User documentation for the Stochastic Collision Risk Assessment for Movement (SCRAM 2)

Developed by:

Biodiversity Research Institute

U. S. Fish and Wildlife Service

With funding from:

The Bureau of Ocean Energy Management

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Acknowledgements

This study was funded in part by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Program, Washington, DC, through Inter-Agency Agreement Number M19PG00023 with the Fish and Wildlife Service (USFWS).

We would like to thank Wendy Walsh and Anne Hecht of the USFWS for their input on regional population size estimates for inclusion in the models, and David Bigger (BOEM) for his review of the models, user interface, and user manual. We would also like to thank five reviewers from the U.S. Geological Survey for their input on an earlier version of SCRAM. SCRAM builds upon significant intellectual and analytical contributions from earlier collision risk models, including models by Band (2012), Masden (2015), McGregor et al. (2018), as well as the current implementation of stochCRM in the stochLAB R package (Caneco et al. 2022). Many thanks also to Brian Gerber at the University of Rhode Island (URI) and Tom Witting (USFWS), for providing feedback on an earlier version of SCRAM and Chris Field and Brian Gerber, URI for early contributions to SCRAM code base.

For More Information

This user manual is for SCRAM tool version 2.1.6 (Glimmering Biquinho), available at https://briloon.shinyapps.io/SCRAM2/. Updates to the tool and user manual will be posted at https://briloon.shinyapps.io/SCRAM2/ and at the SCRAM project webpage at briwildlife.org/SCRAM. Additional information on this effort will also be made available via a report to the Bureau of Ocean Energy Management, which will be made available on the Data and Information Systems webpage at www.boem.gov/Environmental-Studies-EnvData.

For more information on the tool or provide comments, contact Andrew Gilbert at the Biodiversity Research Institute (Andrew.gilbert@briwildlife.org). The R code for SCRAM2 is provided at the SCRAM GitHub repository: https://github.com/Biodiversity-Research-Institute/SCRAM2. Update requests and bugs can be posted at https://github.com/Biodiversity-Research-Institute/SCRAM2/issues, or by contacting Andrew Gilbert at Andrew.Gilbert@briwildlife.org. Users that have species data to contribute for the three species can contact Andrew Gilbert at Andrew.Gilbert@briwildlife.org.

Citation

Gilbert A, Adams EM, Goyert HF, Gulka J, Loring PH, Stepanuk JEF, and Williams, KA. User documentation for the Stochastic Collision Risk Assessment for Movement (SCRAM) Version 2. Available at https://briloon.shinyapps.io/SCRAM2/. 37 pp.

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Overview

This is a user guide to an online web tool that provides access to a model that simulates collision risk to birds from existing or planned offshore wind energy development in the eastern United States. The underlying model is adapted from the widely used framework developed by Band (2012), which is often referred to as a collision risk model (CRM). This CRM for the eastern U.S. (i.e., Atlantic Outer Continental Shelf) is run in the open-source computing software environment R (R Core Team 2023) using code adapted from Masden (2015) and Trinder (2017) and now built substantially on the stochLAB package for R (Caneco et al. 2022). Model calculations are accessed through an online user interface via a web application, similar to the stochCRM application developed by Marine Scotland (McGregor et al. 2018). Collectively, we are calling this adaptation of the CRM and user interface the Stochastic Collision Risk Assessment for Movement (SCRAM) Version 2 or SCRAM2.

The model and web application were developed for three bird species that are often the focus of impact assessments for offshore wind energy development in the northwestern Atlantic: Roseate Tern (*Sterna dougallii*), Red Knot (*Calidris canutus*), and Piping Plover (*Charadrius melodus*). There are two main model options to provide a stochastic estimation of collision risk: one estimate is based on Band (2012) Annex 6 calculations of collision risk, which assumes a uniform distribution of migrants within a specified migratory corridor width, while the second estimate uses tracking data from automated radio telemetry data from the Motus Wildlife Tracking System ('Motus'; www.motus.org) as well as data from GPS/Argos satellite telemetry tags. The spatial and temporal extent of collision risk estimated by these two modules is slightly different, as described in Goyert et al. (2024), so annual collision risk estimates produced by each approach are not directly comparable. However, including both modules in one platform allows end users to more efficiently calculate collision risk using both methods, and provides uniform reporting.

This user manual for SCRAM has been developed to communicate the basics of the models and to guide users in its execution via the user interface. **It is strongly recommended that users also review the SCRAM reports (Adams et al. 2022 and Goyert et al. 2024) to understand the models and their limitations prior to using the app.**

What is the goal of SCRAM?

CRMs generate estimates of the number of bird collisions that are expected to occur at offshore wind farms, which can be used to inform planning, mitigation, and assessments of the impacts of increased mortality for at-risk species. SCRAM can provide decision support for both environmental assessments and research related to avian collision risk from offshore wind. User-generated inputs to SCRAM include project-level turbine operational data. SCRAM facilitates the use of CRMs by providing all necessary species inputs to generate collision risk estimates for locations on the Atlantic Outer Continental Shelf (OCS) for the three target species. The model and web application were developed using Motus telemetry data (Loring et al. 2018, Loring et al. 2019, Loring et al. 2021) for the Roseate Tern, Red Knot, and Piping Plover. The incorporation of GPS tracking data in the movement modeling effort is planned for future updates, to improve occupancy predictions and thus collision risk estimates for the three focal species.

The purpose of the tool is to allow users to compare relative collision risk estimates across wind farms and project design envelopes; collision estimates should only be treated as relative measures – they are neither static nor final. The underlying statistical models that describe movement and flight height are designed to capture the large-scale processes that drive variation in collision risk across the Atlantic OCS, and therefore might not fully capture fine-scale variation (i.e., at the project-level scale) in movement and/or flight height and thus collision risk; users should be cautious about applying SCRAM in anything other than a relative way. For more specialized applications, the underlying code for these models, as well as our adaptation of the Caneco et al. (2022) CRM, is available on GitHub for download and modification.

Intended audience for SCRAM

The intended audience is anyone with an interest in understanding avian collision risk from offshore wind energy development, for the purposes of decision-making, planning, policy, or environmental assessments. This audience includes conservation practitioners, state and federal agencies, non-governmental organizations, and the offshore wind energy industry. The web application was developed for users who do not have previous experience with statistical or computational modeling.

What is a Collision Risk Model?

At its core, a CRM estimates the number of times that individuals of any given bird species are expected to collide with an array of wind turbines. The key pieces of information are: (1) how many individuals of a given species occur in the development area, (2) how many of those animals could pass through the rotor-swept zone of the turbines, (3) the flight behavior of the animals, and (4) the probability that the animal will avoid the turbine blades through meso- or micro-avoidance. The rules of the simulation are determined by first principles of physical phenomena – e.g., blade rotation frequency is used to determine how often blades would strike objects passing through them– as well as basic ecological models that estimate the expected occurrence of birds in the vicinity of turbines.

The simulation relies on turbine array-specific data and physical turbine characteristics (e.g., number of turbines, rotor speed, altitude of the rotor-swept zone), as well as site-specific estimates of passage rates for focal species traveling through the area of interest. In traditional CRMs such as Band (2012), this latter value is calculated differently for migrants than for resident birds; residents are assumed to have a constant flux through the rotor-swept zone of the wind farm that is dictated by their flight speed and active period of flight. For migrants that are assumed to transit through an area once within a specified timeframe (such as a season), the user must estimate the width of the population's migratory corridor to help calculate the number of birds per km moving across this migratory front.

Two methods are used to calculate the flux parameter of the CRM in the SCRAM web application: the SCRAM movement modeling approach, and the method described in Band (2012) Annex 6. The movement modeling is detailed further below and in the SCRAM report (Adams et al. 2022, Goyert et al. 2024). It uses individual tracking data to determine variation in migratory habitat use to estimate migrant flux. Areas where birds are detected more frequently will be estimated to have higher migrant flux. The Band Annex 6 approach estimates migratory corridor width using expert opinion and assumes that animals are evenly distributed across that corridor. The migratory corridor width only varies with latitude and does not use any other movement or habitat use data (such as tracking data) to inform estimates of migratory flux.

The vertical density of birds is calculated from the migratory frontal passage rate multiplied by the diameter of the rotor-swept zone (RSZ). This vertical passage or "flux" value is then scaled to the total area of the RSZ across all turbines, to estimate the total number of passages in the wind farm. Information from the scientific literature (or, in some cases, tracking data) is used to estimate other characteristics of target species (e.g., flight height distributions, flight speed, bird size, and avoidance behavior), to determine what proportion of the birds represented in the flux estimate are at risk of collisions. This type of collision risk model includes all major components that are thought to be likely to influence the risk for a proposed or existing array, but it does not integrate information from other arrays in the region. It is, therefore, best suited for array-specific assessments of relative risk.

How does SCRAM work?

