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# Bighorn Sheep

## Risk of Contact Tool v2

### User Guide



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# 1 Introduction

In response to bighorn sheep population viability concerns, the Payette National Forest developed a methodology for calculating the probability and rates of contact between bighorn sheep and active domestic sheep allotments. Subsequently, in 2011, the Forest Service and Bureau of Land Management (BLM) initiated a process to develop a geospatial platform that would support similar risk of contact analyses on other National Forests and BLM Districts. The resulting Risk of Contact Tool provides a user-friendly geospatial desktop application for use by field unit wildlife biologists and resource managers. Methods implemented by the Tool provide a framework for addressing the potential of contact and disease transmission for use in Forest and project level planning and developing bighorn sheep conservation measures on public lands.

The objective of this user guide is to provide instruction on the installation and use of the Bighorn Sheep Risk of Contact Tool (Tool). The Tool uses several inputs, including a core herd home range (CHHR), a habitat model, and a map of active domestic sheep allotments to estimate the probability and rate of contact between bighorn sheep and occupied domestic sheep allotments. The CHHR is either generated by the Tool from user-supplied telemetry or observation points, or directly provided as a user-delineated polygon based on local expert knowledge. Draft summer habitat raster models for the western states have been developed by the Forest Service and are used in calculating habitat suitability and connectivity for purposes of bighorn sheep movements across landscapes. Forest Service, BLM and the states are collaborating on the review and finalization of these models to fit local biophysical settings. Winter habitat raster models for the western states are also in development. Finally, a local unit active domestic sheep allotment polygon layer is used in the analysis to calculate the probability and rates of contact with the allotment.

This user guide consists of four sections: 1) Introduction, 2) Background, 3) Software and Data Requirements, and 4) Conduct a Risk of Contact Assessment. The Background section briefly describes the history of the model and its applicability to Forest Service and BLM units west-wide. The Software and Data Requirements section lists the software and geospatial data layers needed to conduct a risk of contact assessment. The Conduct a Risk of Contact Assessment section documents the Tool itself, describing the steps and decisions involved in an assessment. The user interface consists of three tabs, each of which directs a major step in the analysis. Separate subsections describe the role and use of the Home Range, Foray Analysis, and Contact Analysis components and document the options available on each tab.

Instructions for installing the required software are contained in Appendix A: Tool Installation Guide. First time users may benefit from the guided tour presented in Appendix B: Quick Start Guide. This tour walks the user through all steps of an analysis using a sample data set. A basic working knowledge of ArcMap, the main module of ArcGIS, is recommended. Users new to ArcGIS can refer to Appendix C: Using ArcMap 10.1 service pack 1 - The Basics for a quick introduction to basic ArcMap functionality and pointers to additional instructional resources.

Appendices D, E and F contain examples of files used or produced by the Tool. Appendix D includes the foray distance probability distribution files derived from telemetry data collected from Hells Canyon bighorn sheep (in 12 herds along the borders of Oregon, Idaho, and Washington) which are used as the default by the Tool. Appendix E contains the configuration file for changing the Tool defaults. Appendix F includes the log file listing the user-specified input parameters for each run of the analysis. A glossary of terms is contained in Appendix G, and Frequently Asked Questions can be found in Appendix H. At its first use in this guide, each term includes a link to its definition in the glossary. Additional information pertinent to the Tool is contained in two supplemental document files provided with the installation package. The "Risk of Contact Tool - R Package Documentation (v10.1).pdf" document includes a detailed description and testing process for the R function used to estimate the CHHR.



## 2 Background

In 2005, the Chief of the Forest Service remanded the Payette National Forest's Forest Plan because of bighorn sheep viability concerns, largely due to the potential for contact and disease transmission between domestic sheep and bighorn sheep on the Forest. In response, in 2010 the Forest published the Bighorn Sheep Viability Analysis and Forest Plan Amendment, which establishes Forest guidance for the management of domestic sheep in proximity to bighorn sheep populations. As part of the analysis process, the Forest worked with scientists from the University of California, Davis' Center for Animal Disease Modeling and Surveillance to develop a set of models to estimate the probability and rates of contact between free-ranging bighorn sheep and active domestic sheep allotments, and to simulate the potential impacts of disease outbreaks on bighorn sheep populations on and adjacent to the Forest.

Three models were used to assess the potential for disease transmission between domestic sheep and bighorn sheep. These models were: (1) a bighorn sheep summer habitat model; (2) a risk of contact model; and (3) a disease model. The summer habitat model used remote sensing derived data (vegetation, topography, etc.) to map suitable summer bighorn sheep habitat and to develop a habitat preference map. The risk of contact model used bighorn sheep locations, movement data, and habitat preference to model the probability and rate of contact between bighorn sheep and active domestic sheep allotments (O'Brien et al., 2014). This model used telemetry or observation data to construct a core herd home range (CHHR). Based on foray rates and habitat preferences, the model then estimated the probability that bighorn sheep (rams and ewes) that foray outside of the CHHR will contact domestic sheep allotments, and calculated a rate of contact with those domestic sheep allotments. The disease model used the calculated rate of contact and demographic characteristics of bighorn sheep given disease perturbations to assess the extirpation probabilities of bighorn sheep herds.

Extensive scientific literature supports the relationship between disease in bighorn sheep populations and contact with domestic sheep. Field observations have associated bighorn sheep respiratory disease events subsequent to being observed near domestic sheep, which has led to numerous independent research efforts. Research results provide strong evidence that bighorn sheep have a high probability of contracting fatal pneumonia following contact with domestic sheep. Consequently, many Federal land management agencies and State wildlife managers recommend eliminating shared use of ranges by bighorn and domestic sheep. In 2010 alone, 11 bighorn sheep die-offs occurred in the western states. Some of these occurred in close proximity to National Forests and BLM-managed lands.

Hence, disease transmission between domestic and bighorn sheep remains an issue for many National Forest and BLM units in the western United States. In August 2011, a four-step approach to viability analysis and standardized risk assessment was outlined and mandated by the Deputy Chief of Forest Service to minimize the potential for disease transmission through interaction between bighorn and domestic sheep. Forests require a strategy and consistent analysis tools to assess the potential contribution of Forest Service active domestic sheep allotments to bighorn sheep disease events.



## 3 Software and Data Requirements

### 3.1 Required Software

This section briefly describes the software needed to conduct a risk of contact analysis. Required software includes ArcGIS 10.1 service pack 1, ArcGIS Spatial Analyst Extension, R-3.1.2 and a collection of R packages, and the Bighorn Sheep Risk of Contact Tool ArcGIS Add-in. For Forest Service personnel, download instructions for ArcGIS and Spatial Analyst are provided in section 3.1.1 below. Appendix A contains detailed instructions for installing the other required software, including the Tool.

#### 3.1.1 ArcGIS 10.1 Service Pack 1 and Spatial Analyst Extension

The Risk of Contact Tool depends on a working installation of ArcGIS 10.1 Service Pack 1 equipped with the ArcGIS Spatial Analyst extension. Forest Service users can download and install ArcGIS from the Software Library accessed through the Chief Information Office (CIO) home page (<http://fsweb.wo.fs.fed.us/irm/index.php>). Spatial Analyst is included with the Forest Service installation of ArcGIS 10.1 Service Pack 1. Local GIS specialists may be available to provide a DVD copy of the software and to assist with software installation. For Bureau of Land Management personnel, software can only be downloaded/installed by submitting a remedy ticket to the BLM National Help Desk (<http://1800blmhelp.blm.gov/>). Be sure to specify the exact software package name(s) as well as the version number(s).

#### 3.1.2 R-3.1.2 and Required R Packages

The Tool uses the open source programming language R as a computational back-end to estimate core herd home ranges from telemetry or observation points. Its home range computations rely on a number of R packages. Two of those, the packages BHSkde and BHSkdeVis, were developed specifically for this project. The others were downloaded from the Comprehensive R Archive Network repository (<http://www.cran.r-project.org>). R (version 3.1.2) and all of the required packages are installed by the customized installer described in Appendix A.

#### 3.1.3 Risk of Contact Tool – ArcGIS Add-in

ArcGIS Add-ins extend ArcGIS functionality with custom commands and specialized features. The Risk of Contact Tool is an ArcGIS Add-in that supplies the Tool's user interface and directs the computations used in estimating risk of contact.

### 3.2 Required Data

Every risk of contact assessment requires three geospatial data layers (or “map layers”) as inputs. These three layers should be loaded into an ArcMap session **before** the Tool is launched:

1. **Bighorn Sheep Telemetry/Observation Points or CHHR Polygon Layer** — The tool supports two options: A) a point layer of bighorn sheep telemetry or observation locations (ideally including an ID field differentiating animals), used by the Tool to calculate core herd home range (CHHR); or B) a [polygon](#) layer delineating CHHR boundaries, drawn using local expertise.
2. **Bighorn Sheep Habitat Preference Raster Layer** — The raster layer cells (pixels) may represent either habitat classes (habitat, non-habitat, etc.) or relative preferences for habitat. If a habitat class layer is used as input, the user will be prompted to enter the relative habitat preference value for each class.
3. **Active Domestic Sheep Allotment Polygon Layer** — A polygon layer of active domestic sheep allotment boundaries, used to calculate contact risk for specific allotments. The allotments layer should only consist of active domestic sheep allotment polygons, and not include vacant, closed, cattle, or other types of allotments.



User-supplied **vector** and **raster** layers may be in any format supported by ArcMap. (The sample data shipped with the Tool and used in the example analysis described in the Appendix B uses shapefiles for vector layers and ESRI grids for raster layers.)

**NOTE:** Users must ensure that all geospatial data layers use the same projection and coordinate system (Section 4.2).

Users may consult GIS coordinators or local specialists for assistance with geospatial data compilation, formatting, and/or generating data, such as polygon layer editing support for delineating core herd home range polygons as needed.

### 3.2.1 Telemetry/Observation Points or CHHR Polygon Layer

The telemetry/observation point layer consists of bighorn sheep location data stored in a vector format (Figure 1), and will ideally include an animal ID field that distinguishes points derived from different animals.

Careful consideration should be given to the telemetry, observation, or a combination of these points used for the home range analyses. These data should represent a *current* population with discrete geographical boundaries, season of use dates, and other potentially relevant factors germane to addressing the risk of contact between bighorn sheep and occupied domestic sheep allotments.

The telemetry/observation point layer is not required if a core herd home range polygon is otherwise available. The CHHR polygon may be delineated by a knowledgeable wildlife biologist (or computed during a previous contact assessment). In that case, the Home Range component can be skipped and the polygon layer can be input directly into the Foray Analysis component described below.

