.00256	0	0.05515
0.00074	0.00109	0.00153	0.00187	0.0014	0.00256	0	0.05515
0.00086	0.00127	0.00177	0.00217	0.00162	0.00298	0	0.06403
0.00086	0.00127	0.00177	0.00217	0.00162	0.00298	0	0.06403
0.00086	0.00127	0.00177	0.00217	0.00162	0.00298	0	0.06403
0.00086	0.00127	0.00177	0.00217	0.00162	0.00298	0	0.06403
0.00086	0.00127	0.00177	0.00217	0.00162	0.00298	0	0.06403
0.00086	0.00127	0.00177	0.00217	0.00162	0.00298	0	0.06403
0.00086	0.00127	0.00177	0.00217	0.00162	0.00298	0	0.06403
0.00086	0.00127	0.00177	0.00217	0.00162	0.00298	0	0.06403
0.00086	0.00127	0.00177	0.00217	0.00162	0.00298	0	0.06403
0.00086	0.00127	0.00177	0.00217	0.00162	0.00298	0	0.06403

Project Name = solotest_20201227	Column1	_1	_2	_3	_4	_5	_6
0.00106	0.00156	0.00218	0.00266	0.00199	0.00365	0	0.07862
0.00106	0.00156	0.00218	0.00266	0.00199	0.00365	0	0.07862
0.00106	0.00156	0.00218	0.00266	0.00199	0.00365	0	0.07862
0.00106	0.00156	0.00218	0.00266	0.00199	0.00365	0	0.07862
0.00106	0.00156	0.00218	0.00266	0.00199	0.00365	0	0.07862
0.00106	0.00156	0.00218	0.00266	0.00199	0.00365	0	0.07862
0.00106	0.00156	0.00218	0.00266	0.00199	0.00365	0	0.07862
0.00106	0.00156	0.00218	0.00266	0.00199	0.00365	0	0.07862
0.00106	0.00156	0.00218	0.00266	0.00199	0.00365	0	0.07862
0.00106	0.00156	0.00218	0.00266	0.00199	0.00365	0	0.07862
0.00112	0.00165	0.0023	0.00281	0.00211	0.00386	0	0.08306
0.00112	0.00165	0.0023	0.00281	0.00211	0.00386	0	0.08306
0.00112	0.00165	0.0023	0.00281	0.00211	0.00386	0	0.08306
0.00112	0.00165	0.0023	0.00281	0.00211	0.00386	0	0.08306
0.00112	0.00165	0.0023	0.00281	0.00211	0.00386	0	0.08306
0.00112	0.00165	0.0023	0.00281	0.00211	0.00386	0	0.08306
0.00112	0.00165	0.0023	0.00281	0.00211	0.00386	0	0.08306
0.00112	0.00165	0.0023	0.00281	0.00211	0.00386	0	0.08306
0.00112	0.00165	0.0023	0.00281	0.00211	0.00386	0	0.08306
0.00112	0.00165	0.0023	0.00281	0.00211	0.00386	0	0.08306
0.00118	0.00174	0.00243	0.00298	0.00223	0.00408	0	0.08783
0.00118	0.00174	0.00243	0.00298	0.00223	0.00408	0	0.08783
0.00118	0.00174	0.00243	0.00298	0.00223	0.00408	0	0.08783
0.00118	0.00174	0.00243	0.00298	0.00223	0.00408	0	0.08783
0.00118	0.00174	0.00243	0.00298	0.00223	0.00408	0	0.08783
0.00118	0.00174	0.00243	0.00298	0.00223	0.00408	0	0.08783
0.00118	0.00174	0.00243	0.00298	0.00223	0.00408	0	0.08783
0.00118	0.00174	0.00243	0.00298	0.00223	0.00408	0	0.08783
0.00118	0.00174	0.00243	0.00298	0.00223	0.00408	0	0.08783
0.00118	0.00174	0.00243	0.00298	0.00223	0.00408	0	0.08783
0.00106	0.00156	0.00218	0.00267	0.002	0.00366	0	0.07871
0.00106	0.00156	0.00218	0.00267	0.002	0.00366	0	0.07871
0.00106	0.00156	0.00218	0.00267	0.002	0.00366	0	0.07871

Project Name = solotest_20201227	Column1	_1	_2	_3	_4	_5	_6
0.00106	0.00156	0.00218	0.00267	0.002	0.00366	0	0.07871
0.00106	0.00156	0.00218	0.00267	0.002	0.00366	0	0.07871
0.00106	0.00156	0.00218	0.00267	0.002	0.00366	0	0.07871
0.00106	0.00156	0.00218	0.00267	0.002	0.00366	0	0.07871
0.00106	0.00156	0.00218	0.00267	0.002	0.00366	0	0.07871
0.00106	0.00156	0.00218	0.00267	0.002	0.00366	0	0.07871
0.00106	0.00156	0.00218	0.00267	0.002	0.00366	0	0.07871
0.00108	0.0016	0.00223	0.00273	0.00204	0.00374	0	0.08048

The Calculator-generated naming convention used for storing geospatial files is as follows:

- T_Project Name_Port_wind farm_route#_Species_month
- 'T' prefix in the name represents transit to distinguish them from wind farm files which start with prefix 'WF'.

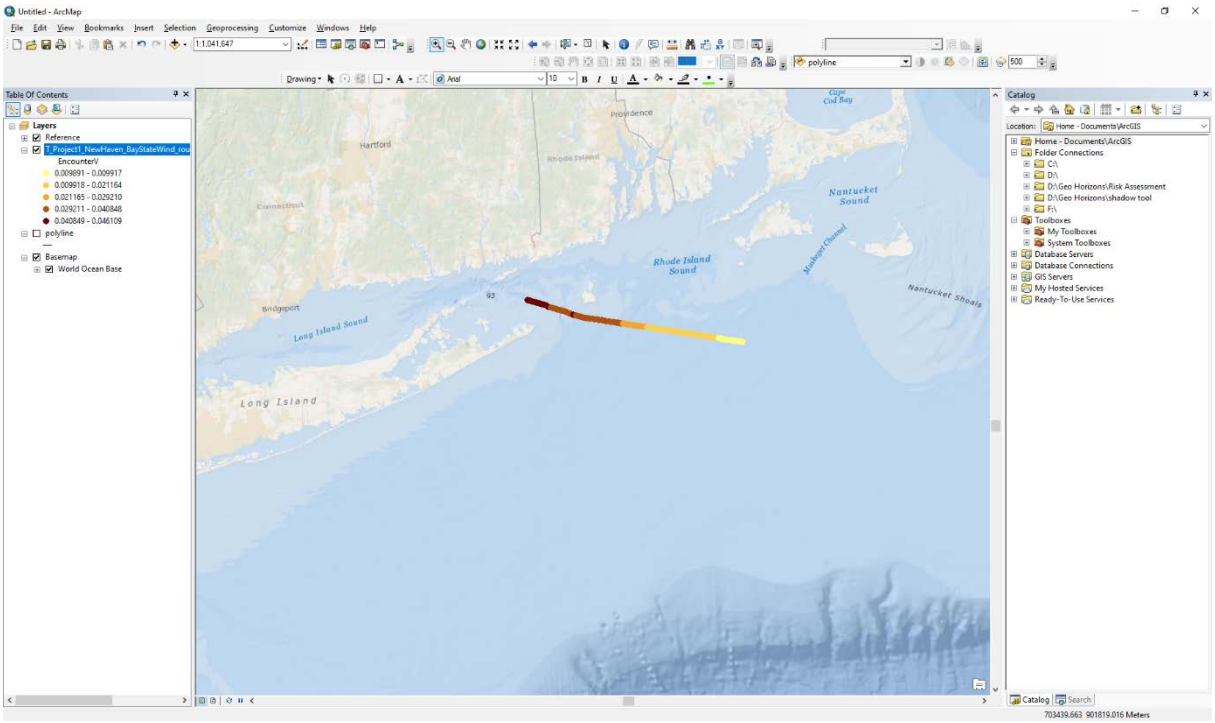


Figure 17. Vessel transit total geospatial format heat map displayed in ArcMap

3.2.2 Inputs for Daily Wind Farm Vessel Risk

Similar to calculating the monthly vessel encounter risk among all the 1-km blocks in a transit using the 'Transit' tab, the 'Wind Farm' tab sums encounter probabilities calculated for each 1-km block within a wind farm area into a combined probability for the entire wind farm area over a 24-hour period (WF total) for a specified month. Vessels are assumed to either travel at an average speed in the wind farm or be stationary within the wind farm during that 24-hour period. See Section 4.2 of the associated report[1] for further discussion regarding GUI inputs and model formulas. The WF total is the expected value based on the following assumptions:

- During a 24-hour period, the vessel's time is divided into two states: vessel at rest and vessel moving at an average speed. These values are derived from Automatic Identification System (AIS) data for European wind farms.
- Each vessel could be engaged in one of the three activities:
  - Construction,
  - Operations and Management (O&M), or
  - Survey.
- The vessel moving at low speeds (generally less than 3 knots but varies by vessel type, wind farm operational status and animal species) were considered to at rest for the computations of the strike risk.
- If users desire to calculate encounter totals for more than 24 hours they can simply multiply the output for 24 hours by the desired number of days in a given month.

Users should select the 'Wind Farm' tab to start the WF Calculator on the Vessel Risk Calculator (**Figure 18**) as follows:

1. The project name (**Figure 18**) helps in aggregating the scenarios together with similar parameters. The project name is optional but highly recommended. In case no project name is assigned an output file will have a 'temp' attached to the filename instead of the project name and temp files are replaced with similar name files from previous scenarios; therefore, it is always recommended to use a unique Project Name to ensure files are not overwritten.
2. Select the desired wind farm from the drop-down list (**Figure 18**) where the Calculator will calculate the encounter risk.
3. Click the 'Select Vessel Parameters' button (**Figure 18**).

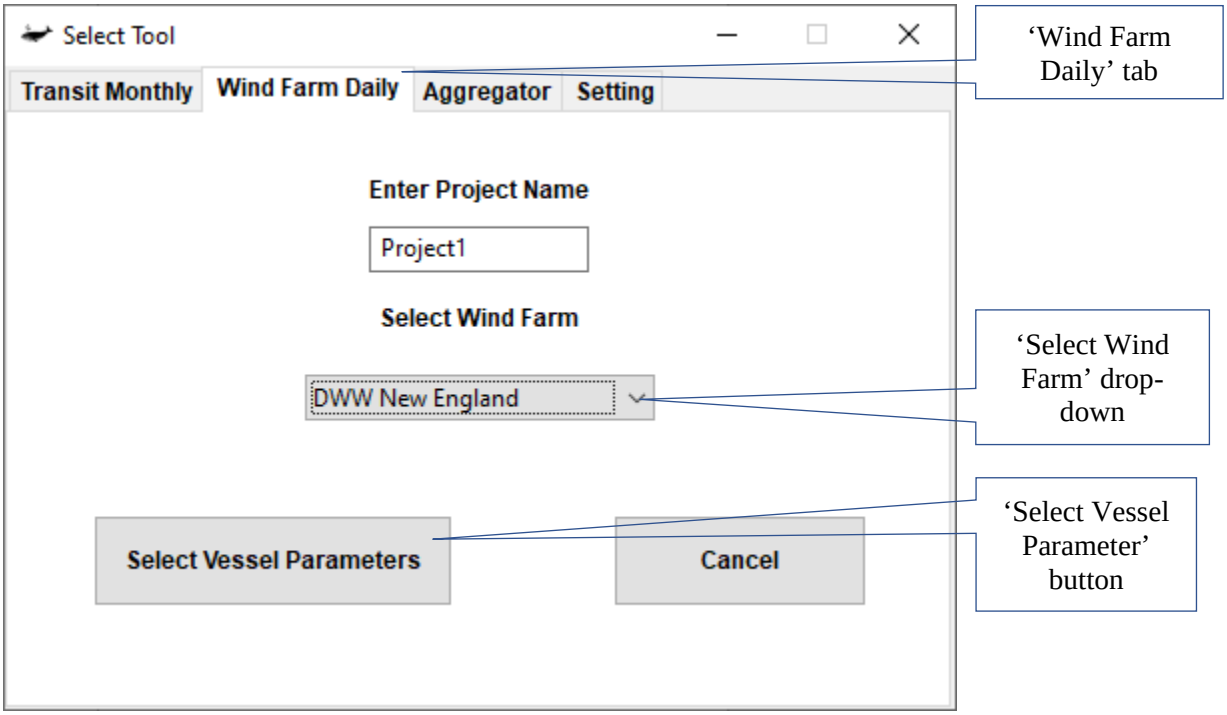


Figure 18. Screenshot showing 'Wind Farm Daily' tab for starting Wind Farm total

The vessel parameters screen (**Figure 19**) lets users select the vessel type and their speeds along with the month. To use this screen:

1. Select the month from the drop-down list (**Figure 19**).
2. Select the vessel categories from the drop-down list (**Figure 19**). Users need to select at least one vessel category to calculate the encounter risk. The typical scenario could range from a single vessel run to a large number of vessels run in all the categories within the selected month to get the aggregate strike risk for those 24 hours.
3. Vessel operation for each category is divided into three separate vessel categories:
   - Construction
   - O&M
   - Survey
   - Users can pick the desired operation for each vessel category selected using the drop-down list (**Figure 19**).
   - **Note**: the default operational status is set to 'Construction'.
4. Users can select the aversion coefficient for each vessel category by sliding the slider (**Figure 19**) to incorporate in the strike risk calculations.

5. The number of vessels within a day lets users select the number of times vessels in each category that operate within the wind farm. Users are required to select at least one trip in either vessel category to calculate encounter risk.
6. After entering the desired information, select ‘Select Animal Parameters’ (**Figure 19**).