The overall framework for SCRAM has four major components:

(1) the estimated number of bird passages (flux) through the project area,
(2) the proportion of those birds estimated to occur within the RSZ (including consideration of avoidance rates),
(3) the proportion of time the turbine is active, and
(4) the collision probability with the turbine.

After we determine the best estimate for the number of expected collisions for a single turbine, collisions are scaled up to an entire wind farm. An example of how SCRAM works is presented in Appendix I. The process for estimating number of passages over a given time period (Step 1) differs between SCRAM and Band 2012 Annex 6 calculations. The Band Annex 6 approach (Appendix II) estimates a migratory corridor width based on expert opinion, which varies with latitude and assumes that animals are evenly distributed across that corridor width. The total number of migrants is divided by the migratory front width (km), as estimated from the latitude of the centroid of the wind farm (birds/km). In contrast, the SCRAM approach uses tracking data including automated radio telemetry ('Motus') and GPS/Argos data to vary the migratory corridor by both latitude and longitude (Adams et al. 2022, Goyert et al. 2024). For SCRAM 2, we devised models that described the satellite-based tracking data, and included updated automated radio telemetry (Motus) datasets. State-space movement models were implemented on both data sources to isolate model uncertainty from two types of error:

ecological process and observation error. Through this process, we estimate daily locations of animals and the model uncertainty in those positions, then overlay these predictions across a spatial grid. We calculate the daily occupancy per grid cell, which is the proportion of tagged individuals found in each grid cell per day. We divide the mean number of individuals per grid cell by the total number of tagged individuals in any given month. Cumulative daily occupancy in a month is the sum of all daily occupancy estimates in that month. Multiplying occupancy by regional population size (as estimated by USFWS experts and monitoring efforts; Adams et al. 2022, Goyert et al. 2024) yields local migratory passage rates, defined as the expected number of passages per month in any given grid cell. This value is converted to a migratory passage rate of birds/km of migratory corridor width by dividing total birds by the width of the grid cell (the migratory corridor). This value is now an estimate of cumulative daily migratory passages for the grid cell (Appendix I).

Steps 2-4 are functionally similar in both the SCRAM movement model and the Band 2012 Annex 6 migratory model, except Annex 6 assumes a uniform distribution along the migratory front (Step 1). As described above, the Band approach estimates the migratory corridor width for a given latitude and calculates the number of migrants/km of that corridor per month (Appendix II).

Step 2 estimates the proportion of animals in the wind farm RSZ. The wind farm frontal area is the width of the total rotor swept zones of the project, i.e., the total area where a bird could collide if they were migrating through the grid cell. This is used to determine the number of migratory passages per km of wind farm frontal width (i.e., the total width of all the RSZs in the wind farm). Next, the number of birds flying within the RSZ using flight height distribution data. SCRAM uses flight height from Motus tracking data for our study species to estimate the proportion of the population within the RSZ or at a given altitude, depending on the model type. Step 3 estimates the “amount of time active” for turbines as proportion of time operational in a month. Wind speed data at the site and the cut-in and cut-out speeds of the turbine model (e.g., to estimate the proportion of time for which a turbine is expected to generate power) which is reduced by the expected maintenance time or other turbine downtime expected. Step 4 accounts for the proportion of birds expected to exhibit avoidance behaviors and is based on monitoring data at European turbines. Collision rate is a function of flight speed, length and wingspan of the bird, and turbine parameters such as rotor length, blade width, and rotations per minute. Note there are two ways to estimate collision rates in SCRAM: Option 2 and Option 3 from the Band Model. In Option 2, collision is estimated for the entire RSZ. In Option 3, the RSZ is divided into discrete altitudinal bands and the collision risk is weighted by the amount of migratory flux at a given band.

SCRAM does not integrate information from multiple wind energy arrays in a region of interest. Plans for future work on SCRAM include exploring risk estimates across multiple projects (cumulative risk). In its current form, SCRAM can be used serially to provide individual array estimates of risk. Added together, these provide a rough estimate of cumulative risk across sites within a region. However, this additive framework assumes that risk is fully additive and linear, which is unlikely to be the case.

How does SCRAM differ from other collision risk models?

One major difference between SCRAM and other CRM frameworks is in the estimation of bird passage rates. Other models typically use observational survey data, most often collected from boats, to estimate passage rates and flight heights. However, observational line-transect surveys at sea primarily target marine birds (as opposed to shorebirds like Piping Plovers and Red Knots), and are not optimal methods for obtaining information on at-sea behaviors or potential for interactions with anthropogenic structures (Camphuysen et al. 2012, Ronconi et al. 2015). Thus, SCRAM estimates bird passage rates using data from the Motus Wildlife Tracking System, an automated radio telemetry network (Taylor et al. 2017, Loring et al. 2018, Loring et al. 2019), as well as satellite tracking data, where available. For technical details of the general modeling framework used in SCRAM, see Band (2012), Masden (2015), Trinder (2017), and McGregor et al. (2018). More information on the differences between SCRAM and previous implementations of Band's (2012) collision risk framework is available in Appendix III. Detailed information on SCRAM data inputs is included in Appendix IV.

Limitations of the current version of SCRAM

The reliability of any collision risk modeling framework is determined by 1) how it handles uncertain data, 2) how representative the data are, and 3) whether the assumptions underlying the model are appropriate. Incorporating uncertain data is relatively straightforward, as current implementations of the Band (2012) framework for collision risk modeling are stochastic – i.e., the bounds of the collision risk estimates reflect the uncertainty of the input data. However, if the input data are biased, this could likewise bias resulting collision risk estimates. Uncertainty estimates should account for bias whenever possible, but unknown or unquantifiable biases are challenging to incorporate. A source of bias could be a spatial or temporal mismatch between the scale of the area of interest (e.g., project wind farm) and the underlying data, which causes fine-scale deviances between the input data and real values for the location/time period of interest. For example, SCRAM facilitates the use of CRMs by providing all necessary inputs to generate estimates for any location within a large area of the Atlantic OCS. The underlying statistical models aim to capture the large-scale processes that drive variation across this planning area, and therefore might not fully capture fine-scale variation. Further, Motus stations can only capture data around active receivers; and based on the terrestrial locations of these receivers in past movement studies, are likely to create estimates that are biased toward coastal areas. This degree of bias could be significant but is difficult to estimate without substantial and reliable data from offshore locations. The addition of Red Knot satellite telemetry data and subsequent movement models to SCRAM does suggest substantial offshore movements for this species, which points to the higher level of positional uncertainty and potential bias in Motus-based models. Using the ensemble approach (of Motus and satellite telemetry models) for Red Knots has improved offshore inference and thus reduce overall uncertainty in the CRM estimate for this species. However, we do not have sufficient offshore satellite tracking data to implement similar approaches for Roseate Terns and Piping Plovers at this time. Additionally, there has been limited empirical validation of collision risk estimates with real-world measurements of collisions (though see Skov et al. 2018 and Tjørnløv et al. 2023).

SCRAM is an evolving tool that continues to be updated as additional data and methods become available. SCRAM's CRM currently uses static flight height distributions, as opposed to distributions that vary over space and time, which would be more realistic (Péron 2020). Our treatment of flight heights as a non-parametric distribution implicitly accounts for some of this potential variation. However, more research is needed to determine how unexplained variation (i.e., uncertainty) influences collision risk (e.g., if flight heights increase substantially with increasing distance from land). One particular challenge to estimating passage rates from movement data is determining the overall number of individuals that could potentially encounter offshore wind farms. While we are using the latest regional population estimates for the target species (Goyert et al. 2024), our knowledge is limited regarding how well the available movement dataset represents broader population-wide movement patterns. Sources of potential bias in movement data include the lack of offshore Motus stations to detect animals, low sample sizes of tagged animals, and the limited geographic range where tags were deployed. More research and data describing population-level movements will improve future estimates of collision risk.

In general, CRMs should be implemented with some amount of caution. As with all models, they are only as good as their inputs and ability to represent observed phenomena. Few major empirical validation tests of CRMs have been conducted to determine if seabird collision rates were similar to model predictions, and these studies reported small sample sizes of actual collisions (Skov et al. 2018, Tjørnløv et al. 2023). Because of the lack of empirical testing of these models, particularly for the focal species of interest, it is unclear whether CRMs are well-tuned to realized collision risk. However, CRMs represent the best available science for estimating collision risk from offshore wind energy development prior to construction. Where lack of information on collisions and avoidance behavior may introduce bias in collision risk estimates, collision estimates may still be compared across sites, assuming constant bias across space. Therefore, we suggest using SCRAM in a comparative context where possible.

What software and/or hardware is required for SCRAM?