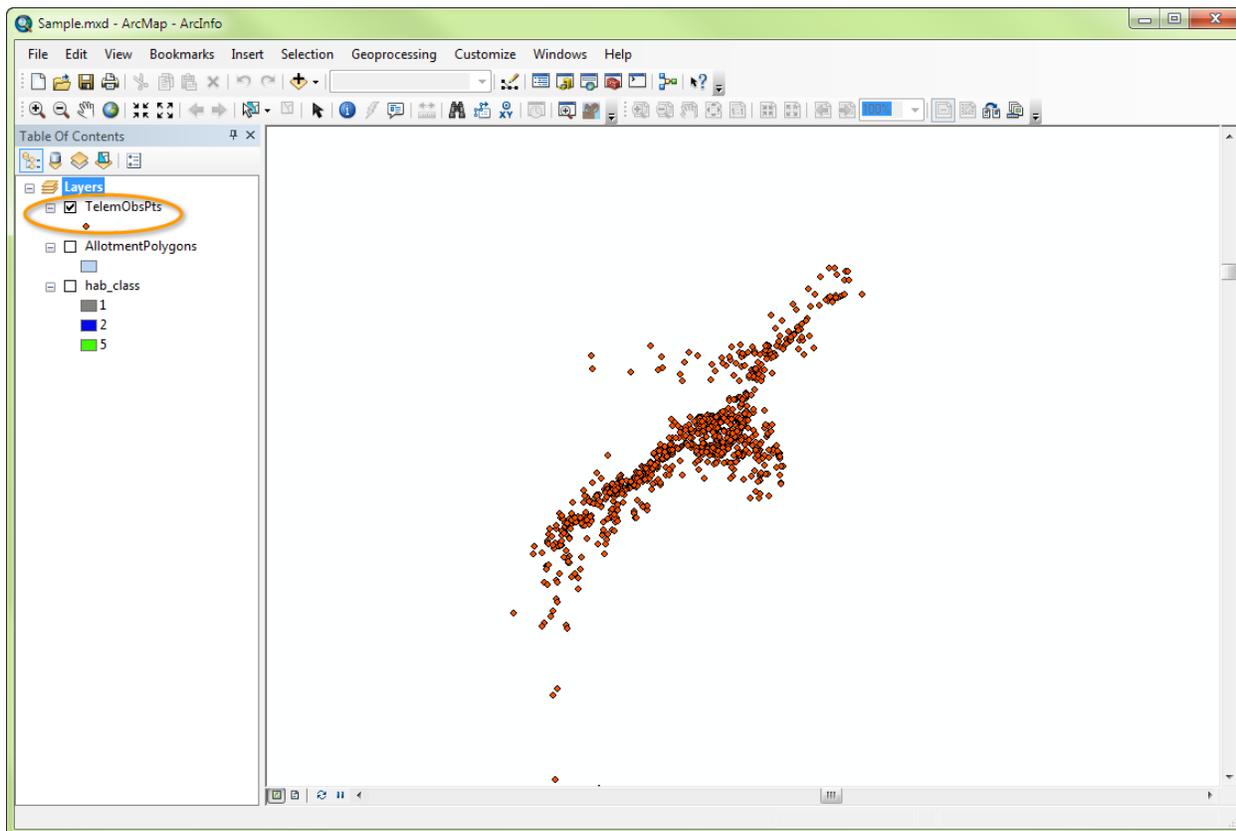


FIGURE 1. TELEMETRY/OBSERVATION POINTS LAYER



### 3.2.2 Habitat Preference Raster Layer

The habitat preference layer consists of data in raster format. The layer can either: 1) be generated by the Tool using a habitat *class* layer as input (Figure 2); or 2) be an existing habitat *preference* layer previously developed from a habitat class layer.

- **Habitat Class Layer**—Habitat class values must be integers representing habitat, non-habitat, etc. If a habitat class layer is supplied, the Tool will prompt the user to provide a relative habitat preference value for each class (Section 4.4.1). The preference for each class should be provided by the wildlife biologist or the raster layer's creator.
- **Habitat Preference Layer**—Habitat preference values must be floating point numbers representing relative habitat preference for the raster cell.

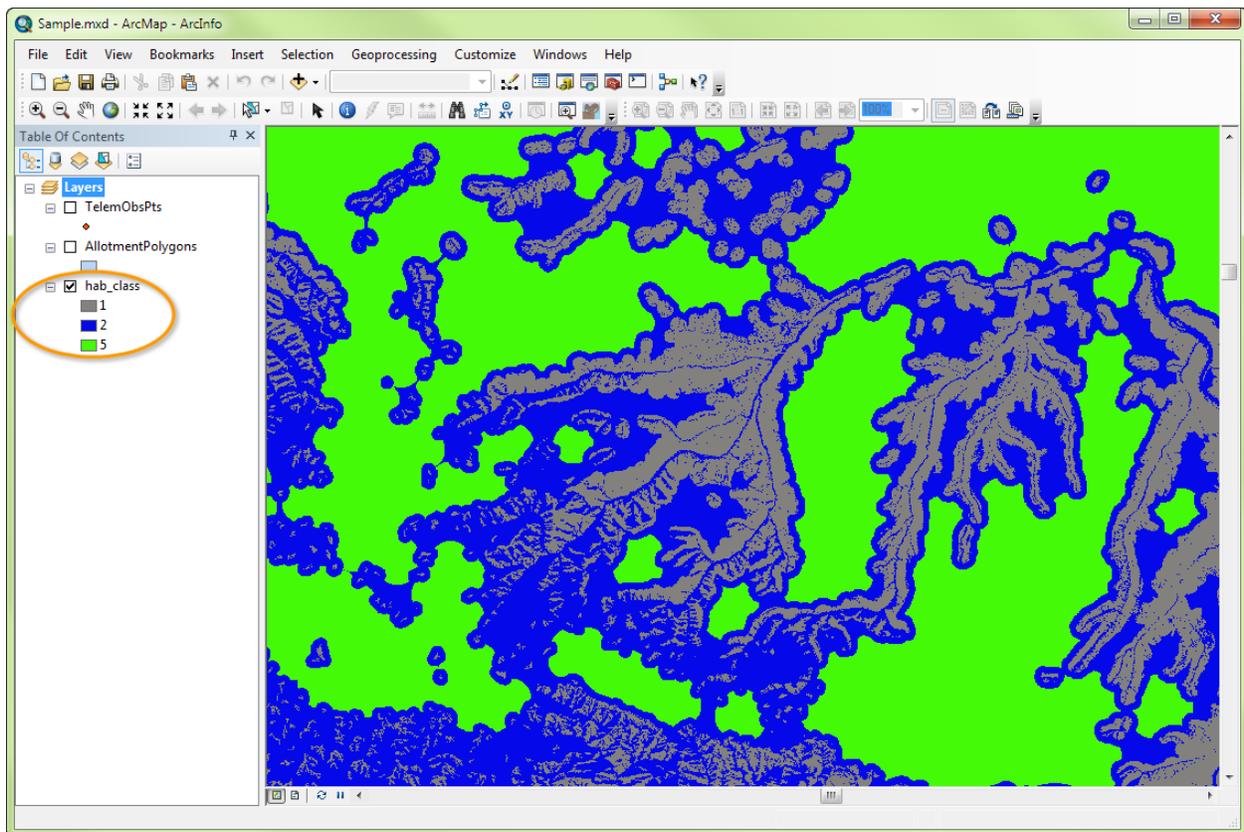


FIGURE 2. HABITAT CLASS RASTER LAYER



### 3.2.3 Active Domestic Sheep Allotment Polygon Layer

The active domestic sheep allotment layer consists of allotment boundaries in a vector polygon format (Figure 3).

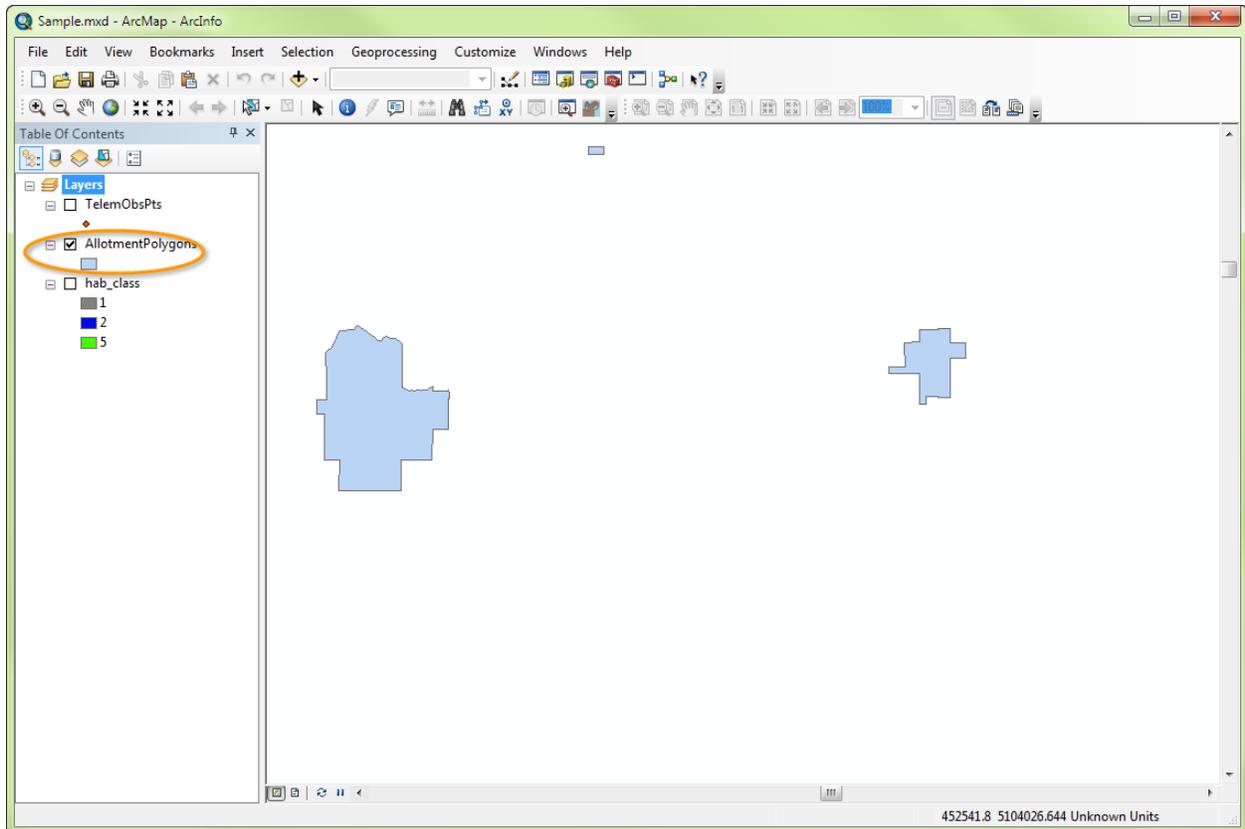


FIGURE 3. ACTIVE DOMESTIC SHEEP ALLOTMENT POLYGON LAYER



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## 4 Conduct a Risk of Contact Assessment

This section describes the components of the Tool's user interface and describes how these components may be used in a risk of contact assessment. For an introduction to the Tool workflow, first-time users may want to follow the sample analysis outlined in Appendix B: Quick Start Guide.