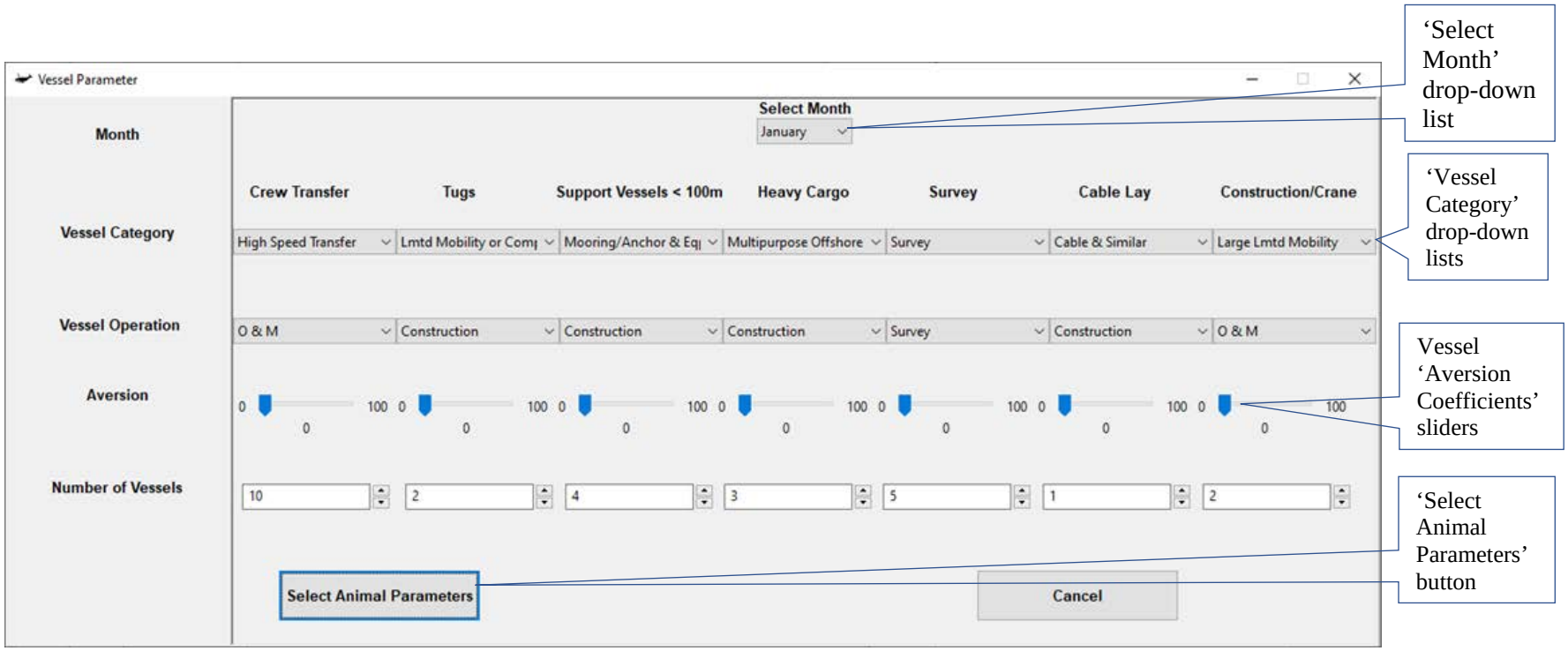


Figure 19. Vessel parameter screen to enter vessel parameters and their number of vessels in Wind Farm total

The Animal Parameters screen (**Figure 20**) lets users select the animal species and their behavior in that region.

1. Select the desired species from the drop-down list (**Figure 20**). Based on the selected species, the other parameters get default values.
2. The animal population parameter (**Figure 20**) lets users select the percentage of the population within each activity category.
    a) Foraging – the percentage of the population in foraging activity can be adjusted using the slider bar, though the foraging and migrating population sums to 100 minus population of calf rearing and SAG.
    b) Migrating – the percentage of the population in migrating activity can be adjust using and slider bar and like foraging the slider moves automatically to adjust the values so it sums up to 100.
    c) Calf rearing – The population percentage is fixed and is displayed in the text box based on the species.
3. SAG – SAG activity only applies to North Atlantic right whale species in Northeast and Mid-Atlantic zones and the population percentage number is fixed.
4. Users can select the animal aversion coefficient for the species by sliding the slider (**Figure 20**) to incorporate in the strike risk calculations.
5. After entering the desired information, select 'Calculate Expected Encounter' (**Figure 20**). This provides the expected number of animal strikes for that scenario, by adjusting by the aversion factor selection.

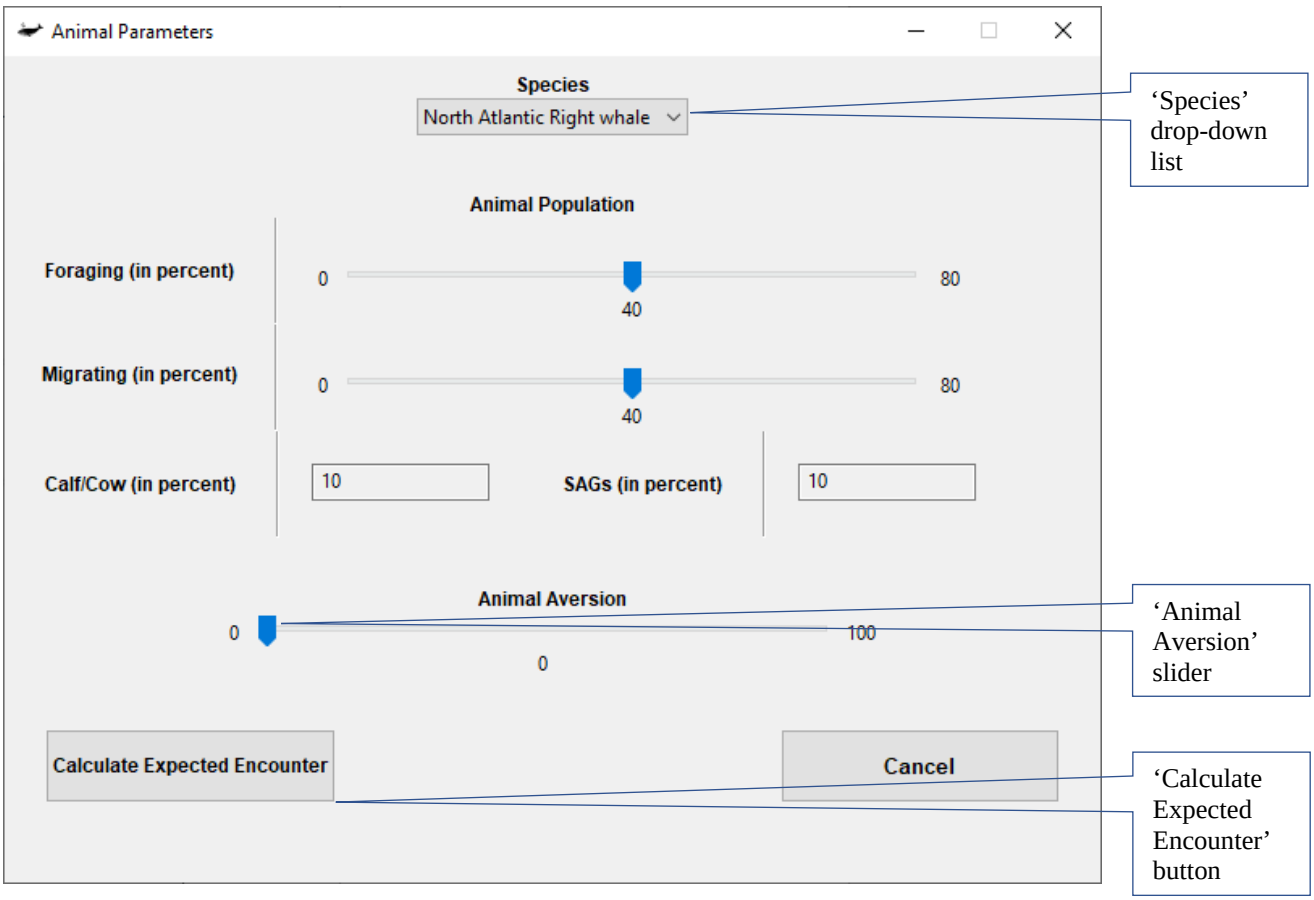


Figure 20. Animal parameter screen to enter animal parameters

The Calculator will go through the calculations of the strike risk with the selected species in the wind farm for all the vessels selected by the user recursively and provide the output in a message box.

IMPORTANT NOTE

To obtain just the expected number of encounters in the transit to and from the selected wind farm area the aversion factors for BOTH vessels and animal must be set to zero. Consequently, setting aversion to 0 can be taken to simply mean the expected number of encounters but also, the most conservative estimate of strikes wherein with 0 aversion, every encounter becomes a strike.

Figure 21 is an example screenshot of the message box showing the cumulative expected number of animal strikes in a 24-hour period once computations are done. Setting all aversion (vessels and animal) to zero changes this value to either mean simply “encounters” or the most conservative strike estimation.

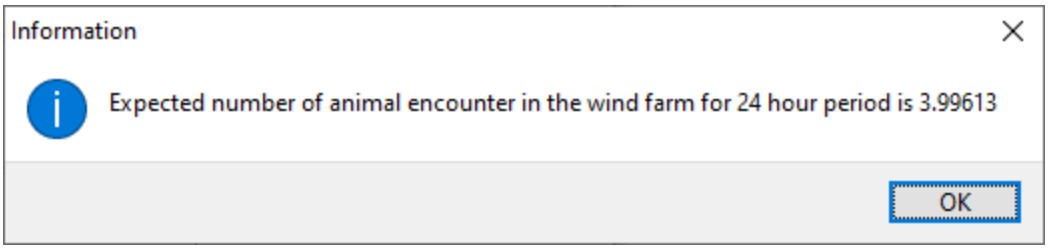


Figure 21. Message box showing the output for Wind Farm Calculator total

The wind farm Calculator provides detailed output in table format as a text file.

The Calculator creates a table output as a text file. The file contains the total expected value for encounter in the wind farm for 24 hours period, adjusted by the aversion selection. The value includes the total contribution of each vessel category and number of the trips. Because there is only one value returned for the wind farm and because color ramps are not comparable among scenarios, no heat map is generated.

The Calculator-generated naming convention used for storing geospatial files where WF stands for wind farm is structured as follows to keep it segregated from Transit solutions:

- WF_Project Name_wind farm_Species_month.txt

3.3 Aggregator Module

The Vessel risk calculator has the functionality to aggregate model runs from user-selected scenarios compiled under a project. **Note**: The Aggregator Module (AM) should be used after running scenarios for transits and or wind farms. All of the project scenarios to be aggregated must appear in the same project folder. Prior to using the AM, scenarios that are not desired to be included in the total aggregated total can be removed from the project folder. The AM is accessed as a tab in the Select Tool page. The AM lets users select the zone (Transit or Wind Farm) where the AM will run (**Figure 22**). The user then 'selects query' and proceeds to the next screen (**Figure 23**).

Before proceeding with selecting query details, the user picks the desired project from which to choose scenarios to aggregate and apply the queries from the drop down. The user then selects the queries that will be used to aggregate their selected scenarios. For the AM (**Figure 23**), there are three checkboxes to select from; any or all may be selected:

- **Month**: For Month, the AM will sum the potential risk value from each month selected (months 1 through 12) for a specified project for all species for all scenarios to provide a total risk value for the month selected;
- **Species**: For species, the AM will sum the potential risk values for all scenarios for each species by month or by year or both, so one could have a monthly or annual risk value for a single species (e.g., right whales). **Note**: if users need just an annual risk value the month dropdown should be left blank.
- **Total**: For total, the AM will sum all potential risk values for all species for all scenarios across all months to provide one overall risk value for the time period for which scenarios were run.

The AM then aggregates scenarios based on the three queries.

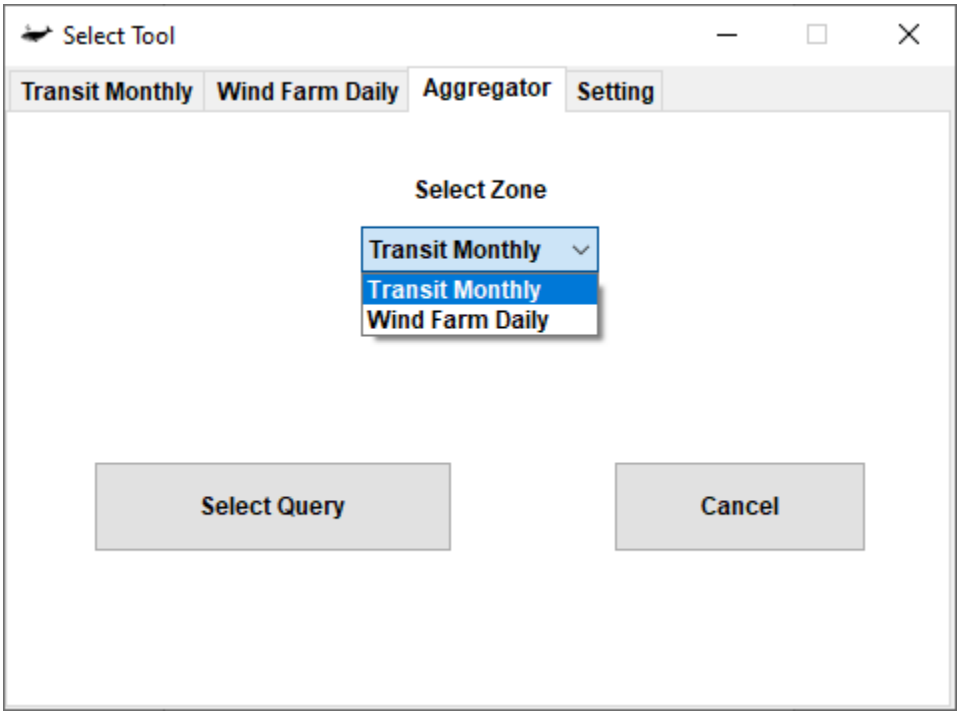


Figure 22. Aggregator tab screen to select zone

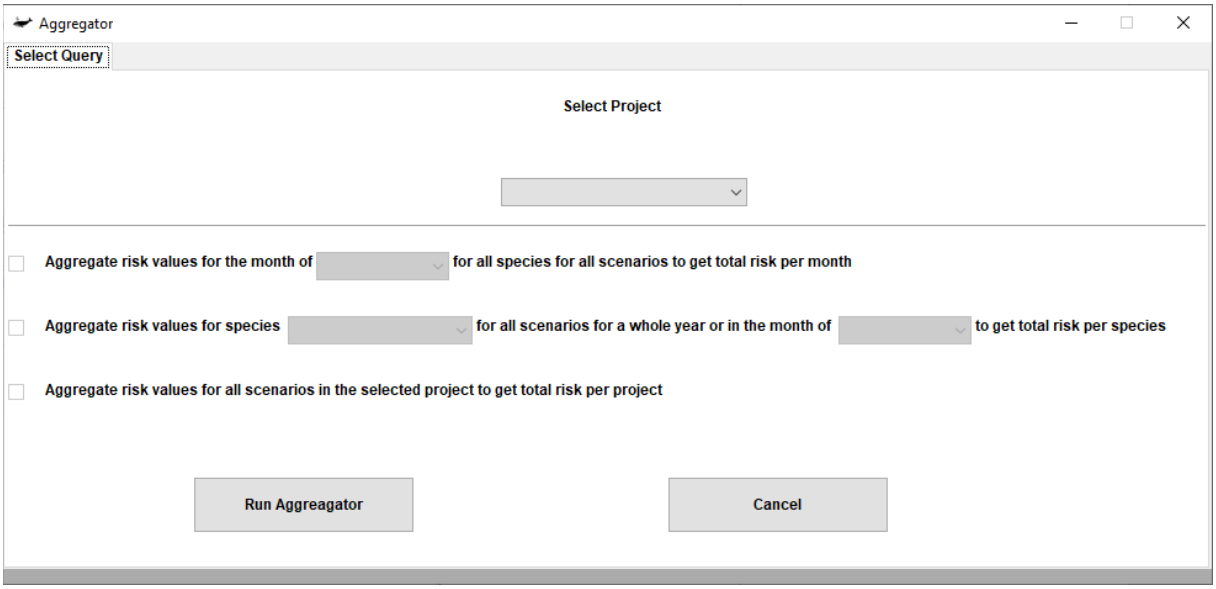


Figure 23. Aggregator tab screen to select project and queries

The AM provides a single number for any of the three queries selected as output; it does not, however, provide a heat map as there would be no gradient with a single value. The output text files are stored in the ‘output/aggregator output’ folder of the GUI Workspace directory.