Masden (2015) adapted the Band (2012) model for the programming language of the computing software R (R Core Team 2023). Trinder (2017), McGregor et al. (2018), Christopher Field, Brian Gerber at the University of Rhode Island, and these authors have further adapted this R code for use with Motus data as well as numerous other enhancements. McGregor et al. (2018) developed online user interfaces for the 'stochLAB' R package (https://cran.r-project.org/web/packages/stochLAB/index.html; Caneco et al. 2022) using the R package 'shiny' (Chang et al. 2021), which allows users to run computational tasks in R on a remote server. SCRAM adapted the code from McGregor et al. (2018) and Caneco et al. (2022) and further modified it to run on the Shinyapps.io remote server. No software is needed other than an up-to-date web browser running on any PC, Mac, or Linux device.

Updates to the Tool

Users experiencing problems with the operation of the tool should contact Andrew Gilbert at Andrew.gilbert@briwildlife.org or post a bug request at the SCRAM GitHub repository (https://github.com/Biodiversity-Research-Institute/SCRAM2/issues). Updates to the tool and/or this user manual will be published at https://briloon.shinyapps.io/SCRAM2/ and at the SCRAM project webpage at briwildlife.org/SCRAM.

How to use the web application (SCRAM)

Overview

SCRAM requires two types of data: 1) "Wind farm data", which are user-provided via a single spreadsheet of turbine and array characteristics, and 2) "Species data", which are incorporated into the tool for the three target species. Currently, custom species data can **NOT** be uploaded - the included species data cannot be changed. Example wind farm data inputs can be downloaded from the application interface (instructions below).

The application is built as a dashboard-type layout in which input is added on the left-hand side of the screen (the sideboard) and outputs are available on the tabs to the right of the sideboard in the main body of the dashboard. Additional links and information are available in the header bar of the app:

The most recent version that is available online is shown in the header along with a series of three symbols:

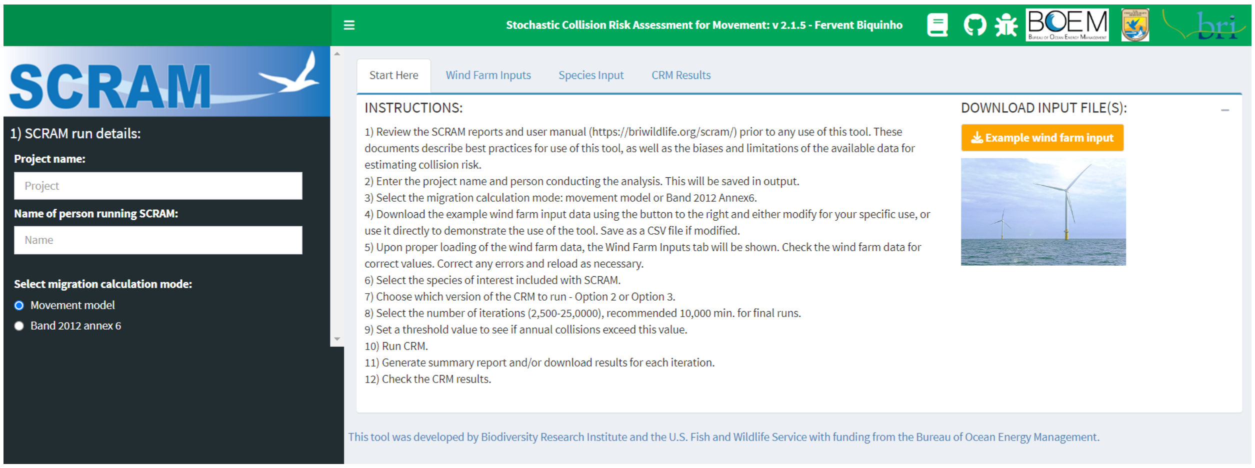
1)  provides a link to the user manual.
2)  provides a link to the SCRAM GitHub project.
3)  provides a link to the bug submission/improvements request for SCRAM in GitHub.

The header bar also includes links to the affiliated institutions.

There are currently four tabs in the main body of SCRAM: "Start Here", "Wind Farm Inputs", "Species Input" and "CRM Results". The last three tabs populate following a SCRAM run.

1) Start Here – this tab includes some basic instructions for use as well as a button for example wind farm inputs as a file that can be modified for loading to SCRAM.
2) Wind Farm Inputs – A table showing the wind farm specifications and operational data for the uploaded wind farm, as well as a map of the wind farm location with the ability to either a) look at the predicted occupancy probabilities for the target species when using the movement models, or b) examine inputs for the migration front and migratory corridor for the Band 2012 Annex 6 input option.

3) Species Input – this tab includes tables of species data and a plot of the flight height data that are included with SCRAM for Red Knot, Roseate Tern, and Piping Plover, and the species monthly mean population estimates with SD.
4) CRM Results – This tab is where basic outputs are provided following a model run. Outputs are provided as a histogram of the number of collisions per year for each iteration. This tab is also where the user can download model inputs and results and a PDF report of the SCRAM inputs and results.



Examples of wind farm data input (Appendix IV) can be downloaded from the application interface using the “Example wind farm input” button shown on the “Start Here” tab.

Once the data for turbine and array characteristics are compiled and formatted appropriately (see examples on interface and in Appendix IV), it should take a few minutes to finish setting up SCRAM to run for a target species. Once the data are uploaded, the run time is generally under a minute per model run in SCRAM 2, depending on which model specification is selected (SCRAM 2 is much faster than SCRAM 1.0.3). The general steps for running SCRAM are discussed below. The interface was created to lead users sequentially through data inputs and model runs, such that some inputs are not available to the user until the prior input has been entered. The basic steps are as follows (with a more detailed description of each step included below):

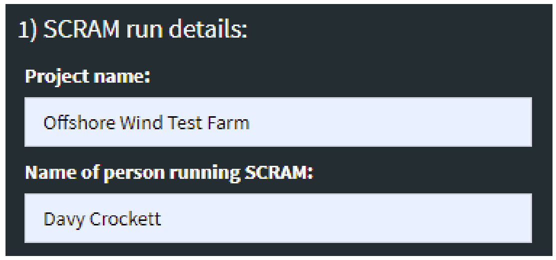
1) Enter the project name and person conducting the analysis.
2) Select the migration calculation mode, either using the (a) movement models, or (b) Band (2012) Annex 6 migratory (uniform) front estimates.
3) Download the example wind farm input data as a comma separated value (CSV) file from the “Start Here” tab using the “Example wind farm input” button to the right. Either use the example data directly for learning or testing purposes or upload a modified file for your use.
4) Upon loading the wind farm data via a CSV file, the “Wind Farm Inputs” tab will be shown. Check the wind farm inputs are correct by examining the maps and tables in the “Wind Farm Inputs” tab. Correct any errors and reload as necessary.
5) Select the species of interest.

6) Once the species is selected, the species habitat use map will show and data on the species data tab will be populated. Subsequent steps and collision risk estimates operate under the assumption that these data represent the best available science.
7) Choose which specification of the CRM to run: Option 2, the faster/approximate version that uses the flight height distribution but does not account for variability in risk along the RSZ, or Option 3 (default), the slower/more precise version that accounts for variability in risk along the RSZ by integrating the differences in risk along the turbine blades for a more robust assessment. *Note that for some species, Option 2 may significantly over- or underestimate risk as compared to Option 3, depending on the distribution of flight heights in the RSZ.*
8) Select the number of iterations (2,500-25,0000) in increments of 500 where 10,000 is the default; 10,000 or more are recommended for final model runs.
9) Set a threshold for which to calculate the number of collisions exceeds this threshold. Estimates that are above the threshold number will be highlighted in model outputs, but are not used in the risk calculations and do not change the outcome.
10) Run CRM. Refer to the status bar to monitor the CRM as it runs. Once complete, a histogram will show the frequency of the total number of collisions estimated per year across iterations.
11) Once the histogram is visible, you may choose to download model results (optional).
12) Instead of, or in addition to, downloading model results, you may choose to generate an output report (optional).
13) Check the CRM results.
14) After downloading all relevant information, it is advised to reload the SCRAM application environment by refreshing your browser and re-entering the address of the website to run SCRAM again, as needed. This will ensure that the prior model inputs and outputs will be cleared from memory.

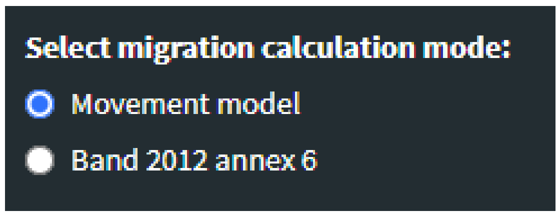
SCRAM results are not provided for locations for which the underlying species movement data are not available. Band results are provided for all locations within the prespecified project study area (Adams et al. 2022, Goyert et al. 2024). Similarly, SCRAM will not provide collision risk estimates for months of the year during which movement data are unavailable or insufficient for a given species (i.e., represented by too few animals to provide adequate results). For the three focal species currently included in SCRAM, predictions are limited to fall migration (Red Knots); incubation period through fall migration (Piping Plovers); and incubation period through post-breeding dispersal (Roseate Terns). Band results are not limited by the availability of movement data, but nevertheless return estimates of zero collision risk in months where the regional population size estimate for the study area is estimated to be zero. As such, the months of the year for which SCRAM vs. Band models present collision risk estimates differ slightly.