### 4.1 Tool Interface Overview

As discussed in the Background section above, a risk of contact assessment proceeds in several distinct stages. In the first stage, a core herd home range (CHHR) boundary is identified, either by estimating it from animal location data (usually from radio-collared animals) or based on a biologist's site specific knowledge of a bighorn herd's use of the landscape. In the next stage, two raster layers are generated representing the estimated probabilities that a single foraging ram or ewe will reach each point on the landscape outside of the CHHR. During the final stage, the resulting bighorn ram and ewe foray probability layers are combined with occupied domestic sheep allotment boundary polygons to calculate estimated individual- and herd-level allotment contact probabilities and rates.

Each analysis stage or component of the risk of contact assessment is assigned to an individual tab within the **Bighorn Contact Assessment** user interface. Tabs corresponding to the three stages of an assessment are circled in orange in Figure 4.

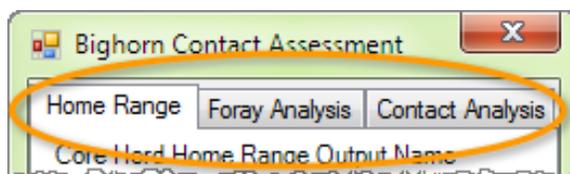


FIGURE 4. BIGHORN CONTACT ASSESSMENT INTERFACE TABS

Below is a brief description for each analysis component:

- **Home Range** — When an adequate number of telemetry points from radio-collared animals or site-specific observations are available, this component may be used to calculate the **CHHR boundaries**.
- **Foray Analysis** — This component calculates the **probability that a foraging bighorn sheep** will reach each point on the landscape surrounding its herd's CHHR.
- **Contact Analysis** — This component returns the **probability that bighorn sheep on a foray will come into contact with an occupied domestic sheep allotment** and the rate of contact for rams, ewes, and the entire herd.

In general, a risk of contact assessment will proceed through these stages sequentially from left to right (i.e., Home Range, Foray Analysis, and Contact Analysis). Figure 5 illustrates this idealized workflow, showing how the output from each component may be used as an input by the next.

While the Foray Analysis calculation **must** be completed (at least once) before the Contact Analysis calculation, the Home Range calculation may be skipped if telemetry and/or observation points aren't available and a knowledgeable wildlife biologist is able to provide an estimated CHHR polygon.

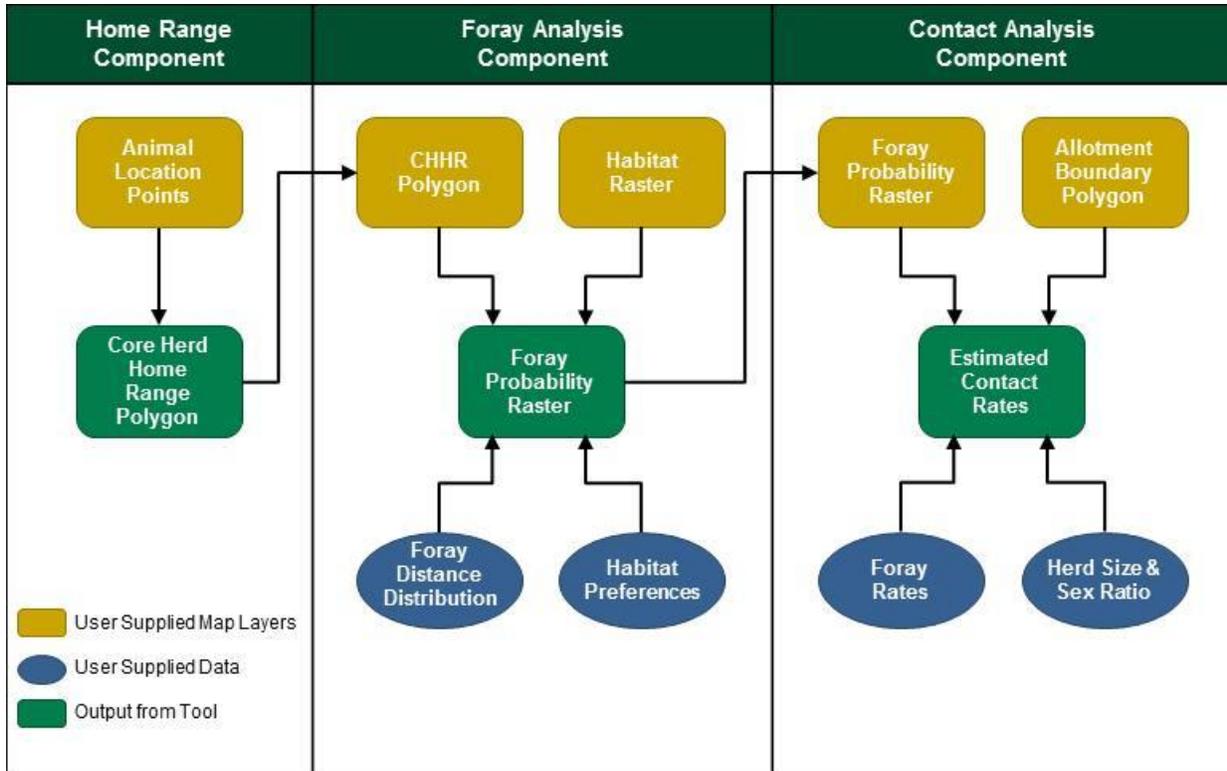
Each analysis component implements a similar work-flow, taking one or more map layers as input and outputting a named map layer or other results file that is used by the next component. Each component requires the following input information from the user:

- **Analysis Name** — The name used to identify the new output layers and other files the component generates. Output files are saved to the project-specific working directory selected by the user when the Tool is first opened.
- **Input Layers** — The name of an input layer, chosen from among those loaded into the current ArcMap session.



- Layer Attributes from Selected Layers to Use as Identifiers** — Once an input layer has been selected, the layer’s attributes are made available for selection from a drop-down menu.

The Risk of Contact Assessment Workflow depicted in Figure 5 is used for analyses in which Core Herd Home Range is estimated from bighorn location points.



**FIGURE 5. RISK OF CONTACT ASSESSMENT WORKFLOW WITH USER-SUPPLIED BIGHORN LOCATION POINTS**



The Risk of Contact Assessment Workflow depicted in Figure 6 is used for analyses in which the Core Herd Home Range (CHHR) polygon layer is supplied by the user. The CHHR layer may have been produced by a previous Home Range Analysis, or it may have been constructed by a knowledgeable wildlife biologist, familiar with the bighorn herd being analyzed.

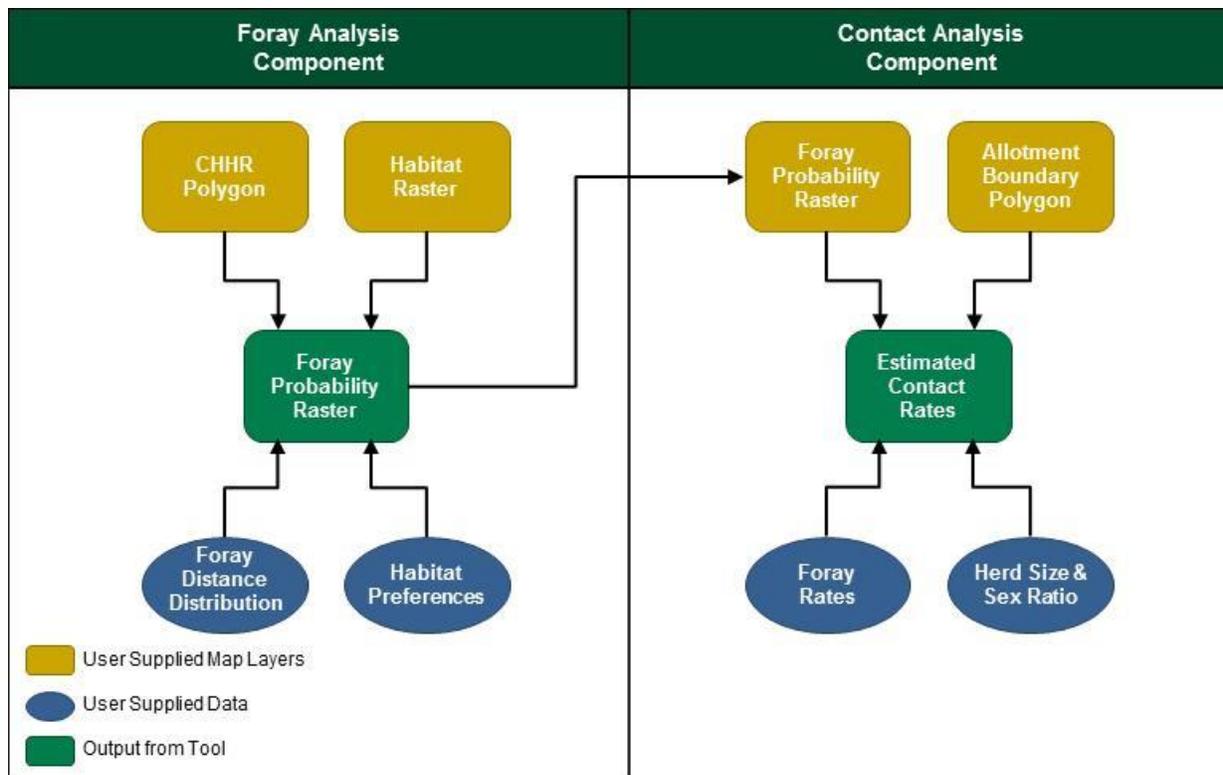


FIGURE 6. RISK OF CONTACT ASSESSMENT WORKFLOW WITH USER-SUPPLIED CHHR POLYGON



## 4.2 Launching the Tool Interface

Launch the Tool's user interface by following the six steps below.

**NOTE:** If an ArcMap project .mxd file containing the required map layers has already been created, e.g. for a previous assessment, use Windows Explorer to navigate to the .mxd file and double-click on it. ArcMap will open with the three layers already loaded, as the example shown in Figure 7. Skip steps 1-3 below.

1. Open ArcMap 10.1 Service Pack 1.
2. Add the required input map layers described in Section 3.2.
3. Save the session to an ArcMap project .mxd file in an informatively named project-specific working directory (e.g. C:\Bighorn Analysis).