The naming convention used for storing aggregator text files are:

- Agg_Zone_Project Name_query.txt

where the ‘Agg’ prefix stands for the aggregator and zone specifies whether it is a transit or a wind farm aggregation. The Project Name is added in the name along with the query details selected.

Each query will create its own text file in the folder and below are their naming conventions.

Query 1 file naming convention:

- Agg_Zone_Project Name_month.txt

Query 2 file naming convention:

- Agg_Zone_Project Name_month species.txt

Query 3 file naming convention:

- Agg_Zone_Project Name_all.txt

The user can pick one query or all depending on their needs before clicking ‘Run Aggregator’.

3.4 Editing Data Files

All the data in the data folder are in a text file or a geospatial format and can be easily edited depending on the needs by an experienced analyst using ArcMap or ArcCatalog.

3.4.1 Adding Track Lines

Users can add their own track lines in addition to the Calculator provided by editing the geodatabase in the track line folder. Below are the steps to add more track lines:

- Open ArcMap and go into the ArcCatalog window and navigate to the track line geodatabase in the track line folder as shown in **Figure 24**.

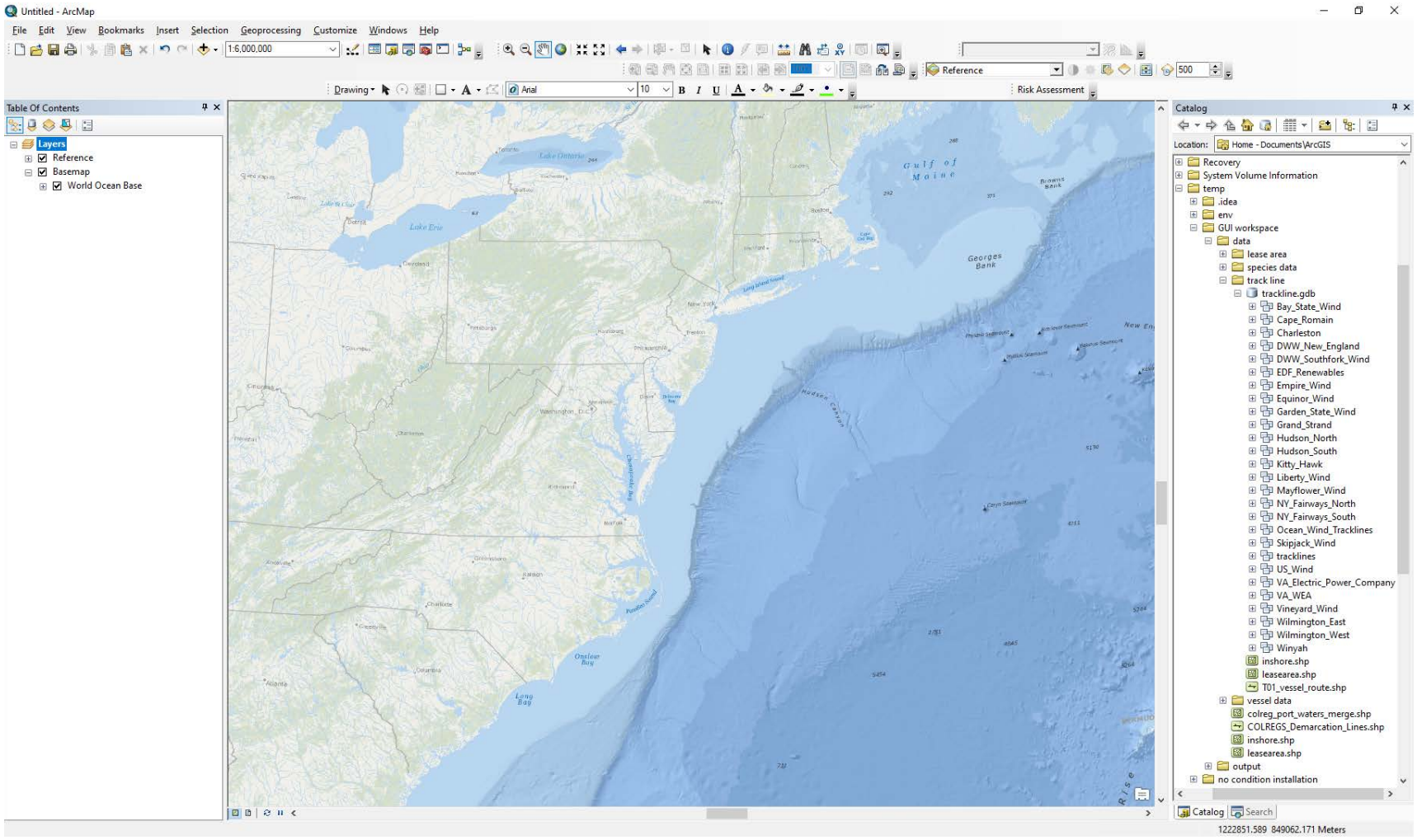


Figure 24. ArcMap screenshot showing track line geodatabase in ArcCatalog window

- Pick the desired wind farm feature dataset from the ArcCatalog window in track line geodatabase. Drag that feature class into the ArcMap to start editing (**Figure 25**).

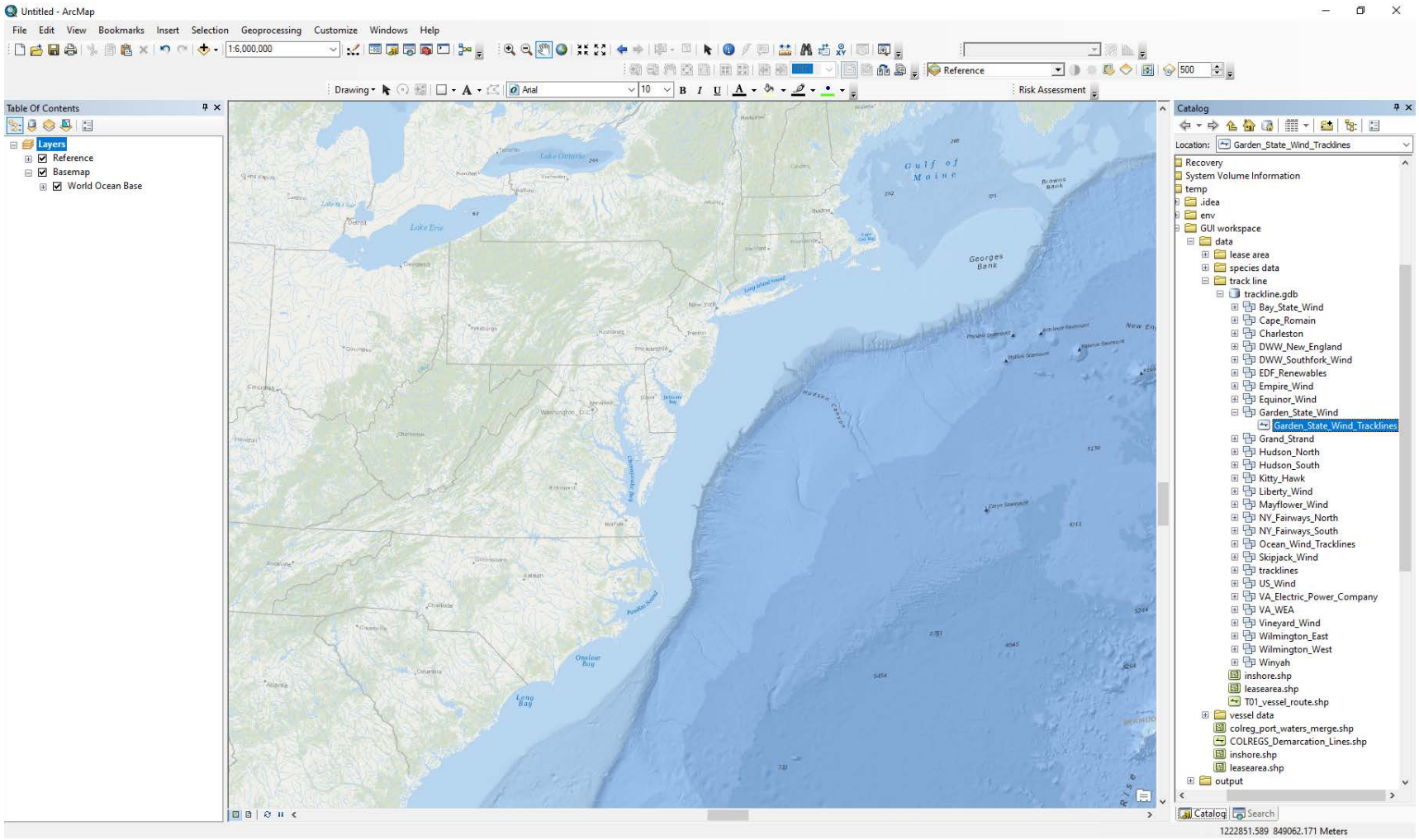


Figure 25. ArcMap screenshot showing selected feature dataset in ArcCatalog window

- Add the desired feature class in ArcMap and right-select and navigate to ‘Start Editing’ as shown in **Figure 26**. For example, in **Figure 26** the ‘Garden State Wind’ feature class was selected.

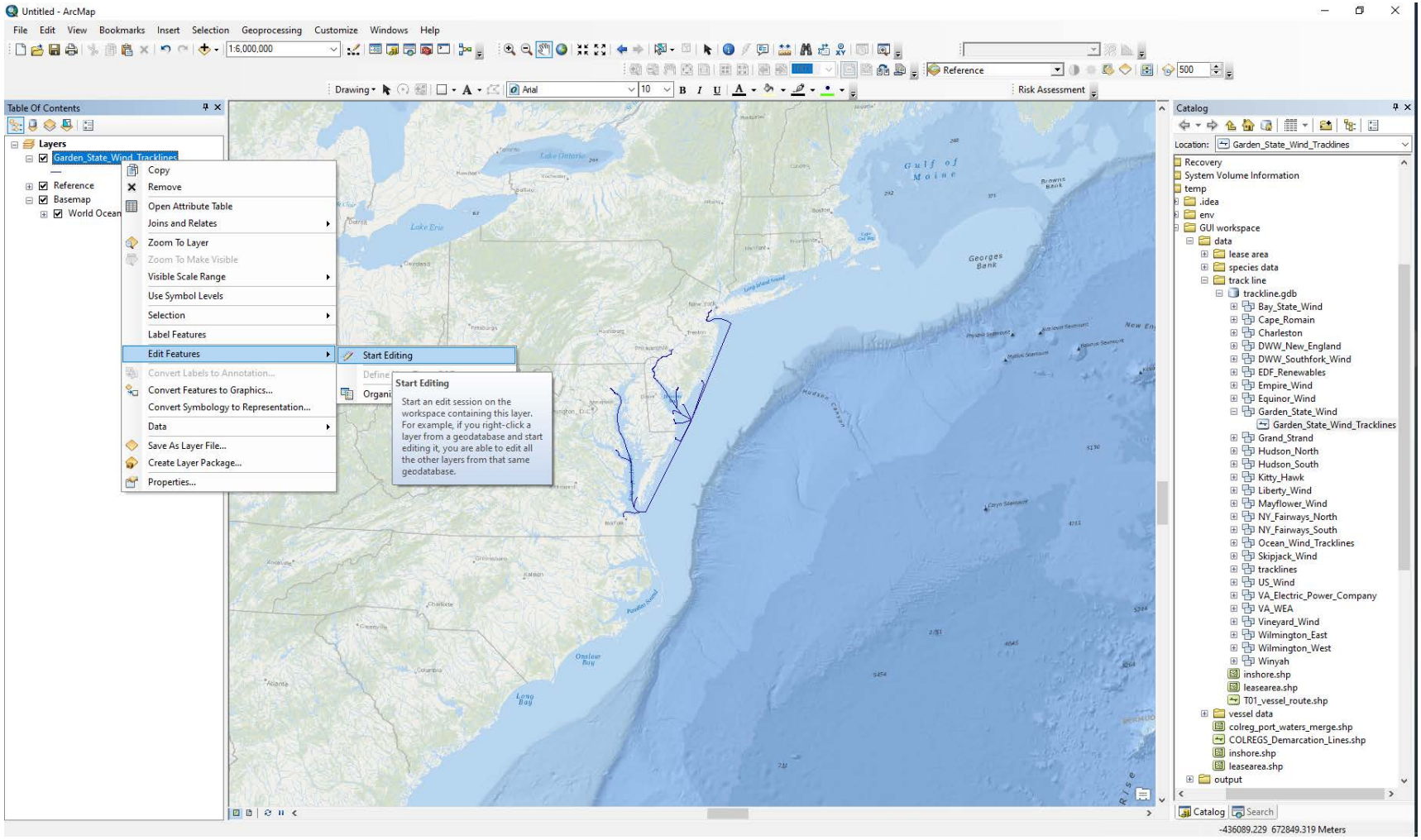


Figure 26. ArcMap screenshot showing the navigation to start editing the track line feature class

- Start editing the file by creating points that represent the new track line. **Note**: **Make sure to go in one direction from the port to the wind farm**. As an example (**Figure 27**) a new track line is added going from the North Carolina port of Morehead City to the Garden State Windfarm.