Detailed description of SCRAM usage

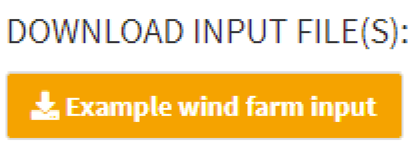
1) *Enter the project name and person conducting the analysis.* Choose whatever project name will be informative for you; this information will be saved in the output once SCRAM is run.



2) *Select the migration calculation mode.*



3) *Download the example wind farm input data from the "Start Here" tab to either use the example data directly or modify the file for your specific use.* Data for turbine and array characteristics are required to run any version of SCRAM. Turbine and array characteristics include the physical and geographic characteristics of the wind farm, including the dimensions of the turbine model, rotor speeds, and the width and geographic coordinates of the turbine array (Table 1 in Appendix IV). The downloadable wind farm input file (TurbineData_inputs_2run_example.csv) provides an example of wind farm alternatives and can be used to test and learn SCRAM.

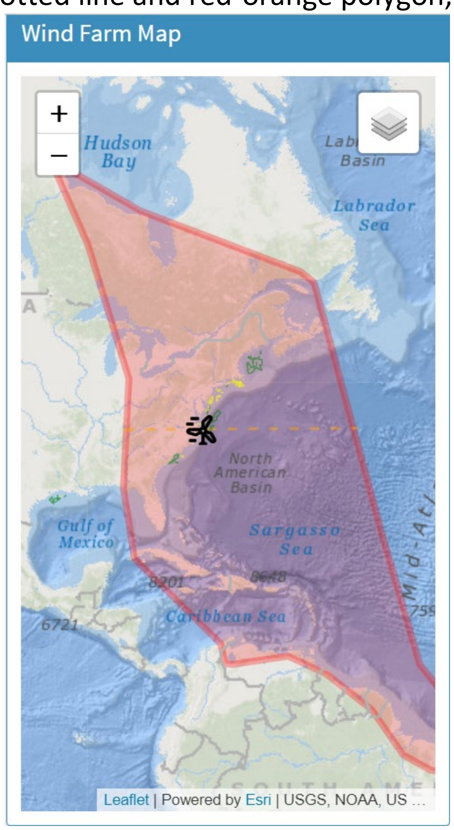


   a. The application accepts these data as a single .csv file that has alternate options for arrays specified as rows. You can provide as many options as you desire, by adding rows or removing the second row when only a single option is desired. SCRAM will run and provide outputs for each row in this table, assuming they have the same geographic location.
   b. Specified array options can vary by parameters including power, size, and turbine model specifications among others. Due to rapidly changing wind turbine technology, offshore wind farms in the U.S. now typically specify a design envelope for wind turbines (range of engineering specifications) during the planning and consulting phases, rather than selecting a single wind turbine specification, to account for the minimum and maximum ranges of engineering measurements under consideration. SCRAM can be parameterized with the range of options given in the design envelope to generate two or more collision risk estimates during a single

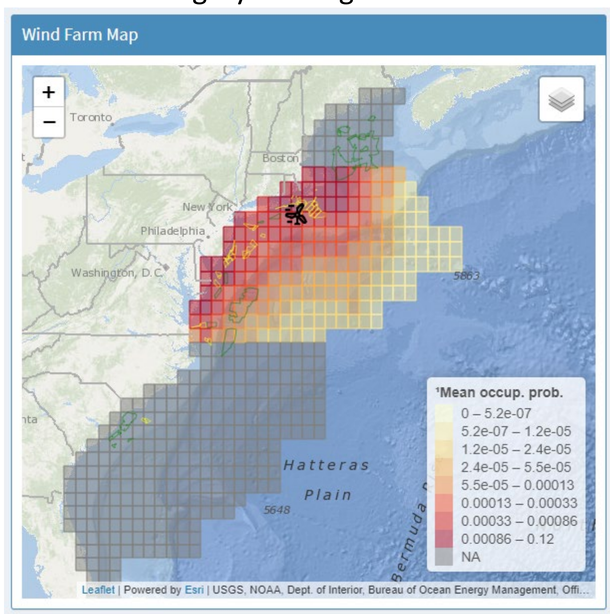
SCRAM run. Also, changing the size of a wind turbine generator (e.g., 6 to 12MW capacity) can lead to fewer turbines being installed; providing different turbine options will allow users to evaluate the differences in collision risk across these scenarios. Note that SCRAM only allows for variability in design parameters (e.g., rotor radius, blade width) across array alternatives (rows); location parameters (latitude and longitude) must be identical across all alternatives within a single input file.

c. SCRAM can run using only **ONE wind farm location at a time**. If the rows for the turbine and array data include more than one set of geographic coordinates (latitude/longitude), you will be prompted to "check values for Latitude and Longitude." To run multiple locations for SCRAM, you must run SCRAM multiple times and change the geographic coordinates for each run. Geographic locations must be entered as latitude and longitude in decimal degree format, determined using the WGS84 datum. Coordinates must be entered as numerical values with western hemisphere longitudes represented as negative numbers, e.g., -70.1234, and northern latitudes as positive values, e.g., 39.1234. If coordinates fall outside the geographic extent of this tool, you will be prompted to "check values for Latitude and Longitude."

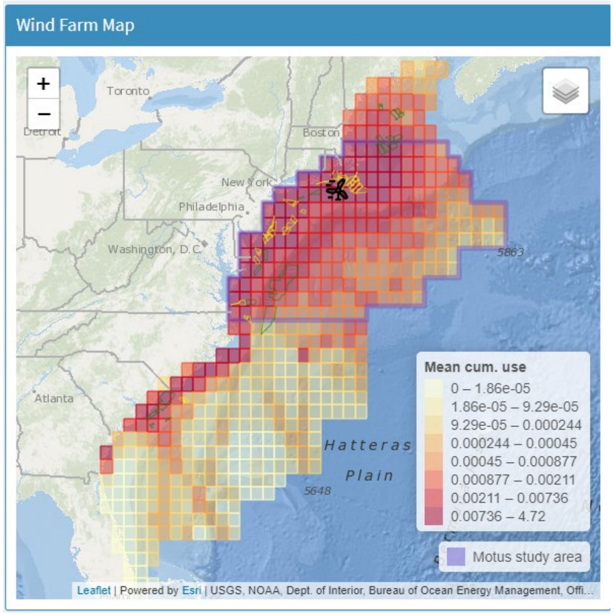
d. For the Band model, the location of the wind farm must fall within the study area on the Atlantic OCS (Adams et al. 2022, Goyert et al. 2024). The latitude of the wind farm centroid (used to estimate the width of the migratory corridor at the wind farm) and the estimated migratory corridor for the species are both shown on the wind farm map (yellow dotted line and red-orange polygon, respectively).



For the movement model for Piping Plover and Roseate Tern, the location of the wind farm must fall within the latitudes of the study area in which Motus stations were actively maintained during the tracking study period (including a 20 km buffer to the north and south to account for detection range; Loring et al. 2018, 2019, 2021, Goyert et al. 2024). For the movement model the modeled area is depicted in the wind farm map as colored rectangles (yellow to red corresponding to cumulative daily occupancy, averaged by month). Areas within the broader Atlantic OCS study area that fall outside the tracking study area are shown as gray rectangles.



For Red Knots, due to the addition of satellite telemetry tracking data and subsequent ensemble model, the location of the wind farm must fall within the study area on the Atlantic OCS (Adams et al. 2022, Goyert et al. 2024).



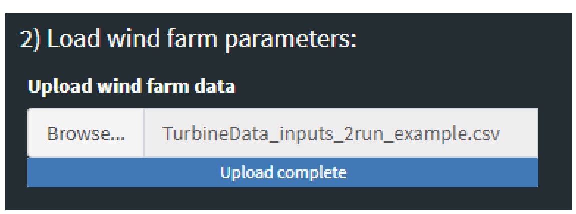
When the user tries to load a wind farm outside of the designated study area for the selected model, the following error is shown and the user will not be allowed to proceed with running the model.

Check values for Latitude and Longitude

Latitude and/or Longitude values fall outside the geographic extent of this tool. Please upload appropriate values with wind farm data or consult documentation for more information on geographic scope.

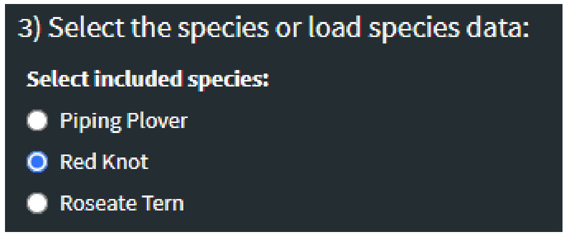
OK

e. The naming convention of the wind farm input file itself does not matter, as long as it is recognized by your computer operational system and the appropriate fields are included and correctly named (Appendix IV).
f. Turbine specifications, such as blade pitch and width, can sometimes be found at locations such as the turbine manufacturers' web pages or the U.S. Geological Survey's Wind Turbine Database.
g. Upload the data file once you are satisfied with the values in the file.