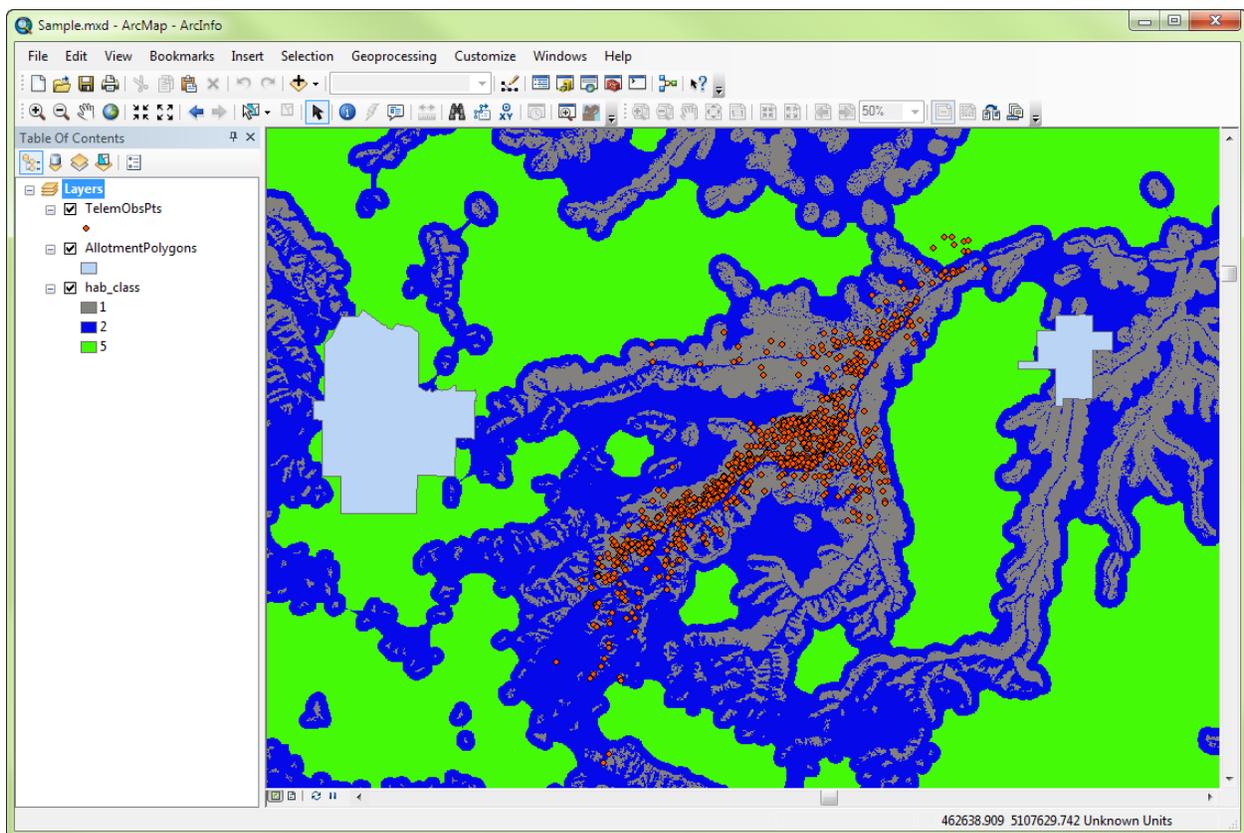


FIGURE 7. EXAMPLE ARCMAP SESSION CONTAINING THE REQUIRED MAP LAYERS



- Click on the **bighorn sheep Tool icon** from the ArcMap toolbar (Figure 8).

**NOTE:** The **Input Data** warning will open, reminding users to check that telemetry/observation points, the habitat raster, and allotment polygons are all formatted to the same projection and coordinate system. To view the projection and coordinate system, right-click the layer of interest in the Table of Contents > Properties > Source tab > Data Source field (scrolling down if necessary).

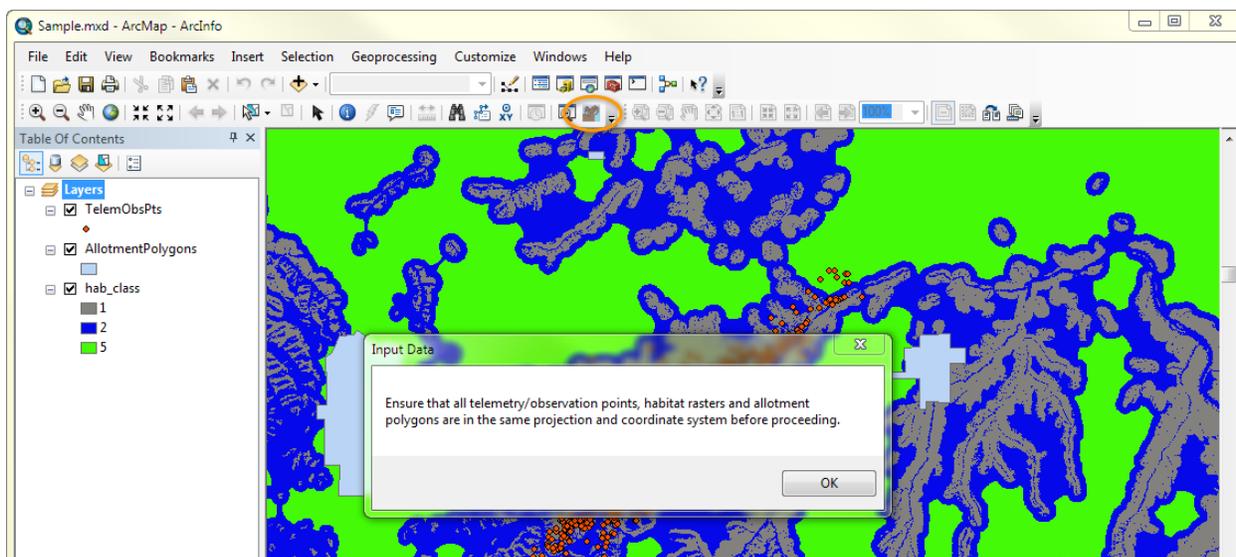


FIGURE 8. BIGHORN TOOL ICON IN THE TOOLBAR (CIRCLED) AND INPUT DATA WARNING

- The **Select working directory** dialog box will open (Figure 9), which allows for setting the location to which all the files produced by the current analysis will be saved. It is **strongly** recommended to click **Yes** and to change the default directory to the project-specific working directory where the ArcMap project file was saved in Step 3.

**NOTE:** Select **Cancel** to close the Tool without running an analysis.

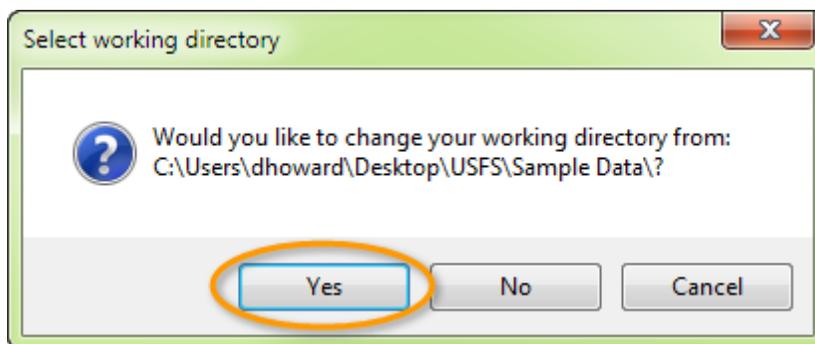


FIGURE 9. SELECT A WORKING DIRECTORY DIALOG BOX



6. After clicking **Yes**, browse to the directory into which the analysis output files will be saved (Figure 10).

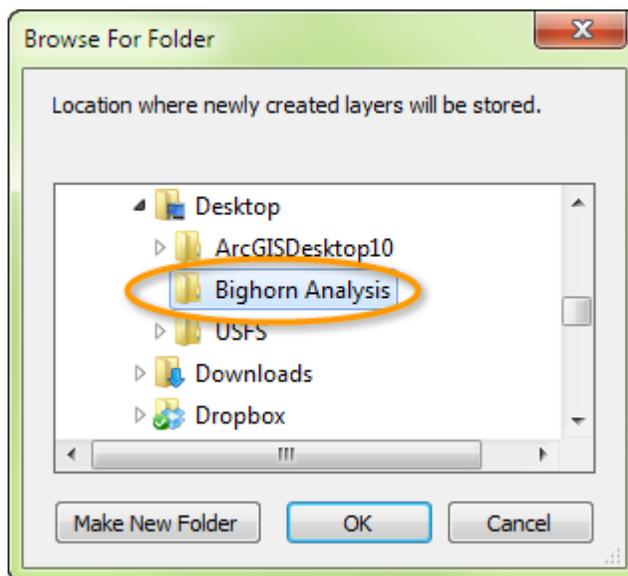


FIGURE 10. BROWSE FOR FOLDER DIALOG BOX

### 4.3 Using the Home Range Component

Estimating the core herd home range (CHHR) is the first step in any risk of contact assessment, so the Tool's user interface launches with the Home Range component open.

This component may be used to estimate a CHHR where an adequate number of telemetry points from radio-collared animals or site-specific observation points are available. It supports home range estimation using several methods as described in Section 4.3.1 below.

The Home Range tab can be skipped where estimated CHHR boundaries have been delineated by knowledgeable wildlife biologists (e.g. as a polygon shapefile) and the CHHR boundary layer has been added to the ArcMap session prior to launching the Tool. If this is the case, skip Section 4.3.1 below and go on to 4.4 Using the Foray Analysis Component.



### 4.3.1 Core Herd Home Range Calculation

The Home Range component calculates the core herd home range, generating a shapefile map layer having the suffix “\_poly”. During the CHHR computations, the Input Point layer is filtered to exclude points from animals having fewer than the minimum number of observations specified by the user in the Minimum Points per Animal field. This field allows the user to exclude animals for whom the number of available observations is too small to reliably estimate an individual-level home range.

Enter information in the Home Range component (Figure 11) as described below:

**NOTE:** *In the absence of site or region-specific data, it is recommended to keep validated default values, which are derived from 12 years of telemetry points, collected from 444 radio collared animals in 12 Hells Canyon area herds. Altering these values without commensurate data will change outcomes and reduce defensibility.*

FIGURE 11. HOME RANGE COMPONENT

estimates based on too few points are less likely to be accurate. Recognize that each included animal's home range is weighted equally in determining the CHHR.

**NOTE:** *Although the Tool allows inclusion of animals with as few as two observations, the cutoff should probably never be set that low. Several past analyses have only included points from animals with 21 or more distinct telemetry observations.*

1. **Core Herd Home Range Output Name:** Enter a name for the current Home Range analysis. The name may not start with a number, contain spaces, “&”, “%”, or “.” and cannot be longer than 25 characters. Both the results folder and the home range polygon layer created by this calculation will be given names based on the value entered in this field:
  - **Folder:** \_output will be appended (e.g., HomeRange\_output)
  - **Layer:** \_poly will be appended (e.g., HomeRange\_poly)
2. **Telemetry/Observation Layer (Point):** The point layer used to generate the home range polygon. Use the drop-down list to select the appropriate point layer from among those loaded in the current ArcMap session. A point layer must be selected to perform a home range calculation.
3. **Animal ID Field:** The **field** used to identify the individual animals whose home ranges will be calculated and then combined to form the CHHR. Select the animal identifier field from the drop-down list that appears once a point layer has been chosen. Users who have chosen to “Treat all animals as one” (see bullet number 5 below) may select the ‘None’ value from the drop-down menu.
4. **Minimum Points per Animal:** The minimum number of observations required for data from an animal to be included in the home range calculations. This cutoff is necessary because individual-level home range estimates based on too few points are less likely to be accurate. Recognize that each included animal's home range is weighted equally in determining the CHHR.
5. **Treat all animals as one:** Select this option to treat all observations as if they came from a single animal whose estimated home range will be treated as the CHHR. When the checkbox is **not** selected (the default), individual animals' home ranges will be estimated, and then combined to generate the CHHR. Opting to “treat all animals as one” may be useful when using field



observation data in which the identities of individual animals are not known. If this checkbox is selected, the 'Animal ID Field' above is disregarded.