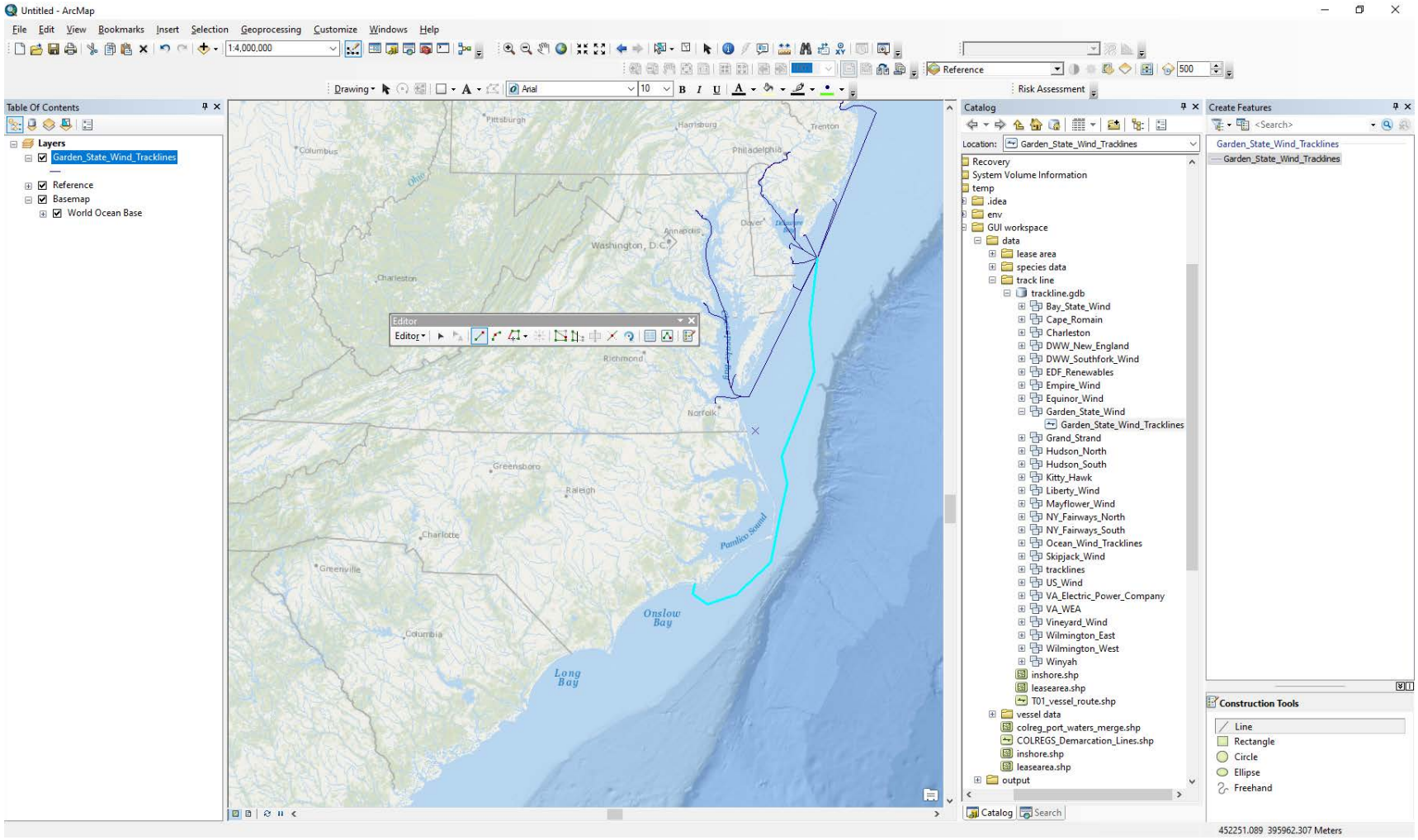


Figure 27. ArcMap screenshot showing the edited track line feature class

- After completing the track line tracing, select ‘save editing’ to save the edits. This will create a new feature in the selected feature class representing the new track line as shown in **Figure 28**.

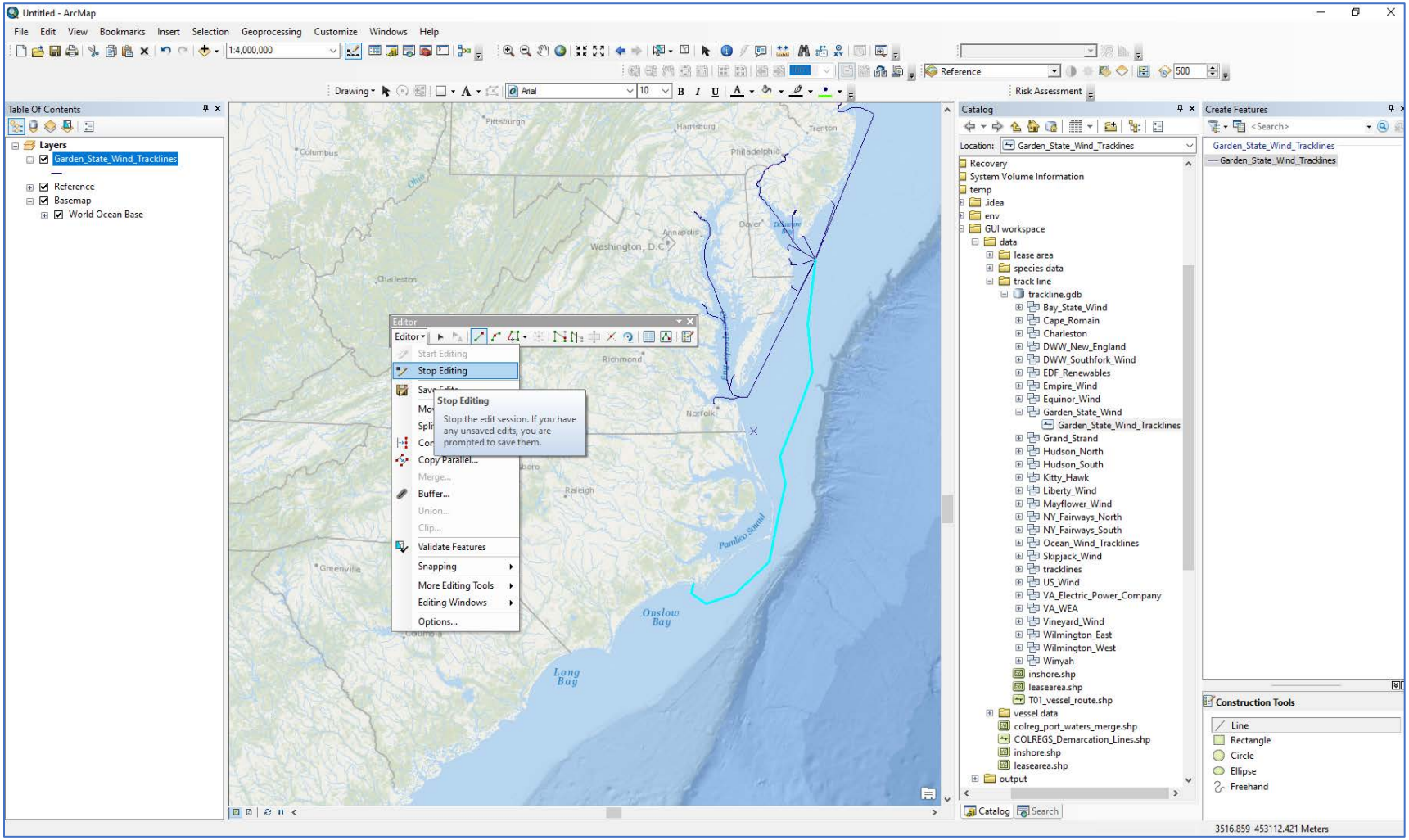
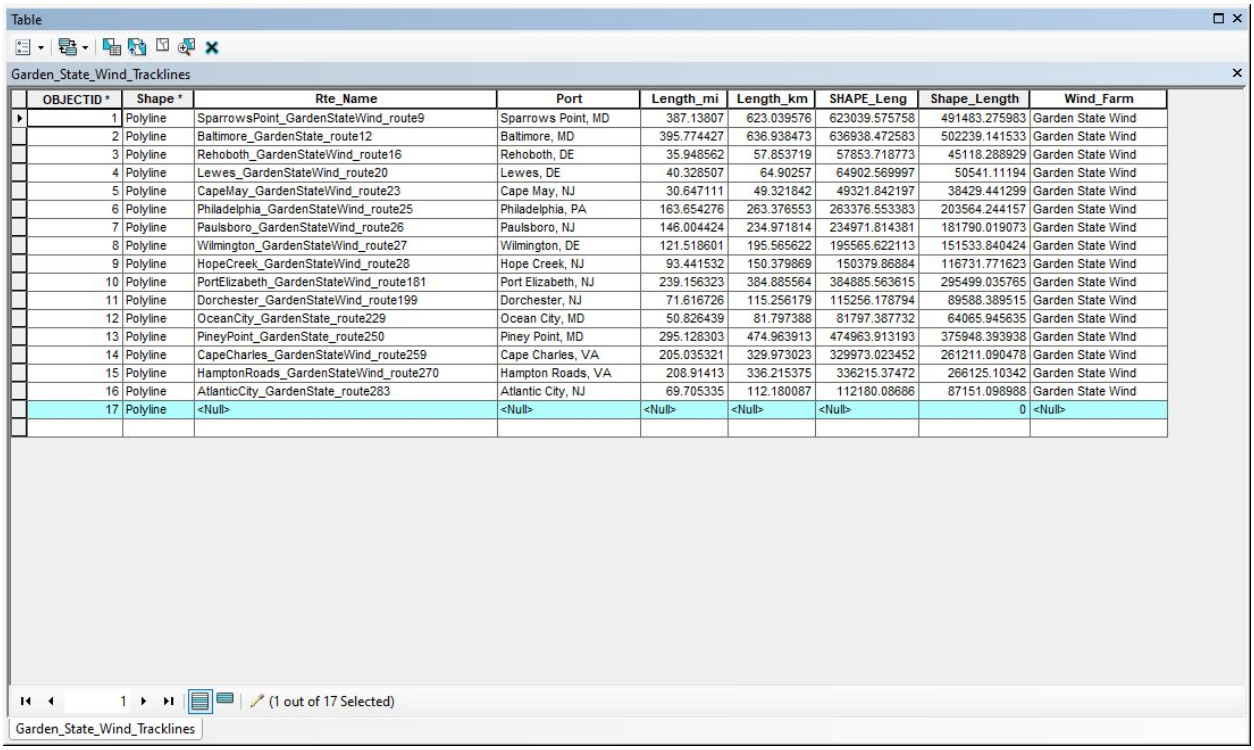


Figure 28. ArcMap screenshot showing the way to stop editing the track line feature class

- The geometric shape of the new track line is created but still requires addition of attributes. To add the attributes, open the attribute table by right-selecting the feature class in ArcMap 'Table of Contents'.

As shown in **Figure 29**, the attributes are currently null, and the user must fill in those attributes.



OBJECTID *	Shape *	Rte_Name	Port	Length_mi	Length_km	SHAPE_Leng	Shape_Length	Wind_Farm
1	Polyline	SparrowsPoint_GardenStateWind_route9	Sparrows Point, MD	387.13807	623.039576	623039.575758	491483.275983	Garden State Wind
2	Polyline	Baltimore_GardenState_route12	Baltimore, MD	395.774427	636.938473	636938.472583	502239.141533	Garden State Wind
3	Polyline	Rehoboth_GardenStateWind_route16	Rehoboth, DE	35.948562	57.853719	57853.718773	45118.288929	Garden State Wind
4	Polyline	Lewes_GardenStateWind_route20	Lewes, DE	40.328507	64.90257	64902.569997	50541.11194	Garden State Wind
5	Polyline	CapeMay_GardenStateWind_route23	Cape May, NJ	30.647111	49.321842	49321.842197	38429.441299	Garden State Wind
6	Polyline	Philadelphia_GardenStateWind_route25	Philadelphia, PA	163.654276	263.376553	263376.553383	203564.244157	Garden State Wind
7	Polyline	Paulsboro_GardenStateWind_route26	Paulsboro, NJ	146.004424	234.971814	234971.814381	181790.019073	Garden State Wind
8	Polyline	Wilmington_GardenStateWind_route27	Wilmington, DE	121.518601	195.565622	195565.622113	151533.840424	Garden State Wind
9	Polyline	HopeCreek_GardenStateWind_route28	Hope Creek, NJ	93.441532	150.379869	150379.86884	116731.771623	Garden State Wind
10	Polyline	PortElizabeth_GardenStateWind_route181	Port Elizabeth, NJ	239.156323	384.885564	384885.563615	295499.035765	Garden State Wind
11	Polyline	Dorchester_GardenStateWind_route199	Dorchester, NJ	71.616726	115.256179	115256.178794	89588.389515	Garden State Wind
12	Polyline	OceanCity_GardenState_route229	Ocean City, MD	50.826439	81.797388	81797.387732	64065.945635	Garden State Wind
13	Polyline	PineyPoint_GardenState_route250	Piney Point, MD	295.128303	474.963913	474963.913193	375948.393938	Garden State Wind
14	Polyline	CapeCharles_GardenStateWind_route259	Cape Charles, VA	205.035321	329.973023	329973.023452	261211.090478	Garden State Wind
15	Polyline	HamptonRoads_GardenStateWind_route270	Hampton Roads, VA	208.91413	336.215375	336215.37472	266125.10342	Garden State Wind
16	Polyline	AtlanticCity_GardenState_route283	Atlantic City, NJ	69.705335	112.180087	112180.08686	87151.098988	Garden State Wind
17	Polyline	<Null>	<Null>	<Null>	<Null>	<Null>	0	<Null>

Figure 29. Attribute table screenshot showing the new track line added to the feature class with 'null' attributes

- To keep the naming convention of the database, utilize:
  - Rte_Name – name of the route specified as Port_Wind Farm_Route#
  - Port – Name of the starting Port
  - Wind Farm – Inclusive of Wind Energy / Planning Areas, Call Areas, Lease Areas, and actual wind farms within Lease Areas.

Start typing in each attribute to fill, following the naming convention. **Figure 30** shows the attributes filled to keep the naming convention for our example.