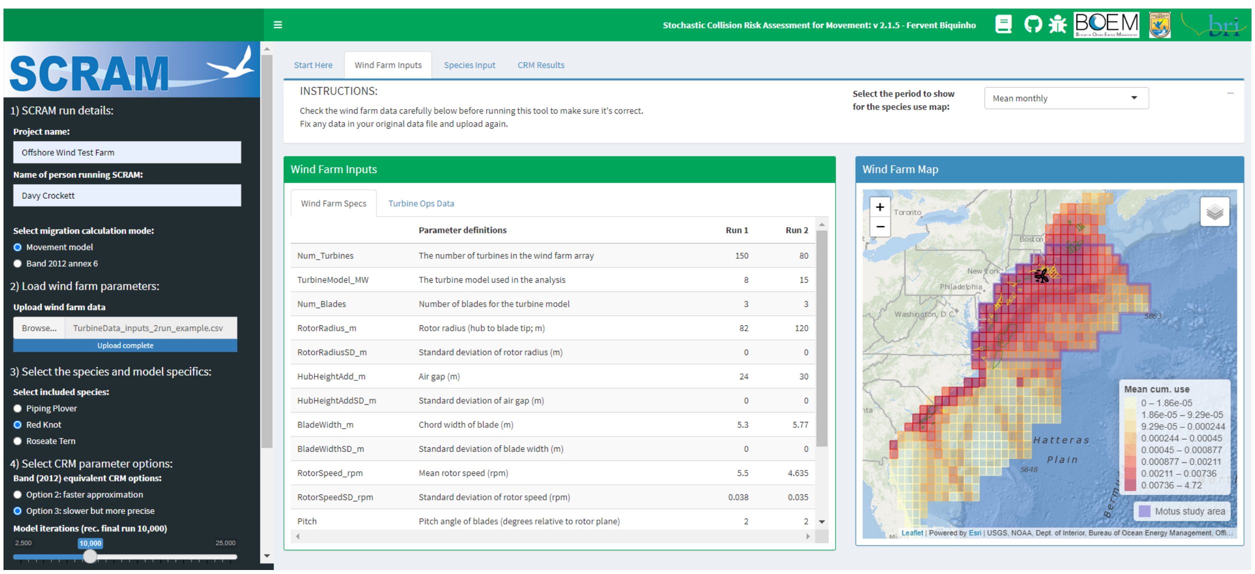


4) *Check the wind farm data tables for correct values*. Make sure the values you uploaded to SCRAM are appropriate for these models by examining the tables in the "Wind Farm Inputs" tab. Correct any errors within the input file and reload as necessary.

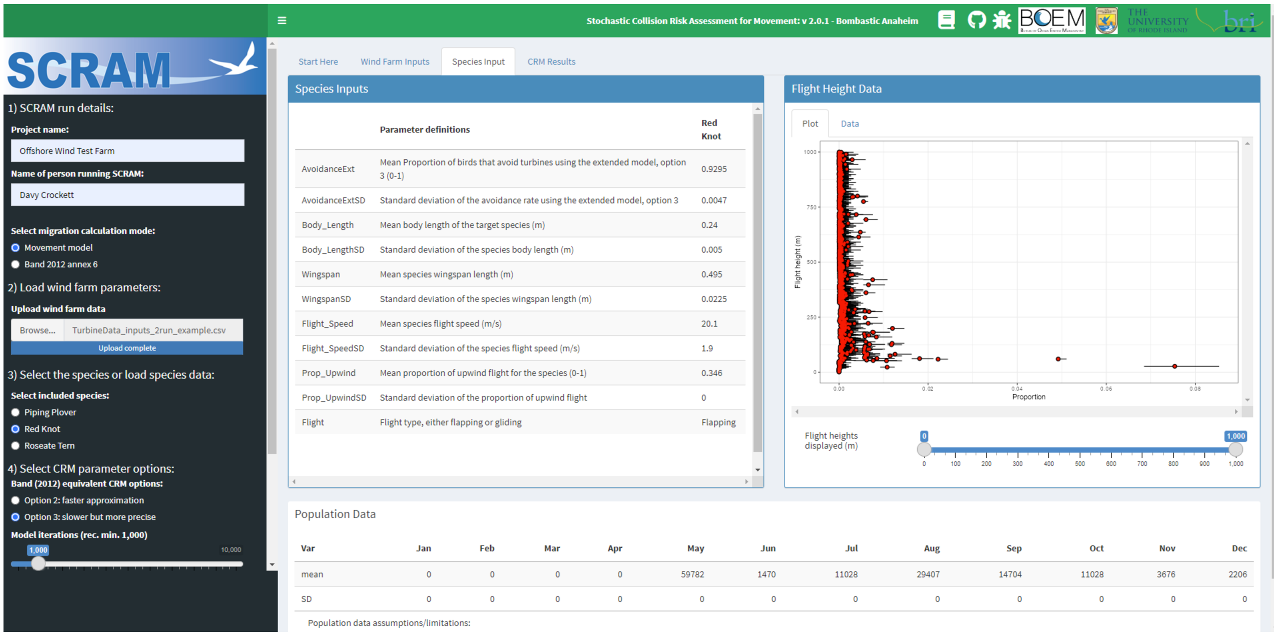
5) *Select the species of interest.* Select one of the included target species (Piping Plover, Red Knot, or Roseate Tern).



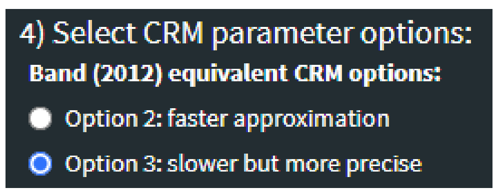
6) The map on the right of the “Wind Farm Inputs” tab shows the cumulative use surface generated from the modeled movement data for each species. The user can also turn off the modeled data layer by clicking on the symbol at the upper right corner of the map. Default map layers turned on include the BOEM lease areas and wind energy areas, the wind farm location, and the species use data. The user can also look at every month a model was produced for each species by selecting the “Select the period to show for the species use map” dropdown. The default is the mean representation of all model months.



7) *Review the “Species Inputs” table values.* Values included in SCRAM represent the best available science. Visualization of the flight height plot and data table can be filtered for the range of flight heights of interest, using the slider input bar, but doing so does not affect the data used in the model. This feature is for viewing purposes only. Population parameters are currently fixed in SCRAM and can’t be modified but are presented in a table for examination and included in model outputs for reference (For details on how the current values were derived, see Adams et al. 2022 and Goyert et al. 2024).



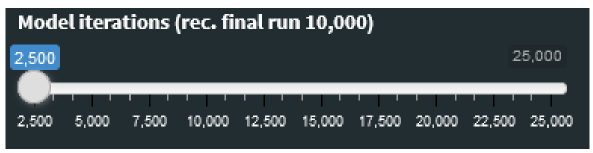
8) *Choose which version of the CRM to run (Option 2: the faster/approximate version or Option 3: slower/more precise version).*



In line with Band (2012) and Caneco et al. (2022), Option 2 provides a rapid approximation of collision risk, whereas Option 3 provides a more precise estimate of collision risk that takes longer to run. When using “Option 2: faster approximation,” SCRAM does not model risk along the rotor blades; collisions are assumed to be constant throughout the RSZ, and as a result the model runs faster. When using “Option 3: slower but more precise”, SCRAM allows collision risk to vary at ~5m or less fixed length increments in altitude along the rotor blades, and thus provides a more precise accounting of collision risk (Trinder 2017) but is slower to run. For some species and turbine models, Option 2 may significantly over- or underestimate risk as compared to Option 3, depending on the distribution of flight heights throughout the RSZ. Option 2 uses basic avoidance values and Option 3 uses extended avoidance values, as defined in Cook 2021.

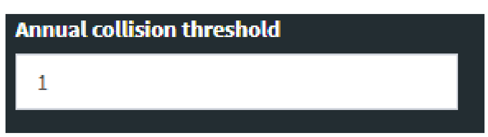
We do not recommend running both options for comparison because, in most cases, the option that estimates risk along the rotor blade (Option 3) will provide the more precise estimate (Trinder 2017). Option 2 is provided as a “short-cut” for exploring SCRAM but should not be used to develop final collision risk estimates. With the latest speed improvements to SCRAM, Option 2 should normally not be used. Future updates may remove this option entirely. **Option 3 should be used to develop final estimates of collision risk**. **Do not use Option 2 to develop final estimates.**

Select the number of iterations. Use the slider to specify how many iterations of the model will be run to propagate the influence of parameter uncertainty on the simulation results. In this CRM framework, uncertainty – i.e., variation in the results among iterations – is a result of the variance estimates provided in the input parameters (Appendix IV). Increasing the number of iterations will give more precise estimates for the model outputs, until the error associated with estimating outputs via stochastic simulation is arbitrarily small. **For final estimates of collision risk, and to get the best estimate from SCRAM, a minimum of 10,000 iterations should be run;** this can execute in less than a minute per turbine model/wind farm specification. Estimates of run time are not given below the iterations slider as in the previous version of SCRAM, since code improvements related to use of the stochLAB package have substantially improved runtime performance.