6. **Bandwidth Estimator:** Select a home range estimation method from the drop-down list. Each option creates different-shaped home ranges:
  - **Reference:** Produces a rounder, larger home range. This is the default and recommended method.
  - **Plug-in:** Produces a longer, narrower home range.

**NOTE:** The reference bandwidth estimator is recommended because the foray frequency and foray distance distributions supplied with the Tool were computed relative to CHHRs which were produced using the reference bandwidth estimator. As a result it is inappropriate to use the default foray frequency and distance distributions in concert with CHHRs defined using another bandwidth estimator. The rationale for any change to this default should be documented.

For more information on this field, refer to the document "Risk of Contact Tool - R Package Documentation (v10.1).pdf", which is included in the zip file used to distribute the Tool and this User Guide (along with other software and documents). The relevant documentation is in that document's Section 1.1 Kernel Density Estimates and CHHR for an Entire Herd.

7. **Percent of h\_ref:** A factor (expressed as a percentage) by which the estimated bandwidth should be multiplied.

**NOTE:** When using the Reference Bandwidth Estimator, modifying the default value will change the size and shape of the CHHR polygon. The default value (100 percent) leaves the automatically selected bandwidth unchanged. Values smaller than 100 will result in smaller estimated CHHRs, while values greater than 100 will result in larger estimated CHHRs.

8. **Max Isopleth Quantile:** Enter a value between 0 and 99. (A 100 percent isopleth cannot be specified, as it is undefined for the home range estimators implemented in this Tool.) The value entered here (call it "Q") determines which "isopleth" or contour will be taken as the boundary of the CHHR polygon; the isopleth that is returned surrounds the smallest region within which the animals in a herd are expected to be found Q% of the time. Entering 95 (the default value) results in a CHHR polygon expected to contain 95% of bighorn movements. Increasing the max isopleth quantile will lead to a larger estimated CHHR.

The 95% contour is commonly used in the home-range literature as a delimiter describing population boundaries, and is the default value for this model. The estimated foray frequency and foray distance distributions used as the Tool's defaults were both computed relative to CHHRs defined by the 95th isopleth, and as a result it is inappropriate to use those default values in concert with CHHRs defined by other isopleths. The rationale for any change to this value (95%) should be documented. Additional changes to other portions of the model will be required to account for changes to the isopleth quantile size relative to foraging bighorn sheep distances.

Once each field in the form has been populated, the **Calculate** button will be enabled.

9. Click **Calculate** to start the home range calculations (Figure 12).



FIGURE 12. HOME RANGE COMPONENT CALCULATE BUTTON



**Note:** If the extent of the input points exceeds either 160,000 square kilometers (or the value of *HomeRangeInputMaxExtentAreaKilometers* set in the configuration file displayed in Appendix E) the Tool will display an error message like the one shown in Figure 13.

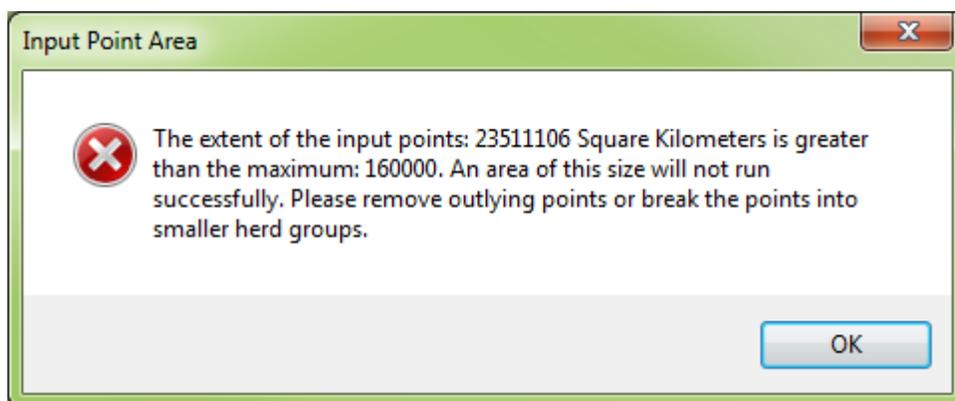


FIGURE 13. INPUT POINT AREA WARNING

The **Calculation Progress** dialog box will open, showing the progress of the calculation (Figure 14).

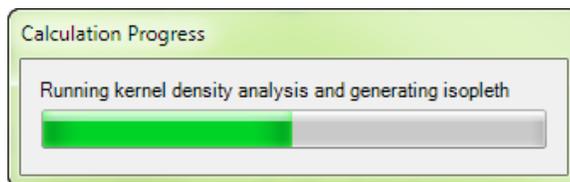


FIGURE 14. HOME RANGE CALCULATION PROGRESS WINDOW

Once R has completed the home range calculations, the **Calculation Progress** window will close. The newly created CHHR polygon layer will be automatically added to the Home Range output folder and ArcMap session (Figure 15).

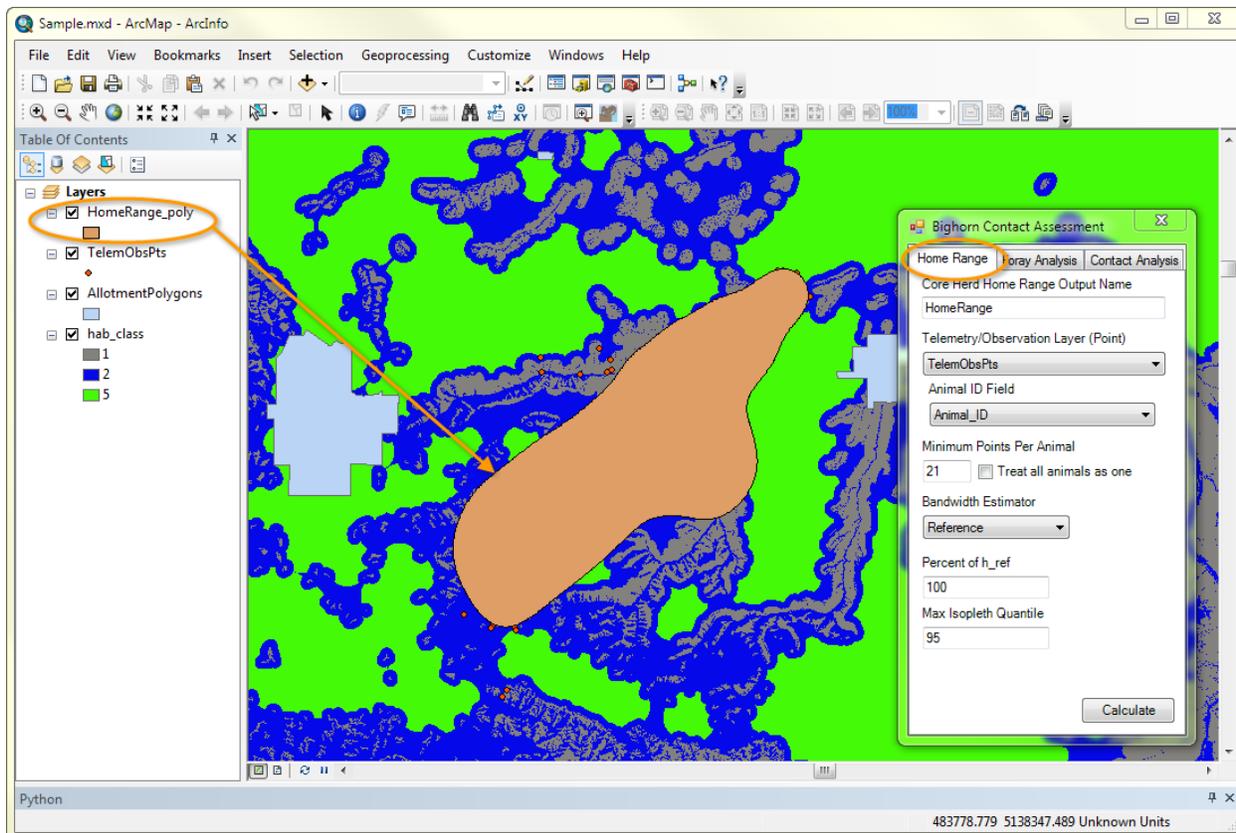


FIGURE 15. EXAMPLE CORE HERD HOME RANGE\_POLY LAYER



Figure 16 provides an example of the contents of the CHHR output folder, which includes both the input telemetry/observation point layer and the estimated CHHR polygon layer.

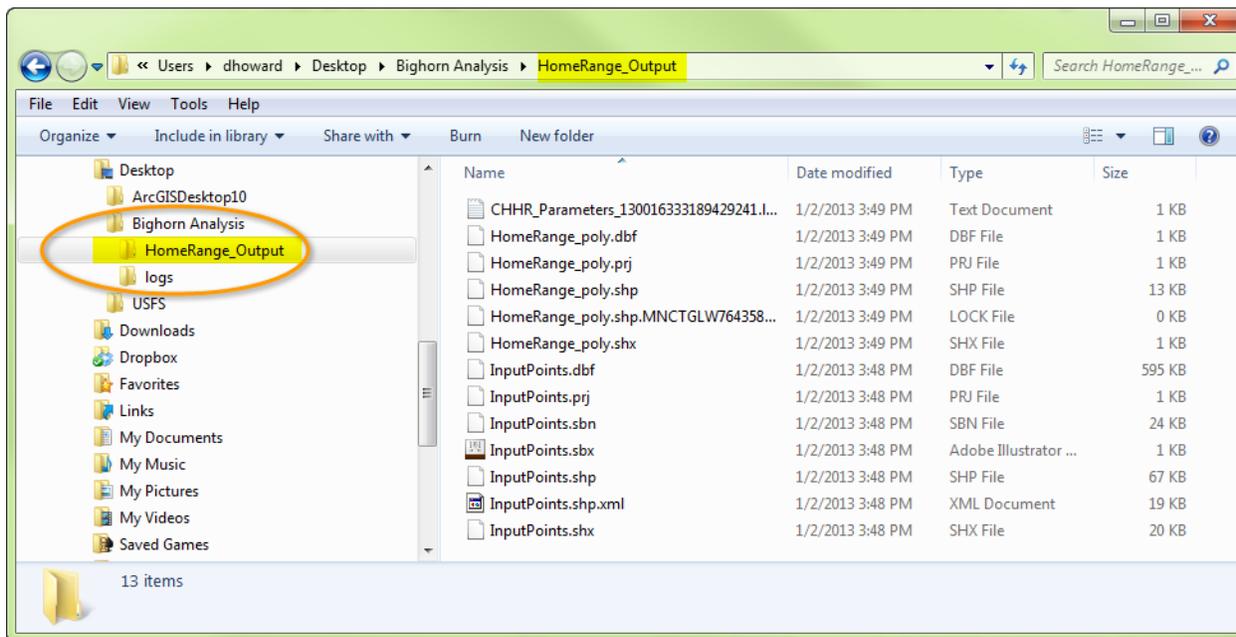


FIGURE 16. EXAMPLE CORE HERD HOME RANGE\_OUTPUT FOLDER DATA



## 4.4 Using the Foray Analysis Component

The **Foray Analysis** component calculates the annual or seasonal probabilities that individual rams and ewes, in forays from their home range, will reach each point on the landscape. The resulting estimates are written to two foray probability layers: ForayProbEwe and ForayProbRam. These are raster layers whose cell values represent the annual or seasonal probabilities of contact by an individual ewe or ram. The subsequent Contact Analysis component (Section 4.5) uses these probability layers by overlaying them with the active domestic sheep allotment polygons to determine the risk that foraging bighorn sheep will reach each allotment.