Table

Garden_State_Wind_Tracklines

OBJECTID *	Shape *	Rte_Name	Port	Length_mi	Length_km	SHAPE_Leng	Shape_Length	Wind_Farm
1	Polyline	SparrowsPoint_GardenStateWind_route9	Sparrows Point, MD	387.13807	623.039576	623039.575758	491483.275983	Garden State Wind
2	Polyline	Baltimore_GardenState_route12	Baltimore, MD	395.774427	636.938473	636938.472583	502239.141533	Garden State Wind
3	Polyline	Rehoboth_GardenStateWind_route16	Rehoboth, DE	35.948562	57.853719	57853.718773	45118.288929	Garden State Wind
4	Polyline	Lewes_GardenStateWind_route20	Lewes, DE	40.328507	64.90257	64902.569997	50541.11194	Garden State Wind
5	Polyline	CapeMay_GardenStateWind_route23	Cape May, NJ	30.647111	49.321842	49321.842197	38429.441299	Garden State Wind
6	Polyline	Philadelphia_GardenStateWind_route25	Philadelphia, PA	163.654276	263.376553	263376.553383	203564.244157	Garden State Wind
7	Polyline	Paulsboro_GardenStateWind_route26	Paulsboro, NJ	146.004424	234.971814	234971.814381	181790.019073	Garden State Wind
8	Polyline	Wilmington_GardenStateWind_route27	Wilmington, DE	121.518601	195.565622	195565.622113	151533.840424	Garden State Wind
9	Polyline	HopeCreek_GardenStateWind_route28	Hope Creek, NJ	93.441532	150.379869	150379.86884	116731.771623	Garden State Wind
10	Polyline	PortElizabeth_GardenStateWind_route181	Port Elizabeth, NJ	239.156323	384.885564	384885.563615	295499.035765	Garden State Wind
11	Polyline	Dorchester_GardenStateWind_route199	Dorchester, NJ	71.616726	115.256179	115256.178794	89588.389515	Garden State Wind
12	Polyline	OceanCity_GardenState_route229	Ocean City, MD	50.826439	81.797388	81797.387732	64065.945635	Garden State Wind
13	Polyline	PineyPoint_GardenState_route250	Piney Point, MD	295.128303	474.963913	474963.913193	375948.393938	Garden State WInd
14	Polyline	CapeCharles_GardenStateWind_route259	Cape Charles, VA	205.035321	329.973023	329973.023452	261211.090478	Garden State Wind
15	Polyline	HamptonRoads_GardenStateWind_route270	Hampton Roads, VA	208.91413	336.215375	336215.37472	266125.10342	Garden State Wind
16	Polyline	AtlanticCity_GardenState_route283	Atlantic City, NJ	69.705335	112.180087	112180.08686	87151.098988	Garden State Wind
17	Polyline	MoreheadCity_GardenState_route400	Morehead City, NC	<Null>	<Null>	<Null>	65099.080326	Garden State Wind

Figure 30. Attribute table screenshot showing the new track line added to the feature class with filled-in attributes

After filling the attributes, stop editing and save it. The new track line has been created and saved. The new track line is added to the list and the next time the Calculator is used it will show the new track line in the dropdown list as shown in **Figure 31**.

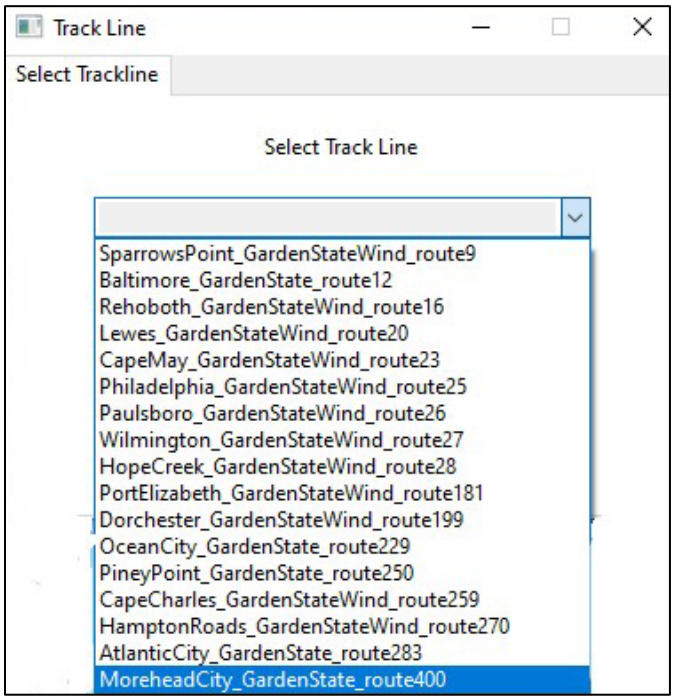


Figure 31. Vessel transit GUI aggregator Track line screenshot showing the new track line added to the list of available track lines

Appendix A: Wind Energy Area GIS Data Table

ID	Id	Job_No	Task_No	Developer	Facility	Lease_No
0	0	3182	102	Orsted US Offshore Wind	Garden State Wind	OCS-A-0482
1	0	3468	4	Orsted US Offshore Wind	Skipjack Wind	OCS-A-0519
2	0	3264	7	Avangrid/Copenhagen Investment Partners	Vineyard Wind I	OCS-A-0501
3	0	3383	2	Shell\EDP Renewables	Mayflower Wind	OCS-A-0521
4	0	3466	1	Orsted/Eversource	Bay State Wind	OCS-A-0500
5	0	3468	1	Orsted US Offshore Wind	Ocean Wind	OCS-A-0498
6	0	0	0		North Carolina WEA - Wilmington West	
7	0	0	0		North Carolina WEA - Wilmington East	
8	0	0	0		South Carolina Call Area - Charleston	
9	0	0	0		South Carolina Call Area - Winyah	
10	0	0	0		South Carolina Call Area - Cape Romain	
11	0	0	0		South Carolina Call Area - Grand Strand	
12	0	0	0		New York Bight Call Area - Hudson South	
13	0	0	0		New York Bight Call Area - Hudson North	
14	0	0	0		New York Bight Call Area - Fairways South	
15	0	0	0		New York Bight Call Area - Fairways North	
16	0	0	0		Virginia Wind Energy Area	
17	0	0	0		Virginia Electric and Power Company	OCS-A-0483
18	0	0	0	U.S. Wind Inc.	US Wind Inc.	OCS-A-0490
19	0	0	0	Avangrid Renewables LLC	North Carolina Lease Area - Kitty Hawk	OCS-A-0508
20	0	0	0	Equinor/BP	Empire Wind	OCS-A-0512
21	0	0	0	Equinor/BP	Equinor Wind	OCS-A-0520
22	0	0	0	Avangrid/Copenhagen Investment Partners	Liberty Wind	OCS-A-0522
23	0	0	0	EDF Renewables/Shell New Energies	Atlantic Shores Offshore Wind, LLC	OCS-A-0499
24	0	0	0	Orsted/Eversource	Deepwater Wind New England, LLC	OCS-A-0487
25	0	0	0	Orsted US Offshore Wind	DWW Rev I, LLC	OCS-A-0486
26	0	0	0	Orsted US Offshore Wind	Deepwater Wind Southfork, LLC	OCS-A-0517

Appendix B: Pre-Drawn Vessel Track Line Figures

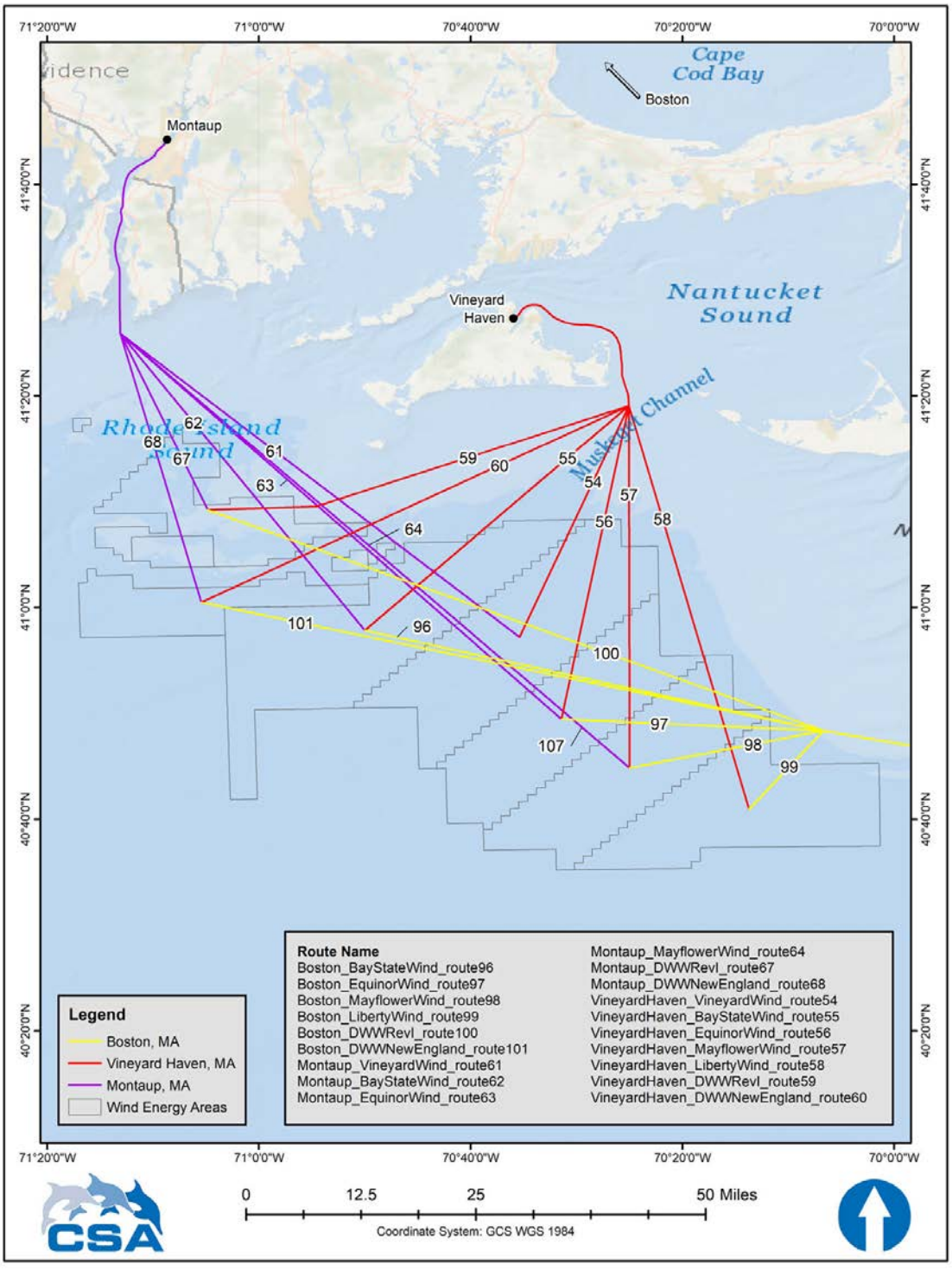


Figure B-1. Pre-drawn vessel routes from Montaup, MA; Boston, MA; and Vineyard Haven, MA to the wind energy areas

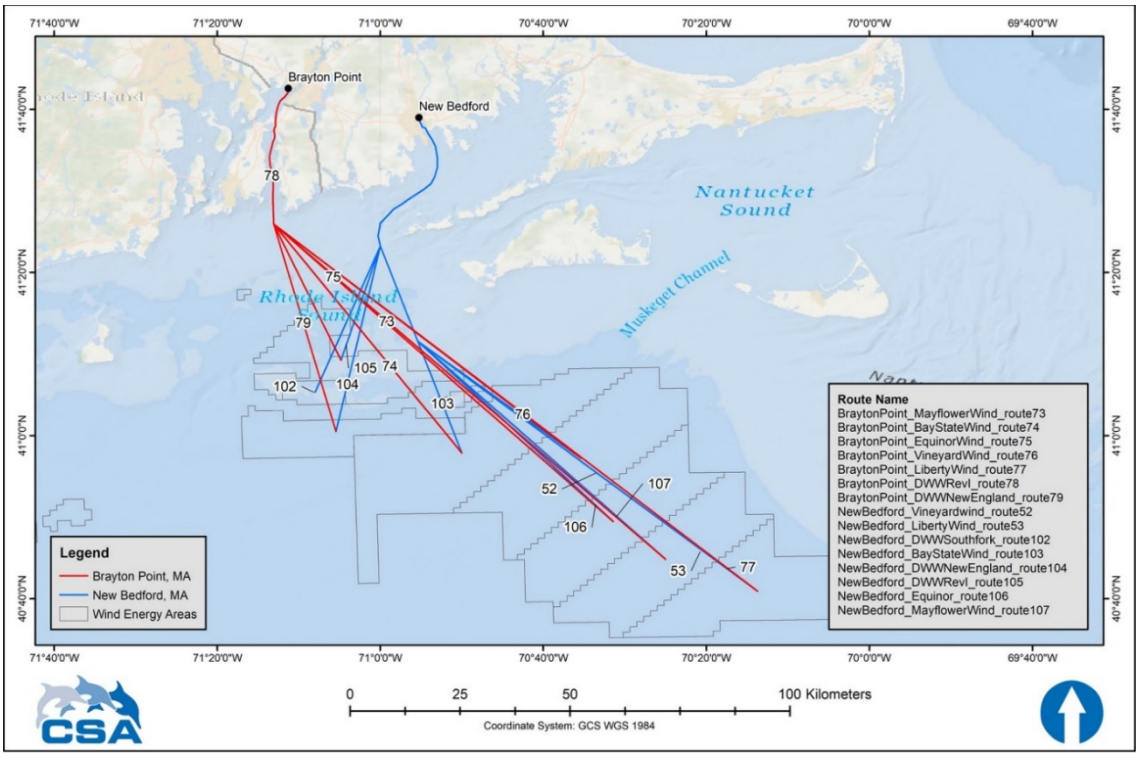


Figure B-2. Pre-drawn vessel routes from Brayton Point, MA and New Bedford, MA to the wind energy areas

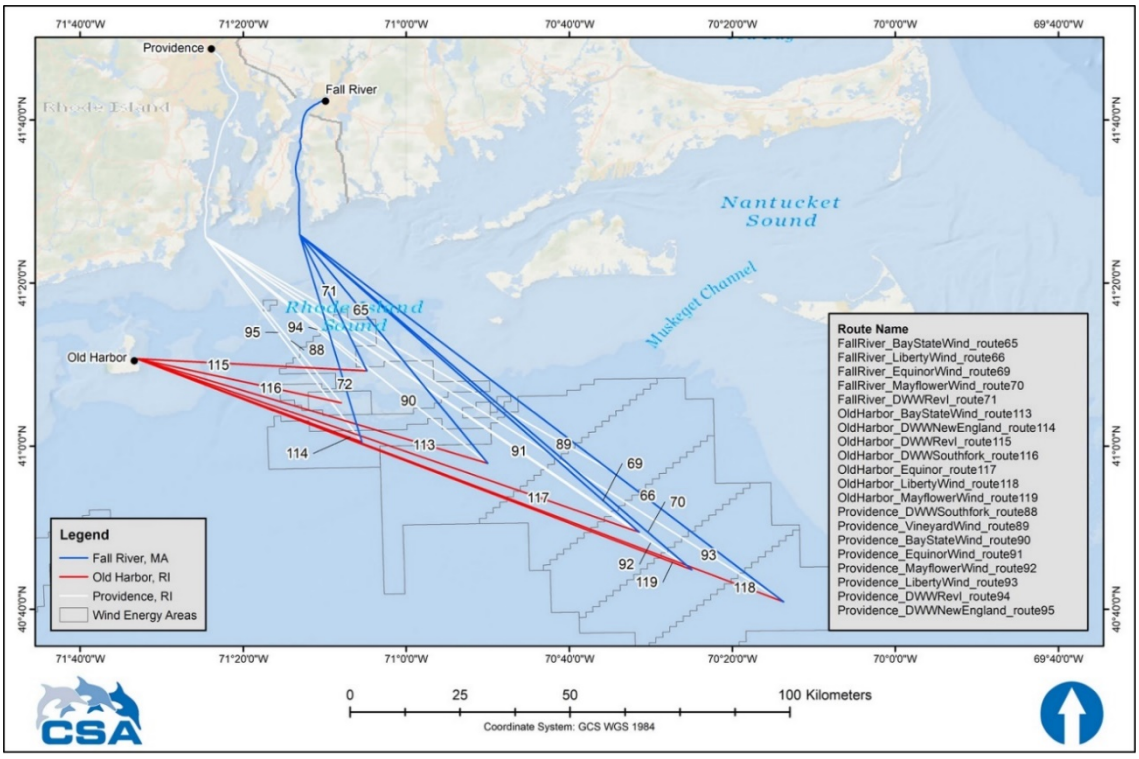


Figure B-3. Pre-drawn vessel routes from Fall River, MA; Old Harbor, RI; and Providence, RI to the wind energy areas