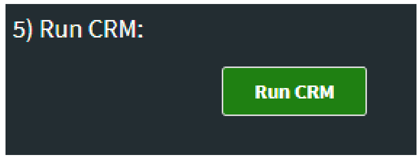


The user must pay attention to SCRAM when the model is running and the browser window is open, because **once it is finished, the application will time out after 30 minutes of inactivity** and will disconnect from the server, and no results will be available for export. Results are not automatically saved, so **the user must export results within 30 minutes after the model finishes**, or otherwise interact with SCRAM to make sure the application is not closed prior to downloading of data and/or report.

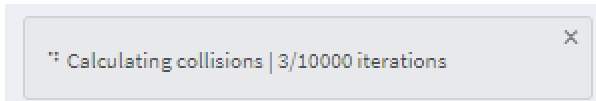
9) *Set a threshold value to see if annual collisions exceed this value.* If desired, the user can specify a threshold value (this number can be zero) to determine what the probability that the output will exceed that value. Note that changing this threshold does not change the results themselves, but rather the presentation of those results. When provided, SCRAM will calculate the proportion of iterations that produce a collision estimate larger than the specified threshold. The application will show the threshold value alongside the results for reference and will include the probability of exceeding this value in a dialog box.



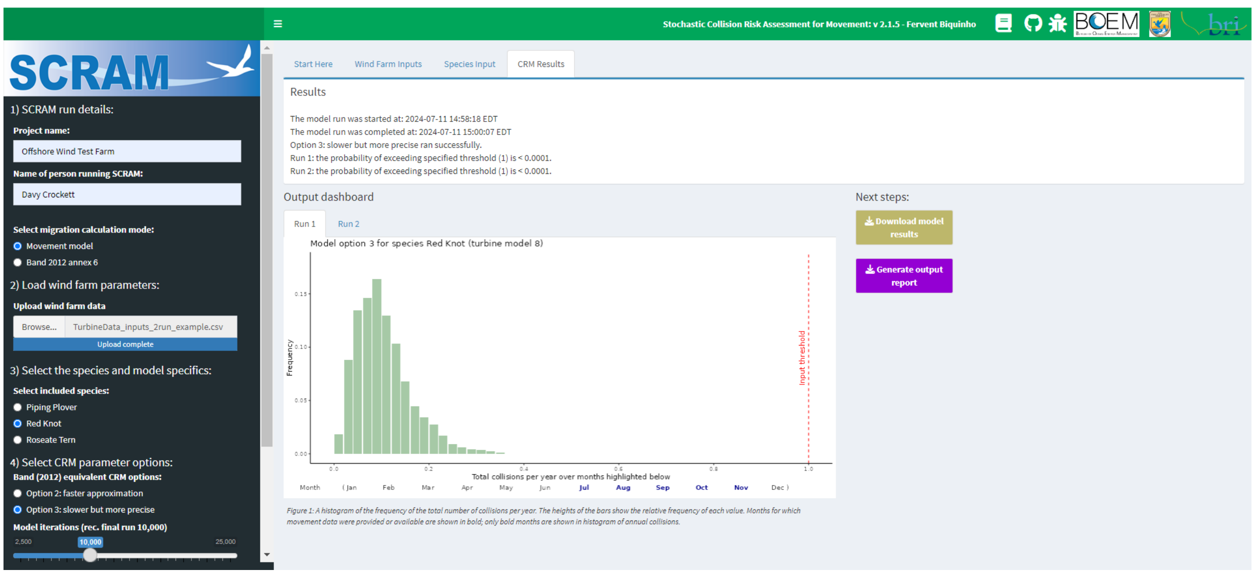
10) *Run CRM.* The button to run the CRM appears when the minimum conditions for running the model are met.



A status bar will update progress through the specified number of iterations, repeating for every wind farm option.



Once the model has completed, the CRM results tab displays basic results including details of the model run times, the model that was run, probability of exceeding the selected annual collision threshold, and histograms (one for each wind farm option) of the number of collisions per year for each iteration. This histogram is also provided in the output report.



11) *Download model results (optional).* Once the model has run successfully, the histogram and option to download the full results will appear. When the user clicks the button, a compressed file will be automatically downloaded containing the following files:

a. Parameter inputs including SCRAM version, project name, modeler, run times, iteration numbers, threshold, migration calculation type (and associated parameters), model option (2 or 3), model cell info, model output, probabilities of exceedance, species labels, population data and assumptions.
b. The original wind farm data file that was uploaded.
c. Turbine parameters.
d. Species parameters.
e. Species flight height modeled data.
f. Species population data.

g. Model output RData file that can be directly loaded into R.
h. Estimated number of birds in the model cell and wind farm per day as .csv files.
i. Collision estimates for each month as daily and monthly estimates in each iteration as .csv files.

12) *Generate output report (optional).* The user can download a custom PDF report for the model runs by clicking the "Generate output report" button. The report provides details about:
    a. the model run (including SCRAM version, run times, project, user, and probability of exceeding the user-specific collision risk threshold),
    b. model input parameters including both species and wind farm parameters,
    c. guidance on biases and interpreting wind farm and species occurrence map,
    d. a table of the estimated daily number of birds present and collisions in the target grid cell for each month,
    e. a table of the monthly mean and 95% prediction intervals for estimated collisions and the annual mean number of collisions and range,
    f. a histogram of the number of collisions per year for each iteration, and
    g. a figure showing the predicted mean and 95% prediction intervals for the number of collisions per month.

If multiple turbine models are run, results will be presented in separate figures/histograms for each model.

13) *Check the CRM results.* Check the results of the model to see that they are sensible. Tips for interpreting the results are discussed below.

14) *Run again.* The model may be run again at this point by selecting another species or varying other model run options. Refresh the app in your browser and begin again with Step 1.

Tips for interpreting the results

SCRAM provides several types of visualizations to aid with interpreting results in the model output report (and in a more limited way in the "CRM Results" tab). It also provides the option to download data as spreadsheets and an RData file of the raw model output (Step 12), to conduct further analysis and/or generate other figures and tables. All figures include uncertainty estimates, either summarized as bars or shown as variation in the model runs across stochastic iterations. In this CRM framework, uncertainty in the collision risk estimates is the result of variation in key parameters (e.g., variation in rotor speed, monthly operational values, wingspan, flight speed) as well as uncertainty in our estimation of these parameters (e.g., uncertainty in flight height estimates due to estimation error or uncertainty in habitat use due to variation in Motus coverage in the region). Increasing the number of iterations will give more precise estimates of the model outputs until the error associated with estimating outputs via stochastic simulation is arbitrarily small (in general, we would recommend running at least 10,000 iterations for this model). Note, however, that we do not measure the bias or uncertainty of the collision risk model itself; rather, we propagate uncertainty in model parameters through the stochastic CRM. If model parameters are biased or uncertainty estimates are inaccurate, then CRM results may be inaccurate or biased regardless of their precision.

The plot on the application interface shows the number of simulation iterations associated with the values on the x-axis, where wider distributions result from greater uncertainty in the number of collisions per year. We have also provided the option to summarize this uncertainty probabilistically by specifying a threshold for the acceptable number of collisions per year. This threshold can be any integer between zero and an arbitrarily large number. When provided, SCRAM will calculate the proportion of iterations that produce a collision estimate larger than the specified threshold (which can be interpreted as an estimate of the probability that the number of collisions will exceed the specified threshold value). This value is a probability, rather than a known outcome, because there is uncertainty in the input data. This probability is also dependent on model assumptions. A plain language interpretation is “X is the probability of exceeding the specified threshold, taking into account the uncertainty of the input data and assuming that the model is a reasonable description of how collisions happen in reality.”

For more detailed visualizations, including variation by month, users should download the output report. We have included tables for the input parameters so that all results are associated with the input data, since the results of CRMs can be sensitive to the availability and quality of the underlying data.

Appendix I. Example of how SCRAM works

The below example uses hypothetical values to illustrate how SCRAM uses input data to estimate passage rates and numbers of collisions. The grid cell of interest is selected based on the centroid of the wind farm location. Note that the below values, including grid cell size, are **NOT** values actually used in SCRAM and are being used here for illustrative purposes only. Additionally, SCRAM incorporates uncertainty into many of these values, which for simplicity's sake is not presented here.