To develop the foray probability layers, the Tool needs two input map layers.

- The first input map layer is a raster layer with cell values representing either habitat classes (the typical choice) or habitat preferences. When a habitat class layer is used as input, the Tool will prompt users to enter the relative preference of bighorn sheep for each habitat class. A habitat preference layer is one with values directly representing the relative preference of bighorn sheep for each raster cell, so it requires no further user input.

Draft summer habitat class layers for the western states have been developed by the Forest Service (Chans O'Brien). The data include suitable habitat, connecting habitat, and non-habitat. Ideally, these data should be reviewed for site relevance and modified as necessary based on local conditions, and in coordination with state wildlife agencies, etc. Forest Service personnel can download the data from T:\FS\NFS\R02\Program\2600WildlifeMgmt\GIS\Habitat\_Types. Bureau of Land Management personnel can access the habitat layers by copying and pasting the following their Windows explorer:

\\blm\dfs\loc\EGIS\OC\Wildlife\Transfers\USFS\_BLM\_Bighorn\_Sheep\_RoC\_Tool.

- The second input map layer is a polygon feature layer that outlines the boundaries of the CHHR. This polygon may have been generated by the Tool's Home Range component or it may have been drawn by a knowledgeable wildlife biologist.

The Foray Analysis component also requires two "foray distance distribution files", which provide the probabilities that individual ram or ewe forays will reach each of the 1-kilometer-wide concentric rings emanating from the CHHR boundary. The format of the files must match that shown in Appendix D: Distance Distribution File Example, with a "Distance" column containing distances in kilometers, and a "ForayProb" column containing the probabilities that a foray will extend at least that far from the CHHR.

By default, the Tool will use distance distribution files that are stored in the same folder as the ArcMap project file and named "Ewe summer foray probabilities (1 km rings).csv" and "Ram summer foray probabilities (1 km rings).csv". If these files are *not* present in the project-specific working directory, the user will need to browse to their location. A copy of the distance distribution files derived from 12 years of Hells Canyon area telemetry data are located in the "Sample Data" folder provided in the Tool Installation zip file. The foray distance distributions exhibited by the Hells Canyon area bighorn sheep were consistent with published observations of bighorn sheep movements from several other areas in western North America. These default data should be used unless other well-supported, scientifically derived estimates of foray distance distributions are available for the area under consideration.



### 4.4.1 Foray Analysis Calculation

Enter information in the **Foray Analysis** component (Figure 18) as described below:

**NOTE:** Unless more regionally appropriate empirically derived habitat preference values are available, it is recommended that users keep the validated default values. If these values are altered, the user must document the rationale or analysis used.

Habitat Class	Relative Preference
1	1
2	.177
5	.029

FIGURE 17. FORAY ANALYSIS COMPONENT

1. **Foray Analysis Output Name:** Enter a name for the current Foray Analysis. The name may not start with a number, contain spaces, “&”, “%”, or “.” and cannot be longer than 25 characters. The value entered here will be used to name the Foray Analysis component’s output folder:
  - **Folder:** **\_output** will be appended (e.g., ForayAnalysis\_**output**)

2. **Core Herd Home Range Layer (Polygon):** Select the home range polygon layer created by the home range calculation from the drop-down list.

**NOTE:** The CHHR polygon layer doesn’t have to be generated during the current run of the Tool. A polygon layer drawn to represent the CHHR can be used. The CHHR polygon layer can only have one feature in it. Multipart polygons, where multiple independent shapes are present but have a single ID, are acceptable.

3. **Habitat Layer (Raster):** Use the drop-down menu to select a habitat class or habitat preference raster layer having the corresponding format specified in Section 3.2.2.

If the values in the selected habitat raster layer are integers, they are assumed to be habitat classes and the grid below the drop-down tool will be populated with one row for each class in the layer. For habitat class layers having the same format as the hab\_class sample data provided with the Tool, the following three rows will be added to the grid:

- Habitat Class 1: Denotes habitat
- Habitat Class 2: Denotes connectors
- Habitat Class 5: Denotes non-habitat

Enter a **Relative Preference** for each habitat class. All values entered in the Relative Preference fields must be  $\geq 0$ , and at least one must be  $> 0$ .

If the values in the habitat raster layer are **floating point** numbers, they are assumed to be habitat preferences and the grid is not populated for user input. The relative preference value is used to calculate the probability that a bighorn sheep will foray to the location of a given raster cell.

4. **Ram Distance Distribution File:** If the default “Ram summer foray probabilities (1 km rings).csv” file (derived from observations of Hells Canyon area radio-collared rams) is present in the project-specific working directory, it will automatically populate in this field. If it is not present there, either copy it to the directory from the Tool’s “Sample Data” directory or browse to it or to another tabular \*.csv file containing information about the probability a ram’s foray will carry it different distances from its CHHR.



5. **Ewe Distance Distribution File:** See instructions for “Ram Distance Distribution File” above, substituting the “Ewe summer foray probabilities (1 km rings).csv” file for the associated ram distance distribution file.

Once each field in the form has been populated, the **Calculate** button will be enabled.

6. Click **Calculate** to launch the foray analysis (Figure 18).



FIGURE 18. FORAY ANALYSIS COMPONENT CALCULATE BUTTON

Once the calculation is complete, the foray probability layers – **(User selected name)\_ForayProbEwe.tif** and **(User selected name)\_ForayProbRam.tif** will be added to the Foray Analysis output folder and ArcMap session (

Figure 19)

**NOTE:** The (User selected name)\_ForayProbEwe.tif and (User selected name)\_ForayProbRam.tif layers will be added above the existing layers in ArcMap. To view the Home Range and Allotment Polygon layers, the (User selected name)\_ForayProbRam.tif and (User selected name)\_ForayProbEwe.tif layers will need to be turned off or moved below the Polygon layers in the Table of Contents. The Tool must be closed before the layers can be moved (

Figure 19).

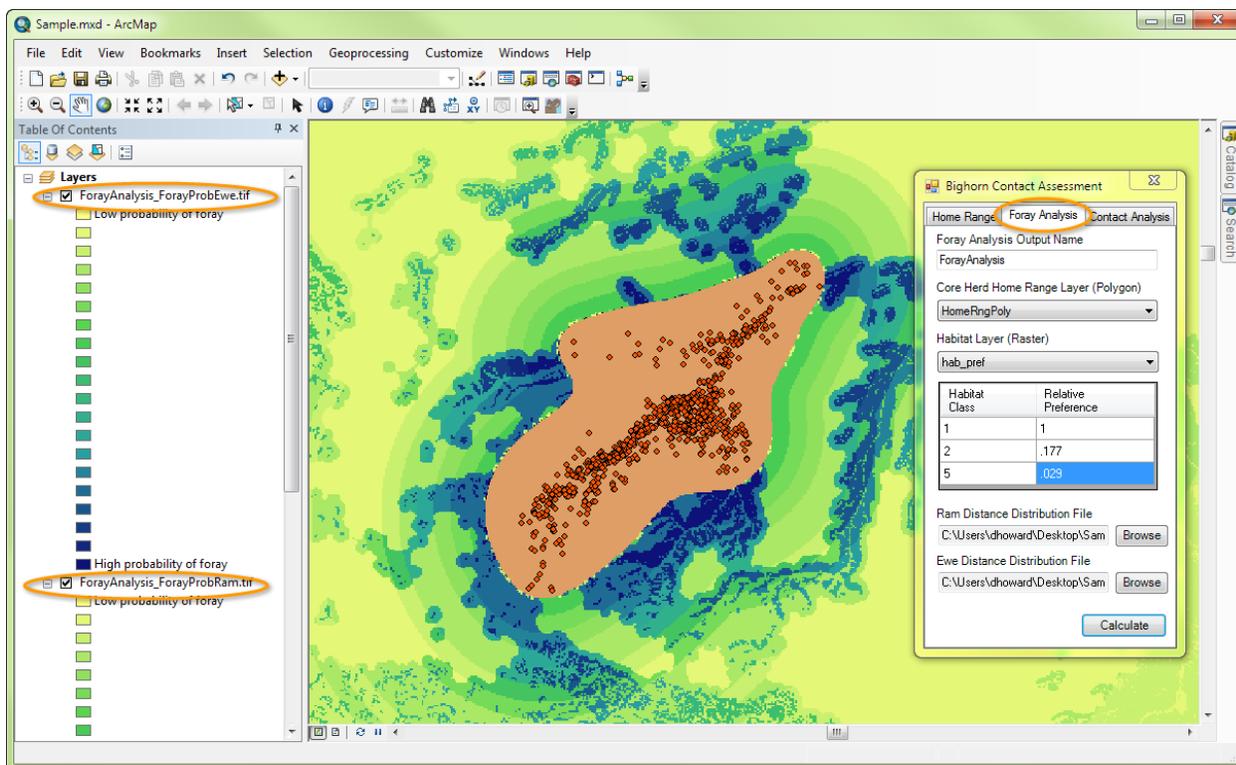


FIGURE 19. EXAMPLE EWE AND RAM FORAY PROBABILITY LAYERS



FIGURE 20 BELOW SHOWS THE RESULTS DIRECTORY CONTAINING THE FORAY LAYERS DISPLAYED IN

FIGURE 19.

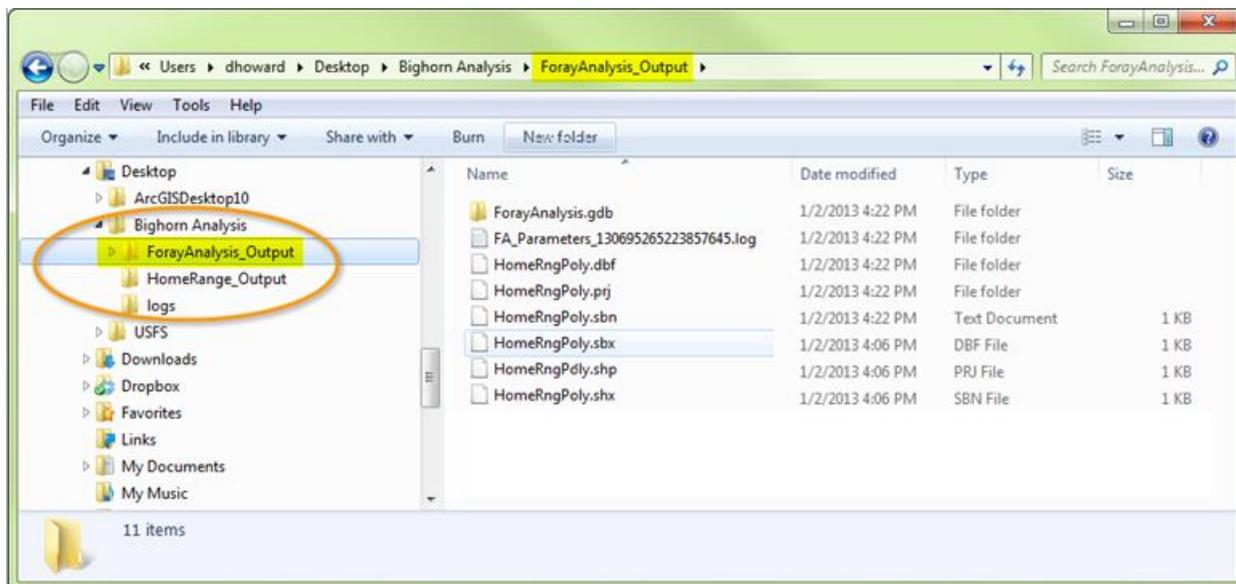


FIGURE 20. EXAMPLE FORAY ANALYSIS OUTPUT FILE STRUCTURE

The probability layers will be used as inputs by the **Contact Analysis** component, as described in the next section.