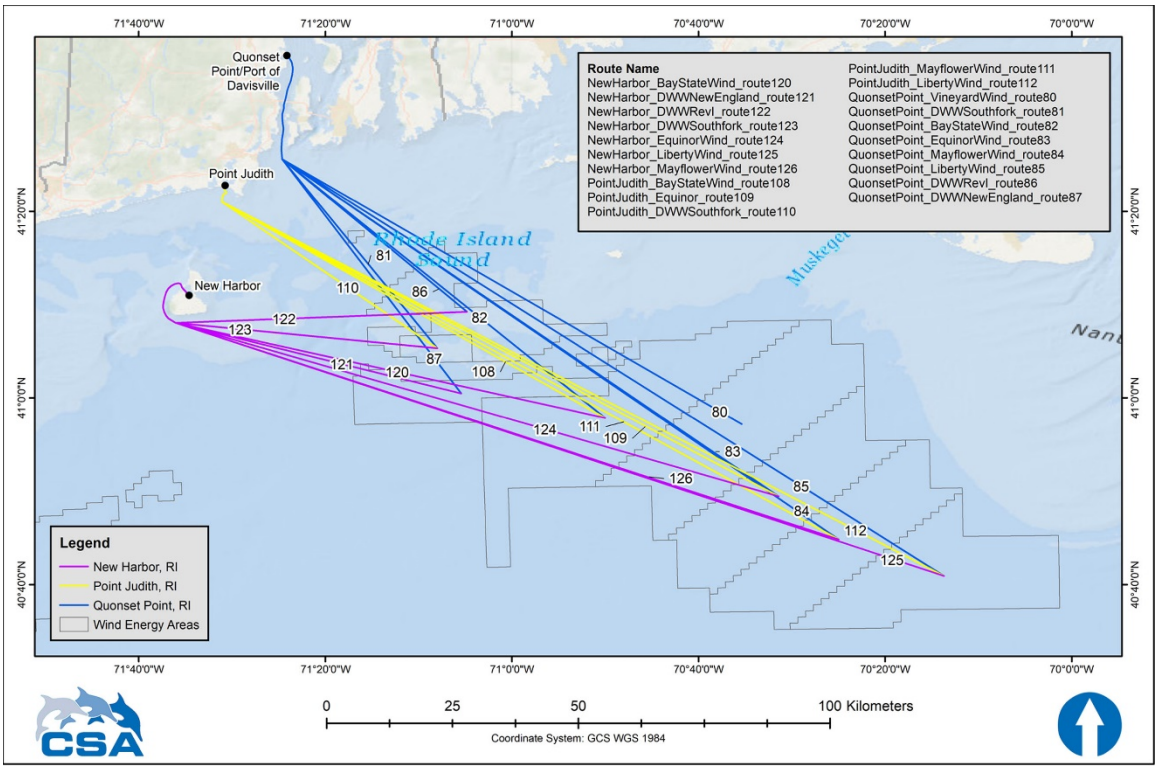


Figure B-4. Pre-drawn vessel routes from New Harbor, RI; Point Judith, RI; and Quonset, RI to the wind energy areas

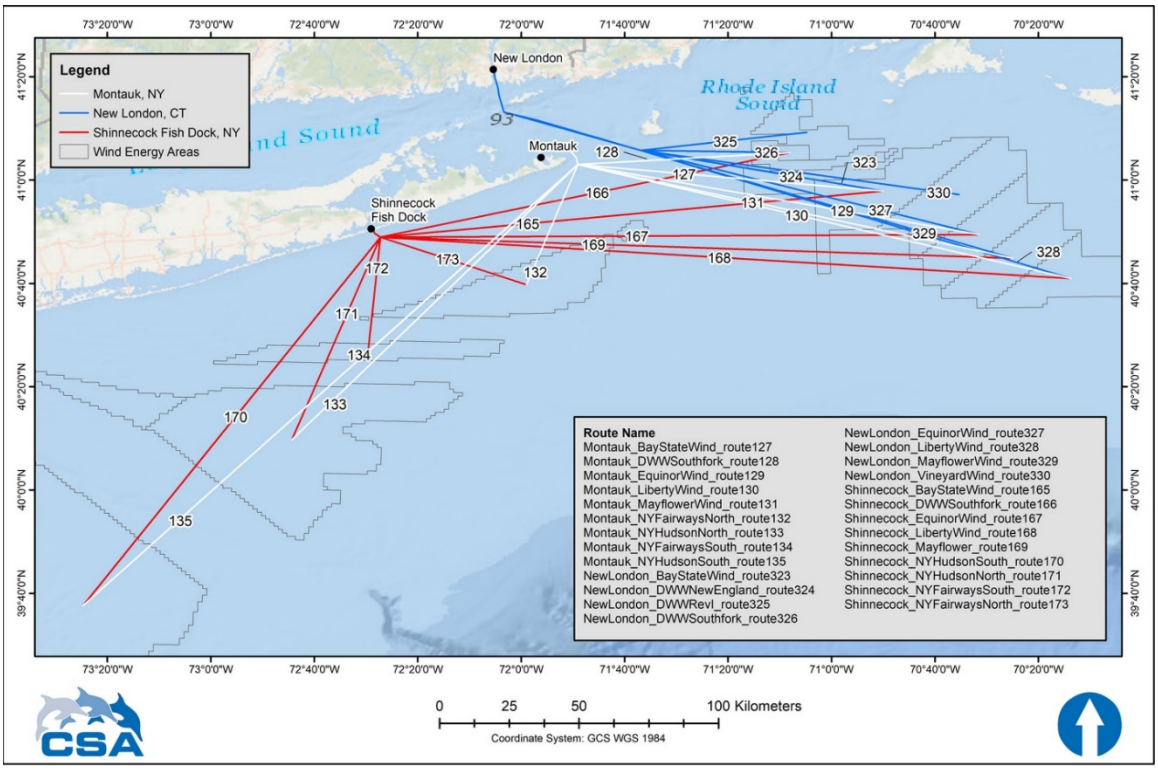


Figure B-5. Pre-drawn vessel routes from New London, CT; Montauk, NY; and Shinnecock Fish Dock, NY to the wind energy areas

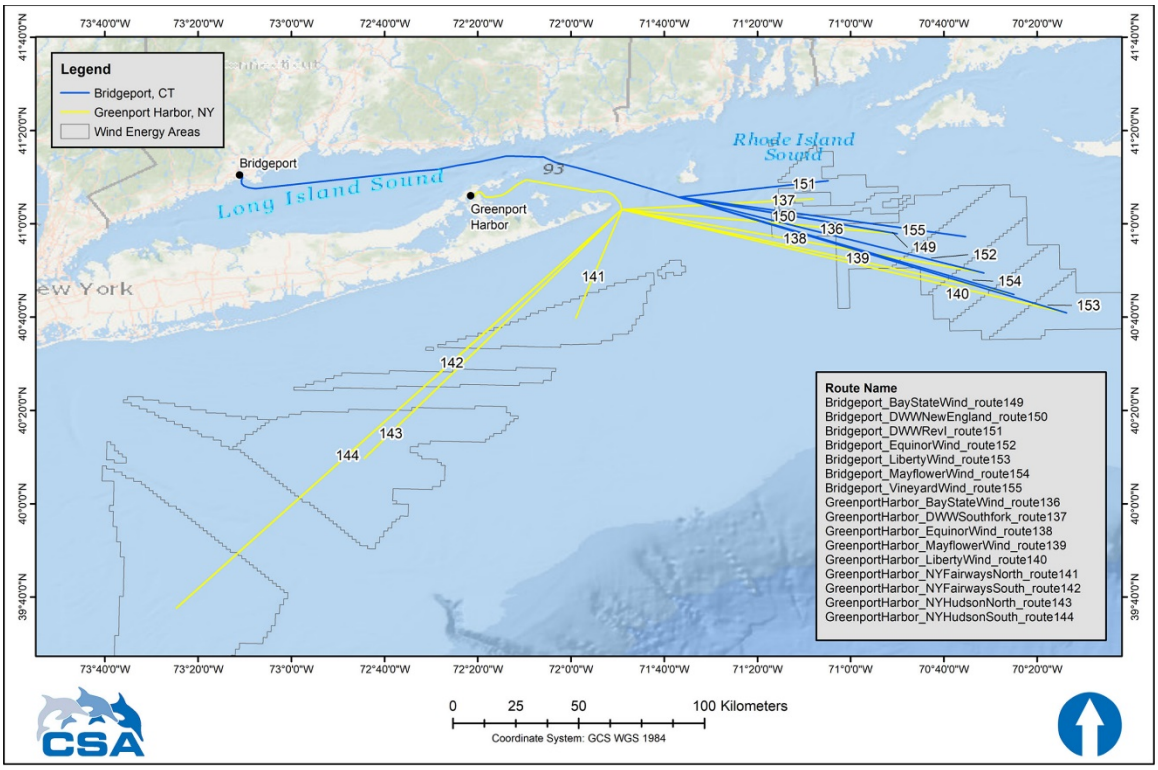


Figure B-6. Pre-drawn vessel routes from Bridgeport, CT and Greenport Harbor, NY to the wind energy areas

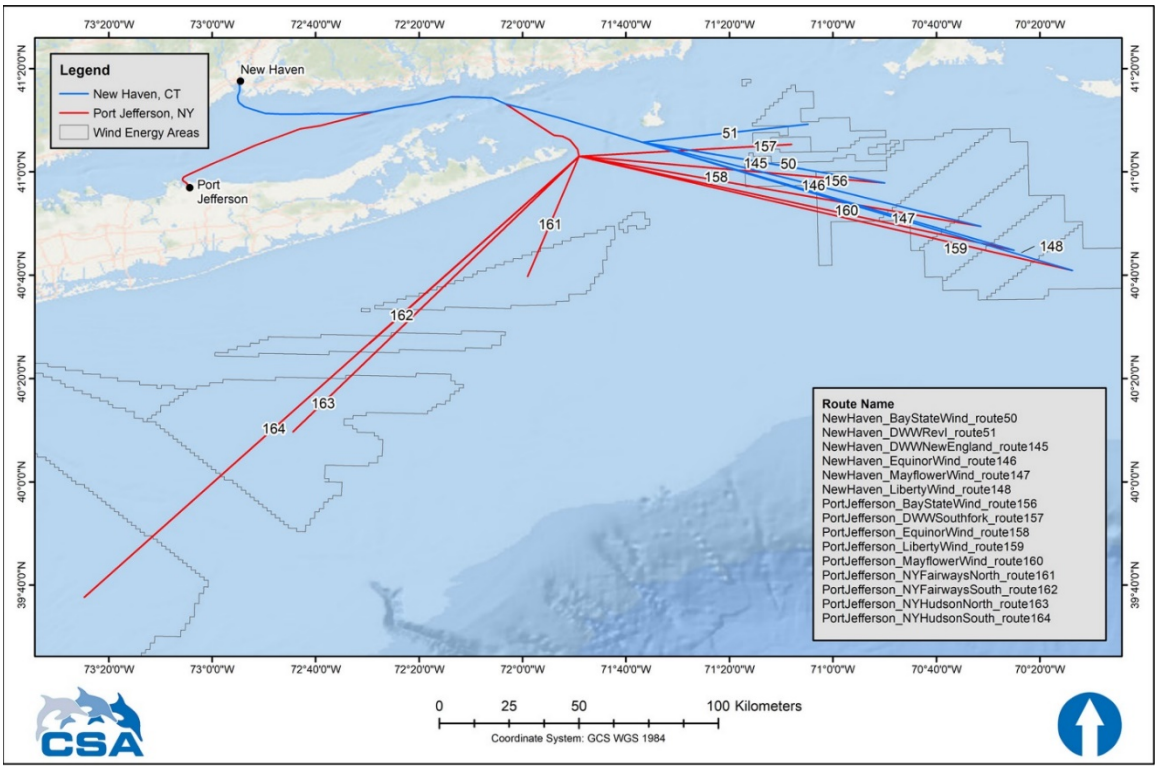


Figure B-7. Pre-drawn vessel routes from New Haven, CT and Port Jefferson, NY to the wind energy areas