Input values:

- Monthly population estimated to be present in the Atlantic study area = 4000 birds
- Cumulative daily occupancy in the month = 0.245 (this is the proportion of tagged birds detected in a selected grid cell as compared to all tagged birds in that month)
- Grid cell size = 50 km wide, 50 km long
- Rotor radius (R) = 0.1 km
- Number of turbines (T) = 100
- Proportion of birds flying at RSZ altitudes = 0.1 (in SCRAM this is a draw from a modeled distribution, not a single value, but we are using one value in this example for simplicity's sake)
- Proportion of time that wind farm turbines are operational = 0.95
- Avoidance rate = 0.925
- Collision rate of birds that do not exhibit avoidance behavior = 0.035

Step 1: Calculate the density of birds in the grid cell by multiplying the monthly population estimate by the cumulative daily occupancy and dividing by the size of the grid cell:

4000 * 0.245 = 980 birds in the grid cell

Step 2: Calculate the number of birds passing through the grid cell as an evenly distributed migratory front:

980 birds / 50km = 19.6 birds/km

Step 3: Calculate the density of birds across the migratory front for a single turbine RSZ:

19.6 birds/km / (2*0.1km) = 98 birds/km^2

Step 4: Scale the vertical density to the RSZ of the wind farm. This is calculated as:

Number of passages = Vertical density * number of turbines * pi * rotor radius^2

Using our input values above, this becomes:

$$98 \text{ birds/km}^2 * 100 * \text{pi} * (0.1 \text{ km})^2 = 307.9 \text{ birds}$$

Step 5: Scale the predicted number of bird passages to the proportion of birds expected to be flying within the altitude of the RSZ and the proportion of time that the wind farm is operational:

$$307.9 * (0.1 \text{ in RSZ}) * (0.95 \text{ wind farm op}) = 29.3 \text{ birds}$$

Step 6: Add avoidance and collision probabilities to estimate number of collisions in that month, where we actually multiply by 1 minus the avoidance rate (the non-avoidance rate):

$$29.3 * (1- 0.925) * (0.035) = 0.077 \text{ collisions}$$

Step 7: Repeat for all months for which we have monthly movement models.

Appendix II. Example of how Band 2012 Annex 6 works

The below example uses hypothetical values to illustrate how Band 2012 Annex 6 uses input data to estimate passage rates and numbers of collisions. The user inputs the location of the wind farm, and the SCRAM tool estimates a latitudinal line spanning the extent of the migratory corridor. The migratory corridors are pre-loaded within SCRAM and are not provided by the user. The SCRAM tool calculates the width of the migratory corridor at that latitude. The bird density (birds/km) is calculated from the migratory population estimate, divided by the width of the corridor. For Piping Plovers, the U.S. state at that same latitude is also identified; this state is used for calculating the monthly regional population sizes for Piping Plovers, as these numbers are state-specific. For more information, see Goyert et al. (2024). Note that the below values are **NOT** values used in Band Annex 6 in SCRAM and are being used here for illustrative purposes only. Additionally, the implementation of Band (2012) Annex 6 in SCRAM incorporates uncertainty into many of these values, which for simplicity's sake is not presented here.

Input values:

- Monthly population estimated to be present in the Atlantic study area = 4000 birds
- Estimated migratory corridor width at the latitude of the centroid of the wind farm = 250 km
- Rotor radius (R) = 0.1 km
- Number of turbines (T) = 100
- Proportion of birds flying at RSZ altitudes = 0.1 (in SCRAM this is a draw from a modeled distribution, not a single value, but we are using one value in this example for simplicity's sake)
- Proportion of time that wind farm turbines are operational = 0.95
- Avoidance rate = 0.925
- Collision rate of birds that do not exhibit avoidance behavior = 0.035

Step 1: Estimated bird density in the migratory corridor at the latitude of the wind farm:

$$980 \text{ birds} / 250 \text{ km} = 3.92 \text{ birds/km}$$

Step 2: Calculate the density of birds across the migratory front for a single turbine RSZ:

$$3.92 \text{ birds/km} / (2*0.1 \text{ km}) = 19.6 \text{ birds/km}^2$$

Step 3: Scale the vertical density to the RSZ of the wind farm. This is calculated as:

Number of passages = Vertical density * number of turbines * pi * rotor radius^2

Using our input values above, this becomes:

$$19.6 \text{ birds/km}^2 * 100 * \text{pi} * (0.1 \text{ km})^2 = 61.6 \text{ birds}$$

Step 4: Scale the predicted number of bird passages to the proportion of birds expected to be flying within the altitude of the RSZ and the proportion of time that the wind farm is operational:

61.6 * (0.1 in RSZ) * (0.95 wind farm op) = 5.8 birds

Step 5: Add avoidance and collision probabilities to estimate number of collisions in that month, where we actually multiply by 1 minus the avoidance rate (the non-avoidance rate):

29.3 * (1- 0.925) * (0.035) = 0.015 collisions

Step 6: Repeat for all months.

Appendix III. Differences between SCRAM and other implementations of the Band model

SCRAM makes full use of recent advancements in quantifying the potential impacts of offshore wind energy development from Band (2012) and adaptations of the Band framework (Masden 2015, Trinder 2017, McGregor et al. 2018). We aimed to advance the implementation of this framework in the western Atlantic by 1) contributing updates to the primary model script and 2) developing an online interface that best addresses the specific needs of users and stakeholders in the eastern U.S. While there is significant overlap in the model description between our version and previous iterations, there are several important differences. The most consequential change to the underlying model is that we have reworked the data inputs to work primarily with movement data, as opposed to at-sea survey data. Movement data are widely available through automated telemetry, such as the Motus Wildlife Tracking System (Figure A 1), for key species of interest which may lack available density estimates to use in the prior CRM versions from which SCRAM was derived.

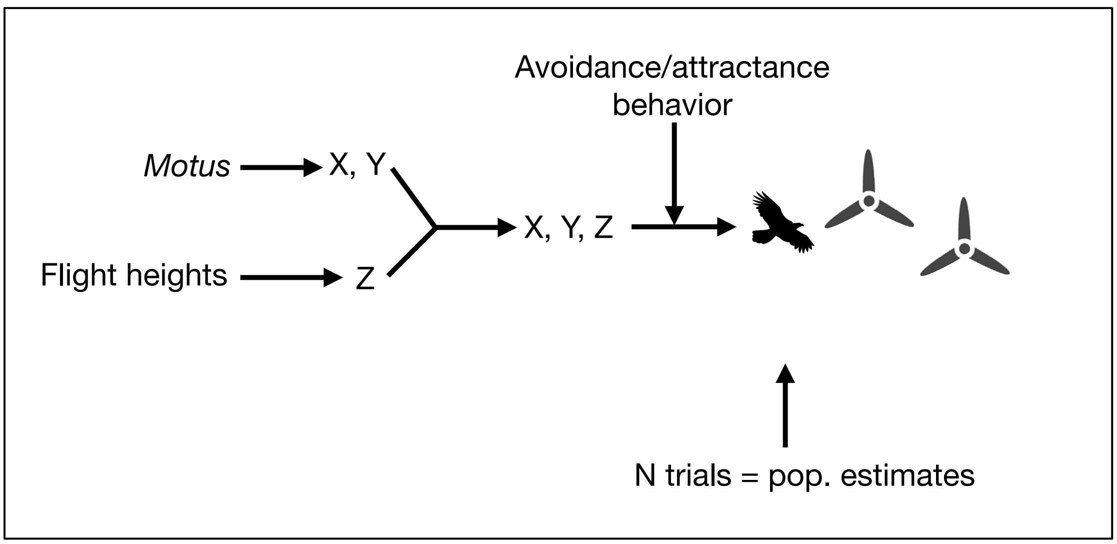


Figure A 1. Conceptual diagram of the primary model inputs for species data.
Estimates of species movements and species-specific flight height distributions from Motus data determine the daily longitudinal (X) and latitudinal (Y) position, and the summed altitudinal (Z) locations of individuals, which are combined with wind farm-specific information on turbine size/numbers to determine their risk of encountering rotor space. These estimated movements are combined with regional population estimates, corresponding to the sampling populations of the Motus projects, to estimate the total number of individuals likely to encounter rotor space for each month in which birds were tracked. Monthly collision risk is then estimated using the same assumptions as the other CRMs based on the Band framework (this component of the model is denoted by the square that contains turbines).