## 4.5 Using the Contact Analysis Component

The **Contact Analysis** component calculates the annual or seasonal probability that individual bighorn sheep will leave their CHHR and come into contact with an active domestic sheep allotment boundary. The results are shown in a single table that contains both individual-level contact probabilities and herd level rates of contact for rams and ewes.

To produce the summary contact probability table, the Tool uses the foray probability raster layer and ring buffer polygons generated by the Foray Analysis component, along with an Allotment Polygons Layer containing the outlines of occupied domestic sheep allotments. Herd-level characteristics such as sex ratio and seasonal foray probability of a ram and ewe are also used in the calculations as described below.



### 4.5.1 Contact Analysis Calculation

Enter information in the **Contact Analysis** component (Figure 22) as described below:

**NOTE:** It is recommended to keep the validated default values unless site or region-specific data are available. Changes to default data should be documented.

FIGURE 21. CONTACT ANALYSIS COMPONENT

1. **Contact Analysis Output Name:** Enter a name 25 or fewer characters long, containing no spaces, and starting with something other than “&”, “%”, “.”, or a digit. Outputs from the Contact Analysis will be saved to a folder whose name is constructed by appending the characters “\_output” to the name entered here. So, if a user enters the name “MyContactAnalysis”, results will be saved to the directory “MyContactAnalysis\_output”.
2. **Foray Analysis Output Directory:** Browse to the project directory (i.e., the directory selected when the user interface was launched) and select the **Foray Analysis\_Output** folder.

**NOTE:** The Foray Analysis\_Output folder contains multiple files required to perform the Contact Analysis and **must be left intact** for the Contact Analysis to run correctly.

3. **Allotment Polygons Layer:** From the drop-down list, select the **Allotment Polygons Layer** loaded in the ArcMap session. This layer contains the boundaries of each allotment to be evaluated for risk of contact.

**NOTE:** Take care not to select a home range **\_poly** layer created by the Home Range component.

4. **Allotment ID Field:** Select an allotment ID field; for example, a “Name” field from the drop-down list. This field will be used to identify the allotment in the results table. The allotment ID must be unique to each allotment analyzed.

**NOTE:** Allotment ID Field must be a string data type, so only string type fields from the selected layer will be displayed in the Allotment ID Field drop-down box. If a layer is selected which does not contain a string type field, an Allotment Layer error will be displayed (Figure 22).

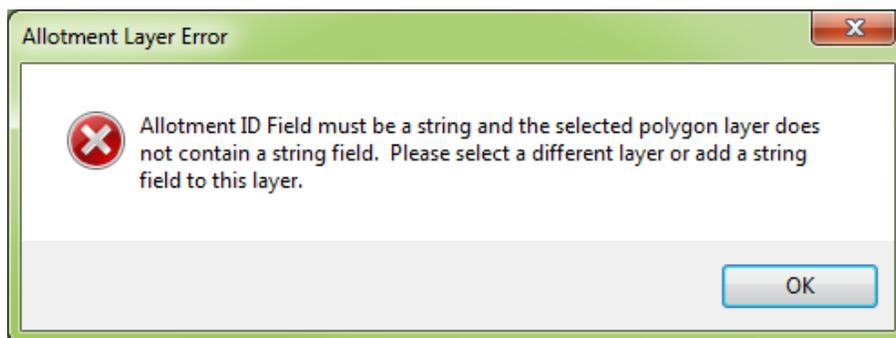


FIGURE 22. ALLOTMENT LAYER ERROR



5. **Herd Size:** Enter the number of adult animals in the bighorn sheep herd. This should be based on estimated herd size for the specific herd being analyzed.
6. **Herd Sex Ratio:** Enter the ratio of rams to ewes in the herd. This information may be supplied as any pair of positive numbers (e.g., 0.35 and 0.65, or 3 and 5, or 0 and 10) from which a ratio can be calculated.

**NOTE:** The default ratio of 35:65 is based on observations of Hells Canyon area herds. These values should be changed as appropriate where better information is available.

7. **Foray Probability:** Enter the probability an individual ram or ewe will foray out of the CHHR during the grazing season being analyzed. Enter the value as a proportion rather than as a percentage (i.e., 0.15 rather than 15%).

**NOTE:** The default values of 0.141 (14.1%) for rams and 0.015 (1.5%) for ewes are derived from 29,800 summer-season (May–October) observations of bighorn sheep in 13 Hells Canyon area herds, collected over a 12 year period. The values represent the proportion of radio-collared individuals that were observed outside their CHHR during the summer grazing season. Changing these values will directly affect estimated probabilities and rates of contact. If different values are used, the rationale for the changes and the observational basis for the estimated rates should be documented.

Once each field in the form has been populated, the **Calculate** button will be enabled.

8. Click **Calculate** to launch the contact analysis (Figure 23).



FIGURE 23. CONTACT ANALYSIS COMPONENT CALCULATE BUTTON

**WARNING!** If an allotment polygon intersects the CHHR polygon, the message dialog box reproduced in Figure 24 will open, displaying a list of intersecting allotment IDs, informing the user that those allotments will not be included in the analysis. Contact probability is calculated only when the allotment is geographically separated from the CHHR. Contact with the allotment is assumed when allotment and CHHR boundaries overlap.

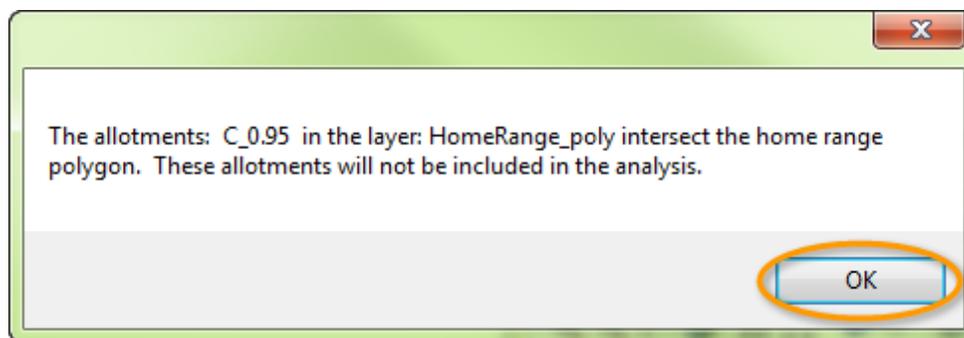
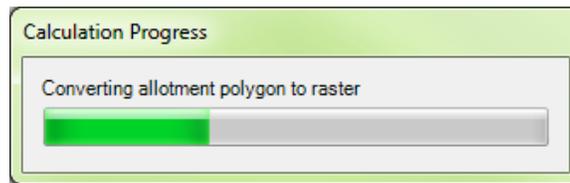


FIGURE 24. MESSAGE WARNING THAT SOME ALLOTMENTS INTERSECT THE CORE HERD HOME RANGE



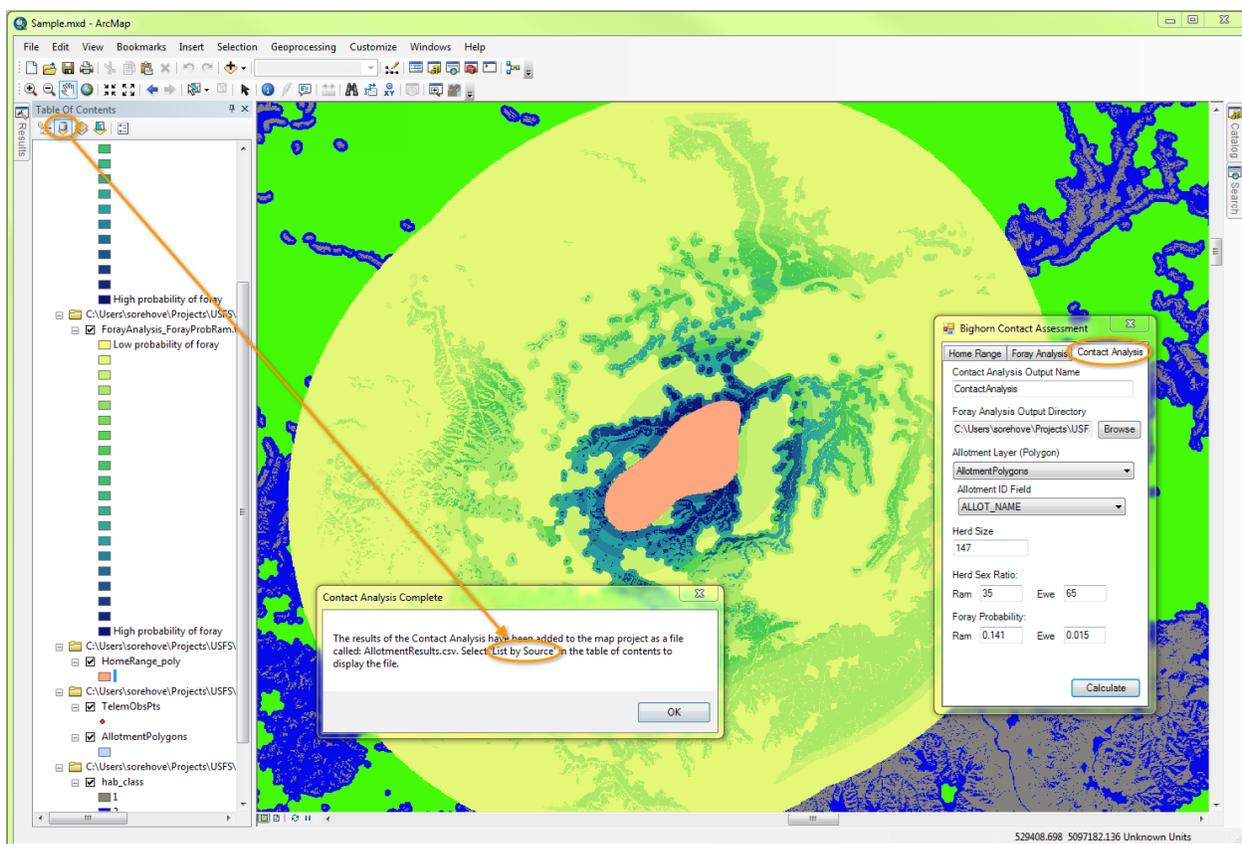
9. Click **OK** and the Contact Analysis Calculation Progress dialog box will open (Figure 25).