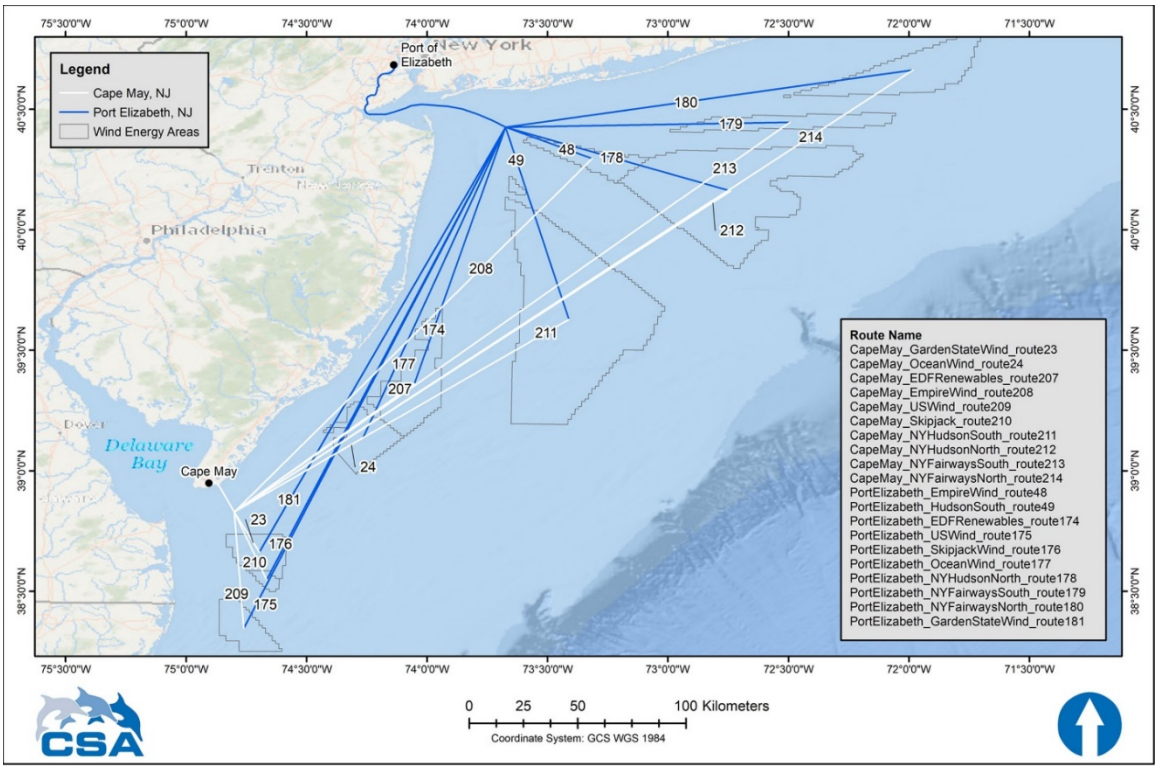


Figure B-8. Pre-drawn vessel routes from Cape May, NJ and Port Elizabeth, NJ to the wind energy areas

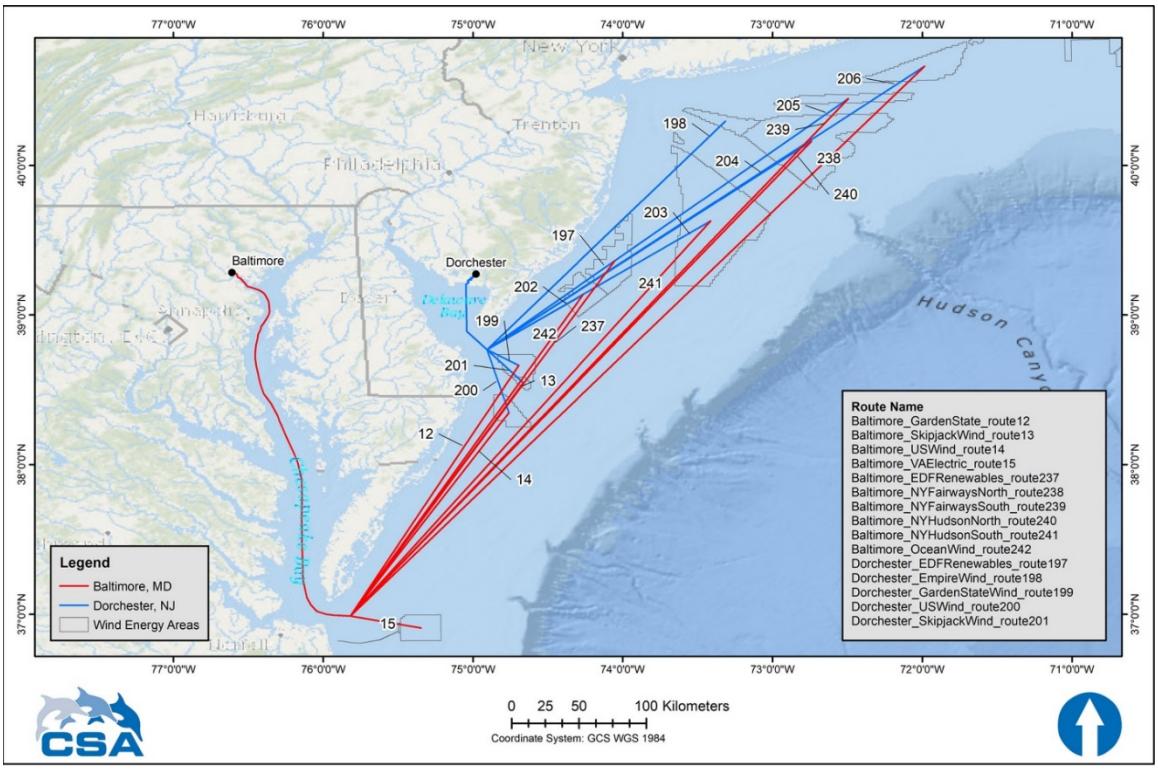


Figure B-9. Pre-drawn vessel routes from Dorchester, NJ and Baltimore, MD to the wind energy areas

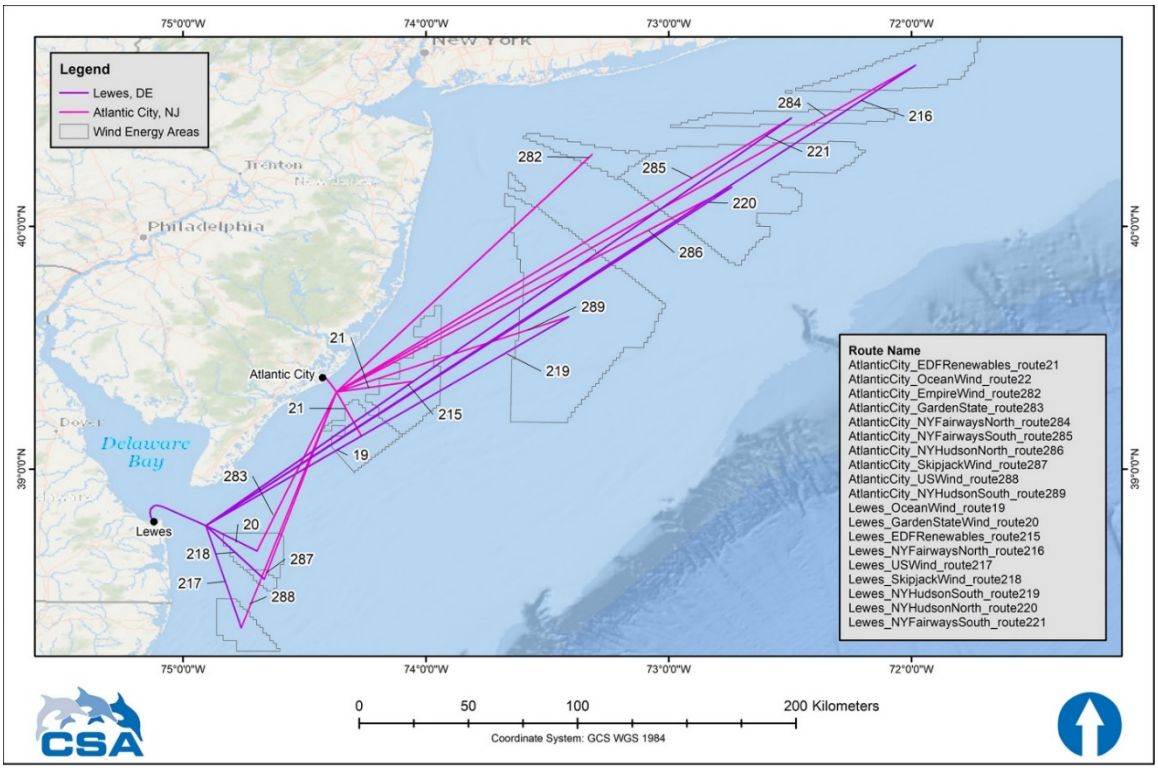


Figure B-10. Pre-drawn vessel routes from Atlantic City, NJ and Lewes, DE to the wind energy areas

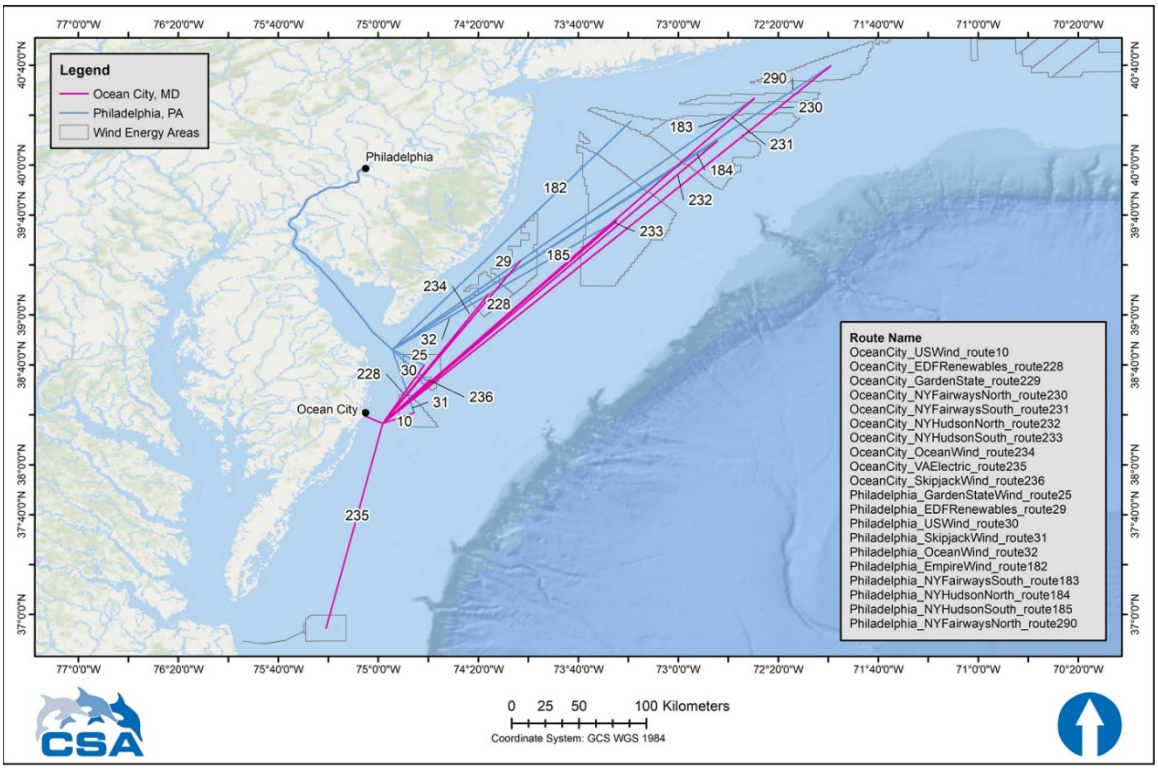


Figure B-11. Pre-drawn vessel routes from Ocean City, MD and Philadelphia, PA to the wind energy areas

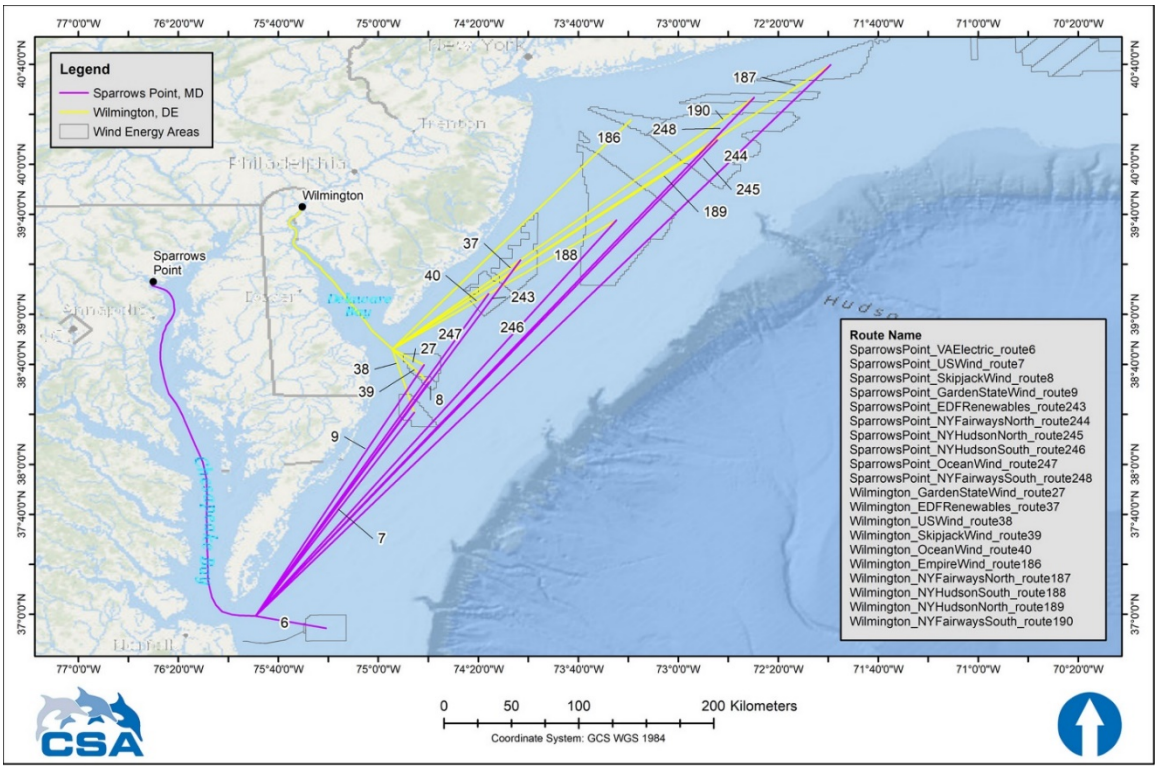


Figure B-12. Pre-drawn vessel routes from Sparrows Point, MD and Wilmington, DE to the wind energy areas