Rather than using density estimates developed from observational surveys, as with other CRMs, in SCRAM we use daily detection data at Motus stations to fit a correlated random walk movement model (Baldwin et al. 2018). Through this process, we estimate the most likely daily locations of animals (along with model uncertainty) and overlay these predictions across a spatial grid. We estimate the number of individuals found in each grid cell and divide by the total number of individuals tracked that month. This allows us to estimate the proportion of the tagged individuals found in each grid cell. Multiplying that by the monthly regional population sizes (as estimated by USFWS experts and monitoring efforts; see Adams et al. 2022, Goyert et al. 2024), we determine the expected number of animals in each cell per month. We use the width of the grid cell to convert those expected individuals to a passage rate per km. Past this point the model goes through the same general process as Band (2012). An illustrative example of this process is presented in Appendix I. While the approach to population density estimation is different from CRM models that use survey data, the estimates of flux and collision risk remain substantially similar to the Band (2012) migratory collision risk model.

We have also revised several components of the primary model script, including an adjustment to how flight height distributions are integrated with risk along the rotor blade. We modified this component to treat flight heights as a statistical distribution, as opposed to point-wise sampling along the range of flight heights (see bullets below for more information). All of the changes to the underlying model code are tracked on GitHub.

In addition to the method whereby we estimate flux (above), perhaps the largest difference between SCRAM and other CRMs relates to the delivery of the primary model script via the online interface. Our general philosophy was to make the interface as simple as possible, with most data inputs embedded in the app or uploaded using a single .csv file that the user can store locally (as opposed to requiring the user to input data on the interface itself). We also designed the tool to encourage linear advancement through the model specification process. We accomplished this by 1) having a defined order of operations, and 2) providing evidence-based guidance to identify the most appropriate model option and discourage the use of more than one option at a time. SCRAM provides the take-home results on the application interface, but most of the model output is delivered via downloads of the raw results or a generated report that contains visualizations and input and output data tables. A more comprehensive list of differences between our version and previous iterations is given below.

Major differences in primary computational script

- SCRAM uses spatially explicit habitat use models derived from Motus and GPS/Argos telemetry data, rather than density estimates derived through surveys. To appropriately scale habitat use to the entire population, an estimate of population size (and uncertainty if available) is used (Adams et al. 2022, Goyert et al. 2024).
- SCRAM's calculation of bird passage rates using habitat use models (referred to as "flux" in Band 2012) defines the migratory corridor width, required in the Band single transit model, as the width of the grid cell.
- SCRAM integrates the flight height distributions with risk along the rotor blade using cell-wise instead of point-wise probabilities. The consequence of this change is that the

first probability of the flight height distribution (labeled as 1 m) corresponds to the band that is 0 – 1 m above sea level.

- SCRAM uses flight height estimates from Motus tracking data for all Piping Plover and Roseate Tern (Loring et al. 2021, Adams et al. 2022). However, for Red Knot satellite telemetry data from 132 individuals with 6900 flight height observations (6658 with successful altitude measurements) were used to estimate the Red Knot offshore flight height distribution which was modeled using a state-space modeling framework (Goyert et al. 2024).
- SCRAM allows for missing values (specified as NA) in the input data. This is useful, for example, when movement data are not available for every month. Missing values are automatically propagated through the model and displayed in the results accordingly.
- SCRAM calculates total operation time as wind availability*(1 – down time) to avoid the fact that negative values can theoretically happen with the original formulation (wind availability – down time).
- SCRAM allows the user to download inputs and outputs from every iteration of the model run.
- Tidal offset and nocturnal activity are not currently user-specified parameters.

Major differences in online interface

- SCRAM's interface was built from the ground up, focusing on simplicity and encouraging a linear path through the tool.
- Only the most appropriate options in SCRAM are available to the user, depending on the input data and model specifications, to minimize the chance of running the model in a way the user did not intend.
- The majority of SCRAM's results are given in a downloadable report rather than on the application interface.

Appendix IV. Metadata for input datasets

SCRAM input datasets for turbine and array characteristics (Table A 1) must match the specified input structure, including exact column names. Underlying species characteristics (Table A 2-Table A 4), as well as movement data (Table A 5), are hardcoded in the tool for the three focal species of Red Knot, Roseate Tern, and Piping Plover and are not provided by the user. Movement data specify the estimated probability that an individual from the target population will pass through the modeled area in each month. SCRAM input datasets may include multiple runs (rows) that each correspond to a different turbine array of interest. However, each array must have identical centroid coordinates (latitude and longitude).

Table A 1. Turbine and array characteristics included in input datasets.
Each turbine/array characteristic, and when appropriate its associated uncertainty, is specified in a column. Each row gives the specifications for a turbine array of interest, so the number of rows should be equal to the number of different wind farm arrays in a single location and will dictate how many times the model will run.

Turbine parameter name	Definition
Run	The model run value – wind farm array number
Num_Turbines	The number of turbines in the wind farm array
TurbineModel_MW	The turbine model; this can be an descriptor
Num_Blades	Number of blades for the turbine model
RotorRadius_m	Rotor radius (hub to blade tip; m)
RotorRadiusSD_m	Standard deviation of rotor radius (m)
HubHeightAdd_m	The lower air gap – distance between lower blade tip and mean sea level (m)
HubHeightAddSD_m	Standard deviation of the air gap (m)
BladeWidth_m	Max. chord width of blade (m)
BladeWidthSD_m	Standard deviation of blade width (m)
RotorSpeed_rpm	Mean number of turbine rotations per minute (RPMs) when active (e.g., for the periods during which wind speeds are between cut-in and cut-out speeds of the turbine
RotorSpeedSD_rpm	Standard deviation of turbine rotations per minute (RPMs) for the periods during which wind speeds are between cut-in and cut-out speeds of the turbine
Pitch	Pitch angle of blades (degrees relative to rotor plane)
PitchSD	Standard deviation of pitch angle of blades
WFWidth_km	Wind farm width (km)
Latitude	Latitude (decimal degrees) of the wind farm centroid
Longitude	Longitude (decimal degrees) of the wind farm centroid
MonthOp *(x12)*	Maximum proportion of time turbines can be operational/month based on wind availability. One column for each month, e.g., JanOp, FebOp…

MonthOpMean *(x12)*	Mean proportion of time that turbines will not be operational ("down time"), assumed to be independent of "MonthOp" – i.e., total operation = MonthOp*(1 – MonthOpMean). One column for each month, e.g., JanOpMean, FebOpMean…
MonthOpSD *(x12)*	Standard deviation of mean operational time. One column for each month, e.g., JanOpSD, FebOpSD…

Table A 2. Species characteristics included in input datasets.
Each species characteristic, and when appropriate its associated uncertainty, is specified in a column. Note: these data cannot be user-specified.

Species parameters	Definitions
Species	Species name for associated data
Avoidance	Proportion of birds that avoid turbines – basic or extended versions depending on CRM model option (2 or 3)
AvoidanceSD	Standard deviation of avoidance estimates
Body_Length	Body length of target species (m)
Body_LengthSD	Standard deviation of body length
Wingspan	Wingspan of target species (m)
WingspanSD	Standard deviation of target species
Flight_Speed	Flight speed of target species (m/sec)
Flight	Flight mode ("flapping" or "gliding")

Table A 3. Flight height data example.
This dataset specifies the estimated flight height distribution for the species of interest. The flight height distribution gives the relative probabilities of an individual flying at each height across the range of possible heights, at 1 m intervals from 1 - 1000 m. Columns are samples from the uncertainty distributions of the relative probabilities, which can be bootstrap samples or draws from a posterior distribution. Note: these data cannot be user-specified.

Species	Height_m	BootId_1	BootId_2	BootId_3	BootId_4	…	BootId_100
Roseate_Tern	1	0.10	0.08	0.10	0.08		0.09
	2	0.09	0.08	0.09	0.07		0.08
	.						
	1000	0.08	0.07	0.08	0.07		0.04

Table A 4. Count data example.
This dataset specifies population sizes associated with the movement dataset for each species of interest. Columns specify the mean and standard deviation for the estimated population size, which can vary by month. Note: these data cannot be user-specified.

Species	Jan	JanSD	Feb	FebSD	Mar	MarSD	…	Dec	DecSD
Roseate_Tern	8598	912	8598	912	8598	912		8598	912

Table A 5. Format of underlying movement data.
Data are integrated within the tool for Piping Plover, Red Knot, and Roseate Tern and do not need to be provided by the user. This dataset incorporates the summed daily (total monthly) occupancy, defined as the probability that an individual would use habitat in a given grid cell for each month they are present in the area. Since each day can have an occupancy value from 0-1, the max value that can occur for any cell in any month is 31 (max. value 1 x 31 days = 31, range = 0-31 but depends on month length). Typically, values will be much less than that since distribution is spread over a large area. Each row is a sample from the uncertainty distributions of these estimates (i.e., a draw from a posterior distribution). Note: these data cannot be user-specified.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Roseate_Tern	NA	NA	NA	NA	NA	0.009	0	0.049	0	NA	NA	NA
	NA	NA	NA	NA	NA	0.104	0.37	2.1	6.6	NA	NA	NA
	.	.	.	.	.	.	.	.	.	.	.	.
	NA	NA	NA	NA	NA	0	0.21	1.2	7	NA	NA	NA

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