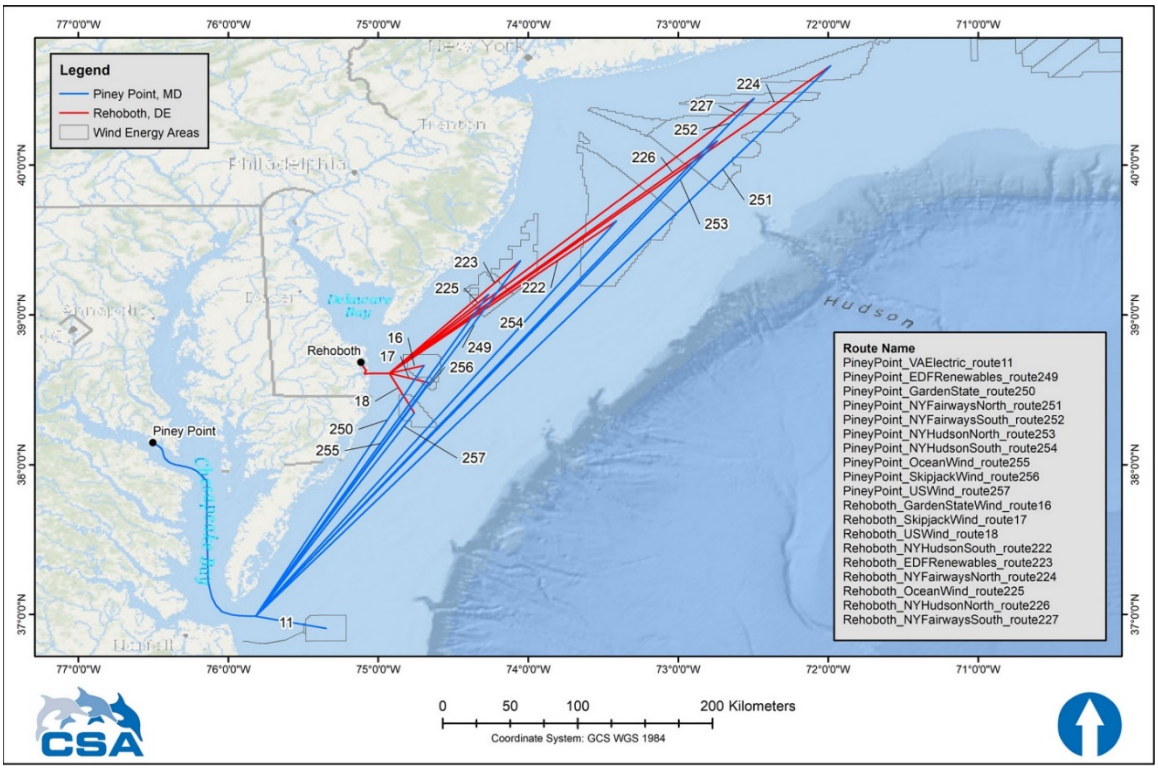


Figure B-13. Pre-drawn vessel routes from Piney Point, MD and Rehoboth, DE to the wind energy areas

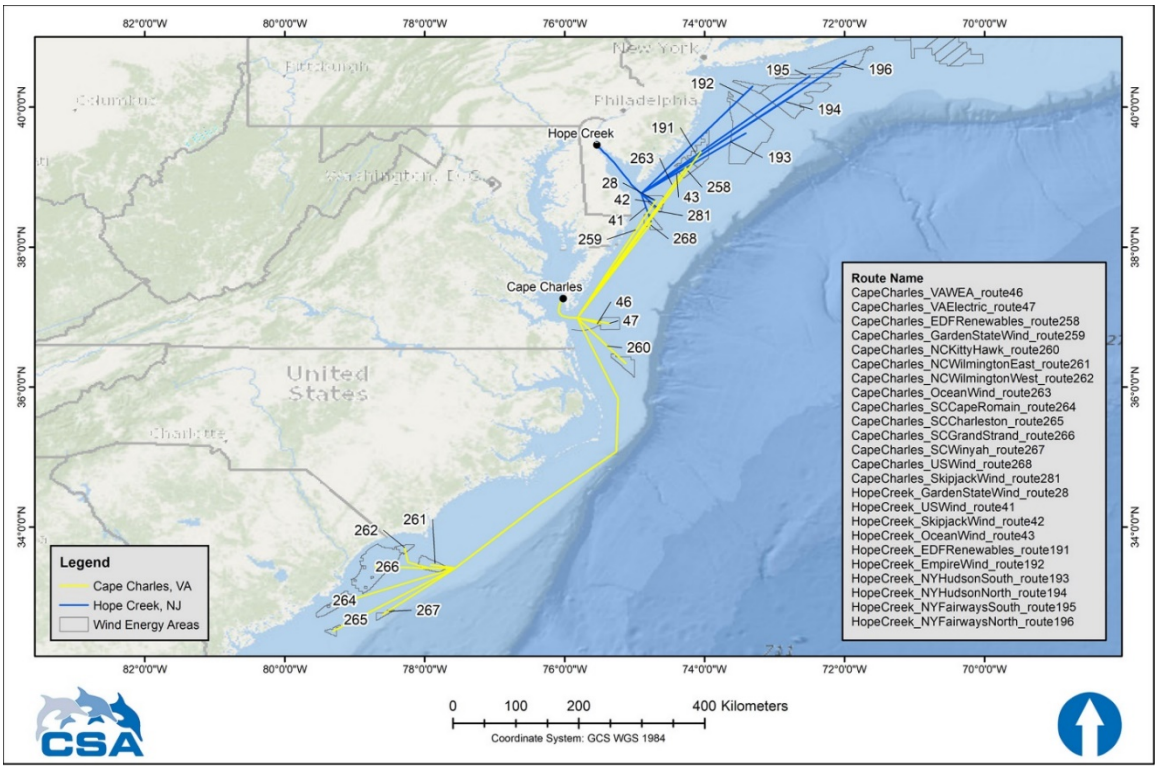


Figure B-14. Pre-drawn vessel routes from Hope Creek, NJ and Cape Charles, VA to the wind energy areas

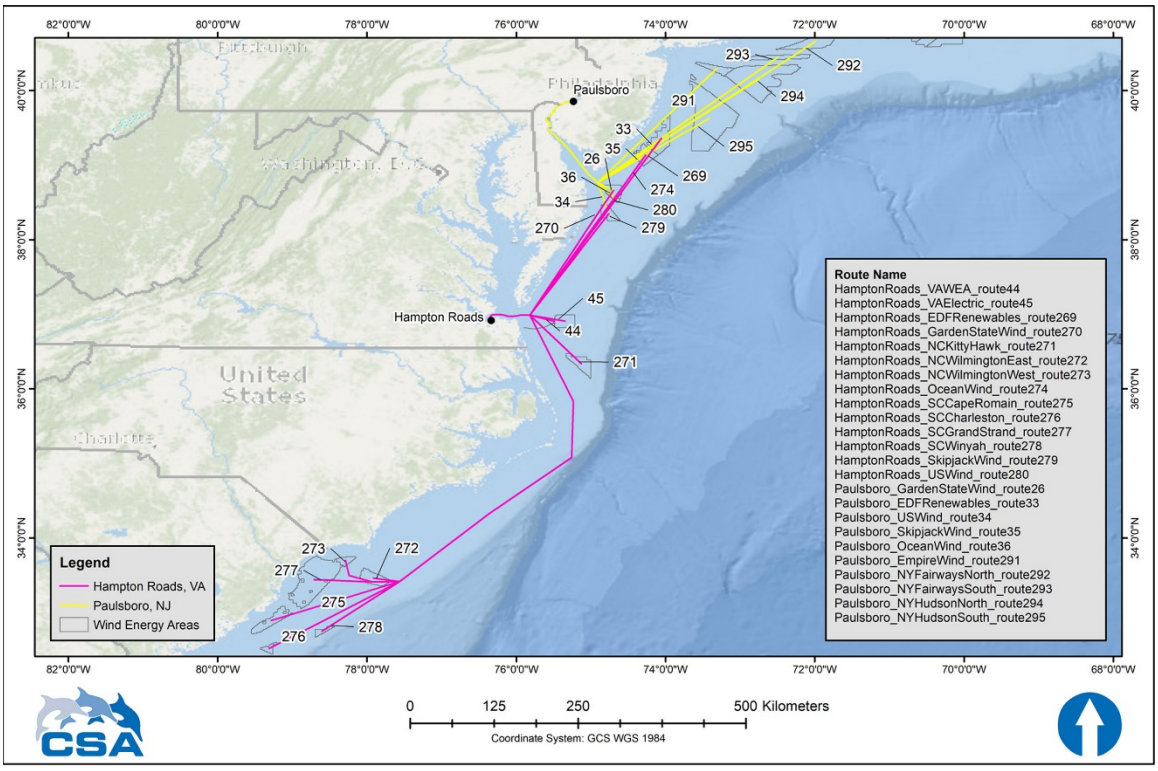


Figure B-15. Pre-drawn vessel routes from Paulsboro, NJ and Hampton Roads, VA to the wind energy areas

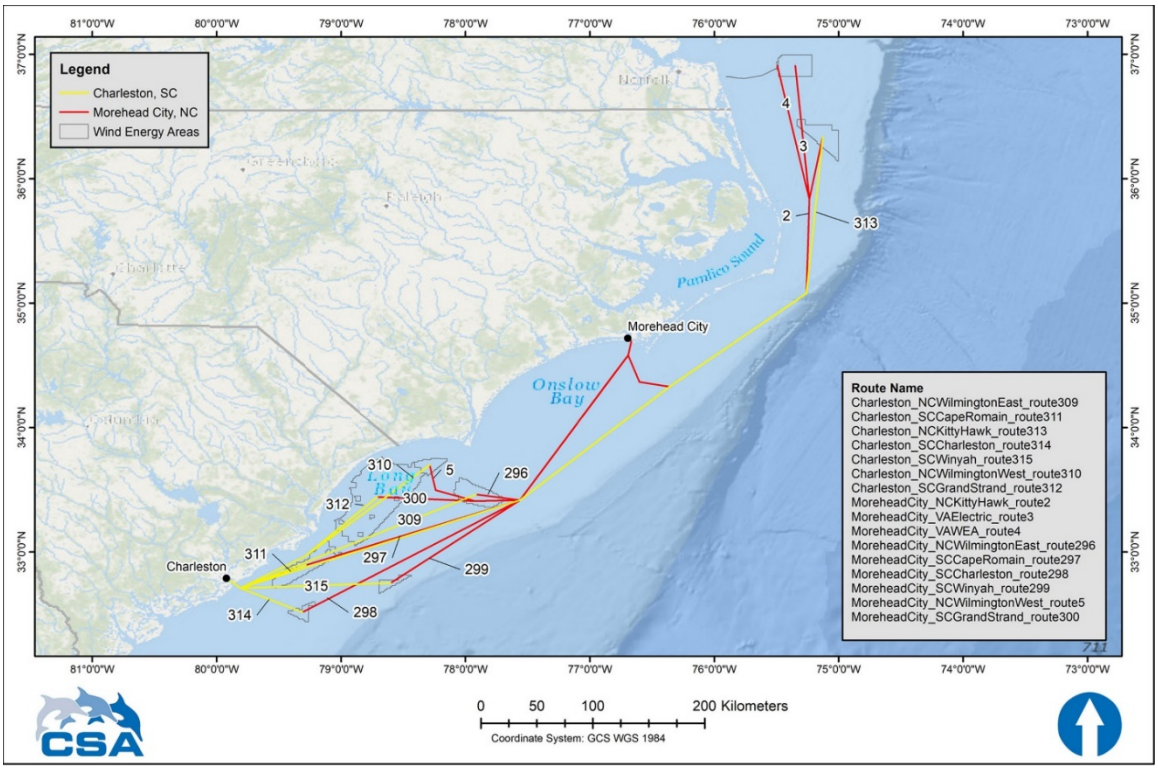


Figure B-16. Pre-drawn vessel routes from Moorehead City, NC and Charleston, SC to the wind energy areas

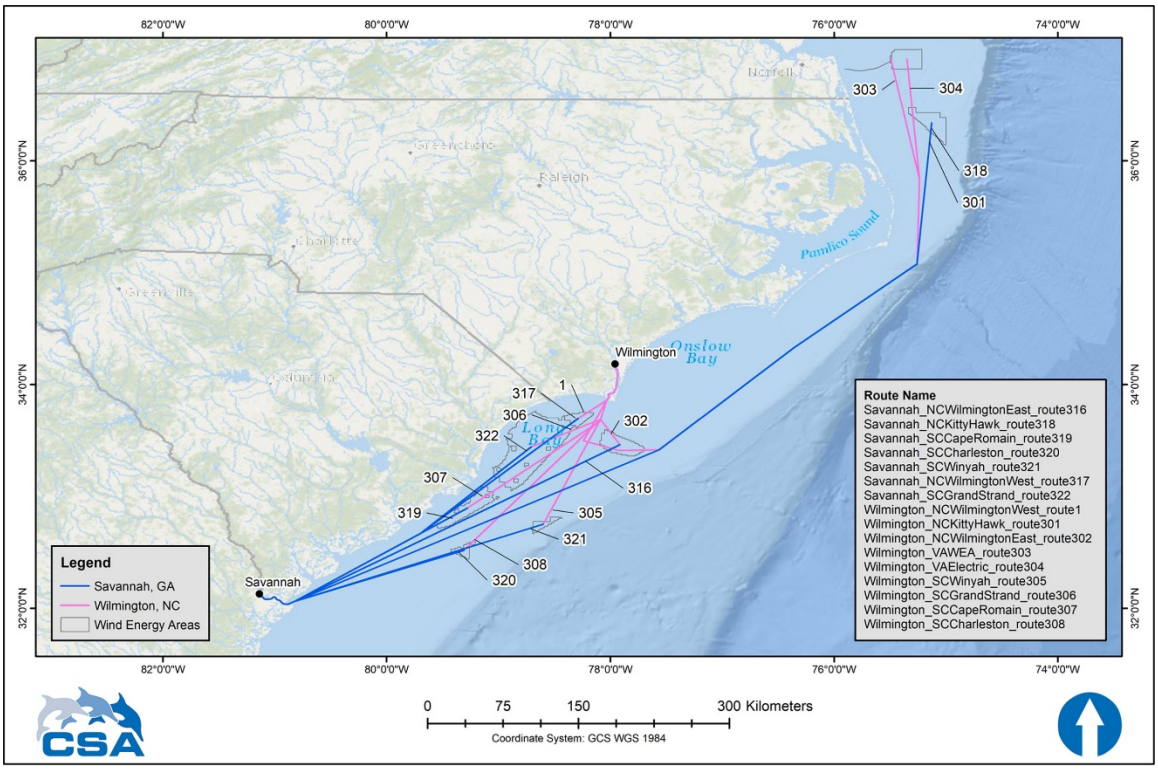


Figure B-17. Pre-drawn vessel routes from Wilmington, NC and Savannah, GA to the wind energy areas

Department of the Interior (DOI)

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors the Nation’s trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

Bureau of Ocean Energy Management (BOEM)

The mission of the Bureau of Ocean Energy Management is to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way.

BOEM Environmental Studies Program

The mission of the Environmental Studies Program is to provide the information needed to predict, assess, and manage impacts from offshore energy and marine mineral exploration, development, and production activities on human, marine, and coastal environments. The proposal, selection, research, review, collaboration, production, and dissemination of each of BOEM’s Environmental Studies follows the DOI Code of Scientific and Scholarly Conduct, in support of a culture of scientific and professional integrity, as set out in the DOI Departmental Manual (305 DM 3).