**FIGURE 25. CONTACT ANALYSIS CALCULATION PROGRESS DIALOG BOX**

Once the contact analysis calculations are complete, the Contact Analysis Complete dialog box will open with instructions on how to access the **AllotmentResults.csv** table by closing the Tool and clicking on the second icon in the Table of Contents to switch the view to **List by Source** (Figure 26).

10. Click **OK** in the Contact Analysis Complete dialog box, and close the tool.

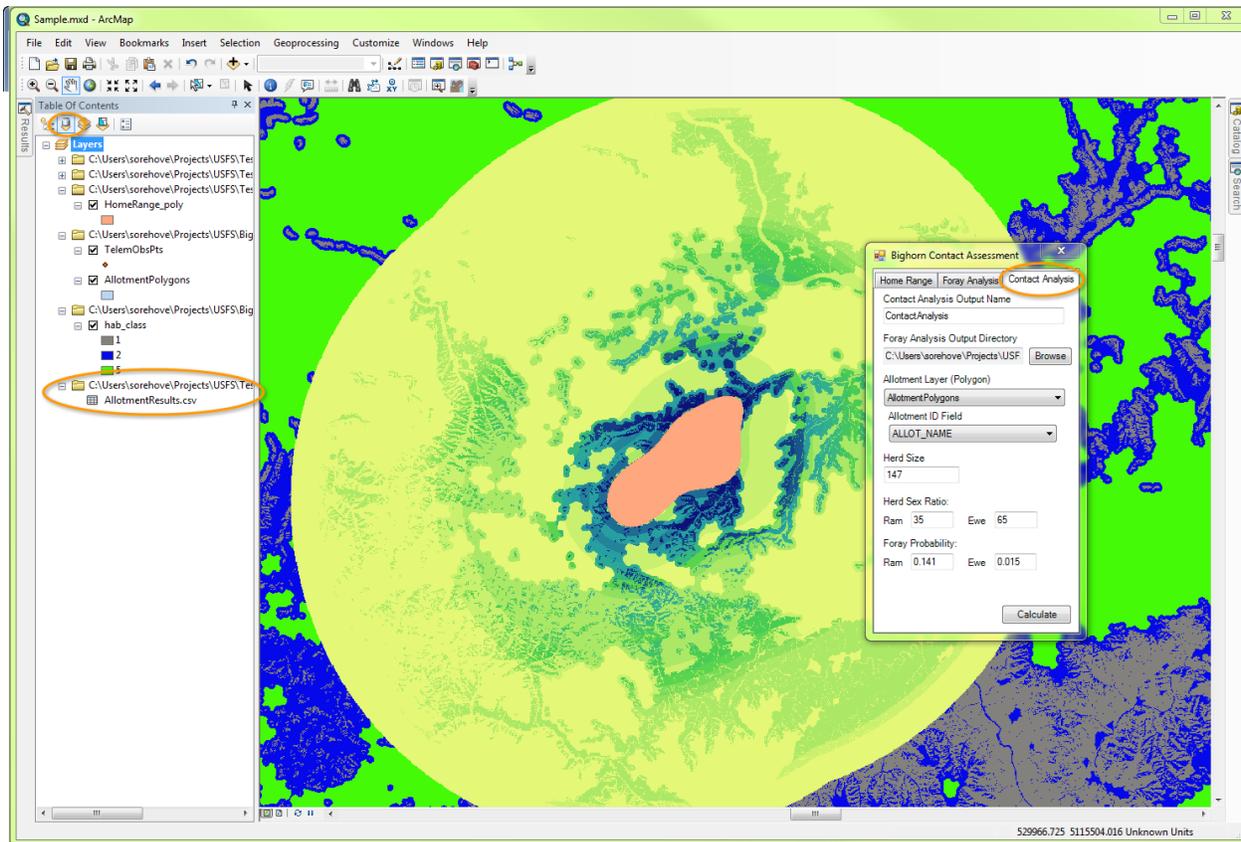


**FIGURE 26. CONTACT ANALYSIS COMPLETE DIALOG BOX**



11. Select the **List by Source** icon in the Table of Contents.

The file **AllotmentResults.csv** was added to the bottom of the ArcMap Table of Contents (Figure 27) and the Contact Analysis output folder (Figure 28).



**FIGURE 27. ALLOTMENT RESULTS TABLE AND 'LIST BY SOURCE' ICON (BOTH CIRCLED)**



Figure 28 below is an example of the results folder containing the output of the contact analysis.

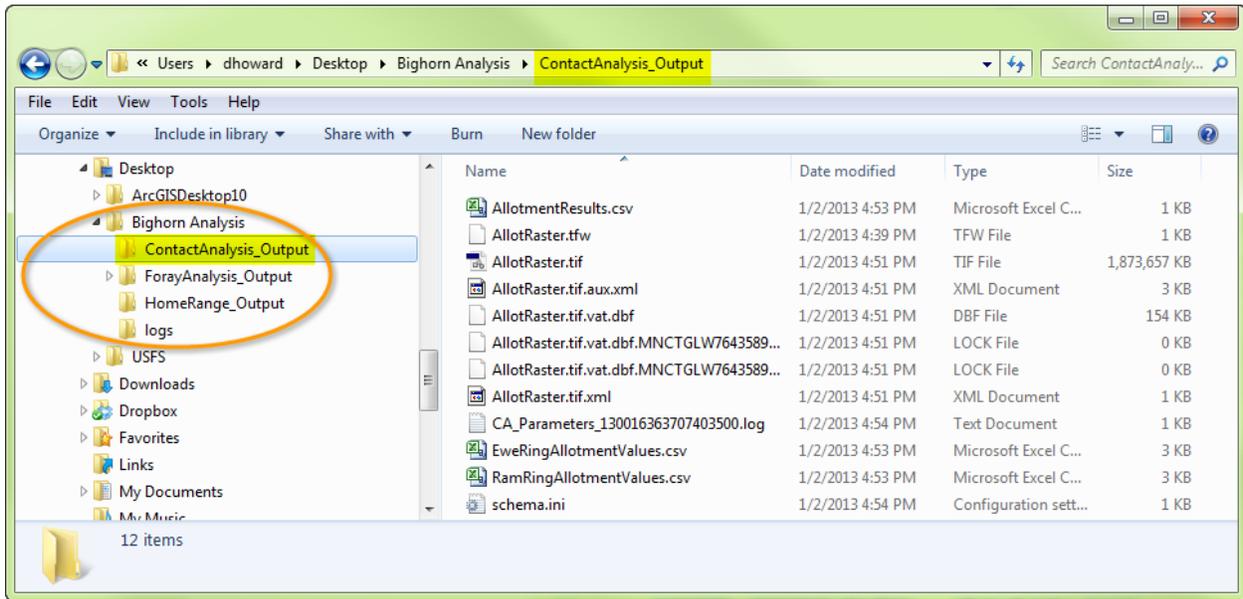


FIGURE 28. EXAMPLE CONTACT ANALYSIS OUTPUT FILE STRUCTURE

12. In the **List by Source** view, right-click on the table icon in the Table of Contents (Figure 29).
13. Click **Open** in the drop-down list (Figure 29).

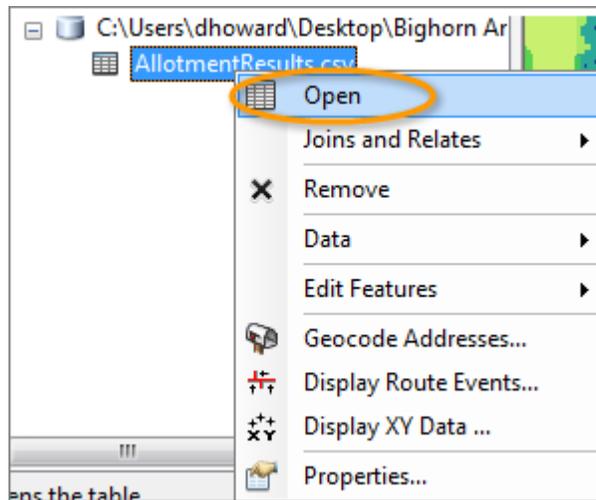


FIGURE 29. OPEN ALLOTMENT RESULTS TABLE



The table will open as shown in the example in Figure 30. In this example, none of the allotments in the data set intersect the CHHR polygon.

Allot_ID	Single_Ram	Single_Ewe	All_Rams	All_Ewes	All_Herd	Notes
Limestone East	0.001914	0.000057	0.097617	0.005448	0.103066	<Null>
Ray Creek	0.008528	0.000433	0.434913	0.041534	0.476448	<Null>
Summit	0.000553	0.000014	0.028182	0.001385	0.029567	<Null>

FIGURE 30. EXAMPLE TABLE FROM ANALYSIS WITH NO ALLOTMENTS INTERSECTING CORE HERD HOME RANGE

When occupied allotments **do intersect** the CHHR polygon in an analysis, the “Notes” column in the results table will contain the following notification: “This allotment intersects the home range polygon and is therefore not included in the analysis” (Figure 31).

Allot_ID	Single_Ram	Single_Ewe	All_Rams	All_Ewes	All_Herd	Notes
Limestone East	0	0	0	0	0	This allotment intersects the home range polygon and is therefore not included in the analysis.
Ray Creek	0	0	0	0	0	This allotment intersects the home range polygon and is therefore not included in the analysis.
Summit	0.000553	0.000014	0.028182	0.001385	0.029567	<Null>

FIGURE 31. EXAMPLE RESULTS WITH INTERSECTING ALLOTMENTS

Below is a description of each column in the table. (For a more detailed discussion of how the values in each column are related, and how they might be described in narrative form, see Appendix H:Frequently Asked Question (FAQs), in particular the question titled “What do the rates in the contact model’s output table represent, and how can they be described in narrative form?”):

- **Allot\_ID**: Name or ID of allotment or pasture selected via the “Allotment ID Field” in the Contact Analysis user interface
- **Single\_Ram** : Annual/seasonal probability that any given ram will foray outside its CHHR and contact this allotment
- **Single\_Ewe** : Annual/seasonal probability that any given ewe will foray outside its CHHR and contact this allotment
- **All\_Rams** : Average number of rams expected to foray outside the CHHR and contact this allotment each year/season
- **All\_Ewes** : Average number of ewes expected to foray outside the CHHR and contact this allotment each year/season
- **All\_Herd** : Average number of adult bighorn sheep (rams plus ewes) expected to foray outside the CHHR and contact this allotment each year/season



- **Notes :** For allotments not given estimated risks of contact, a note about why they were excluded from the analysis

## 4.6 View Analysis Results and Bighorn Sheep Locations

After the tool has completed all three analyses and has been closed, you may want to adjust the order of the layers in the Table of Contents to better view the results and bighorn sheep locations (Figure 32).

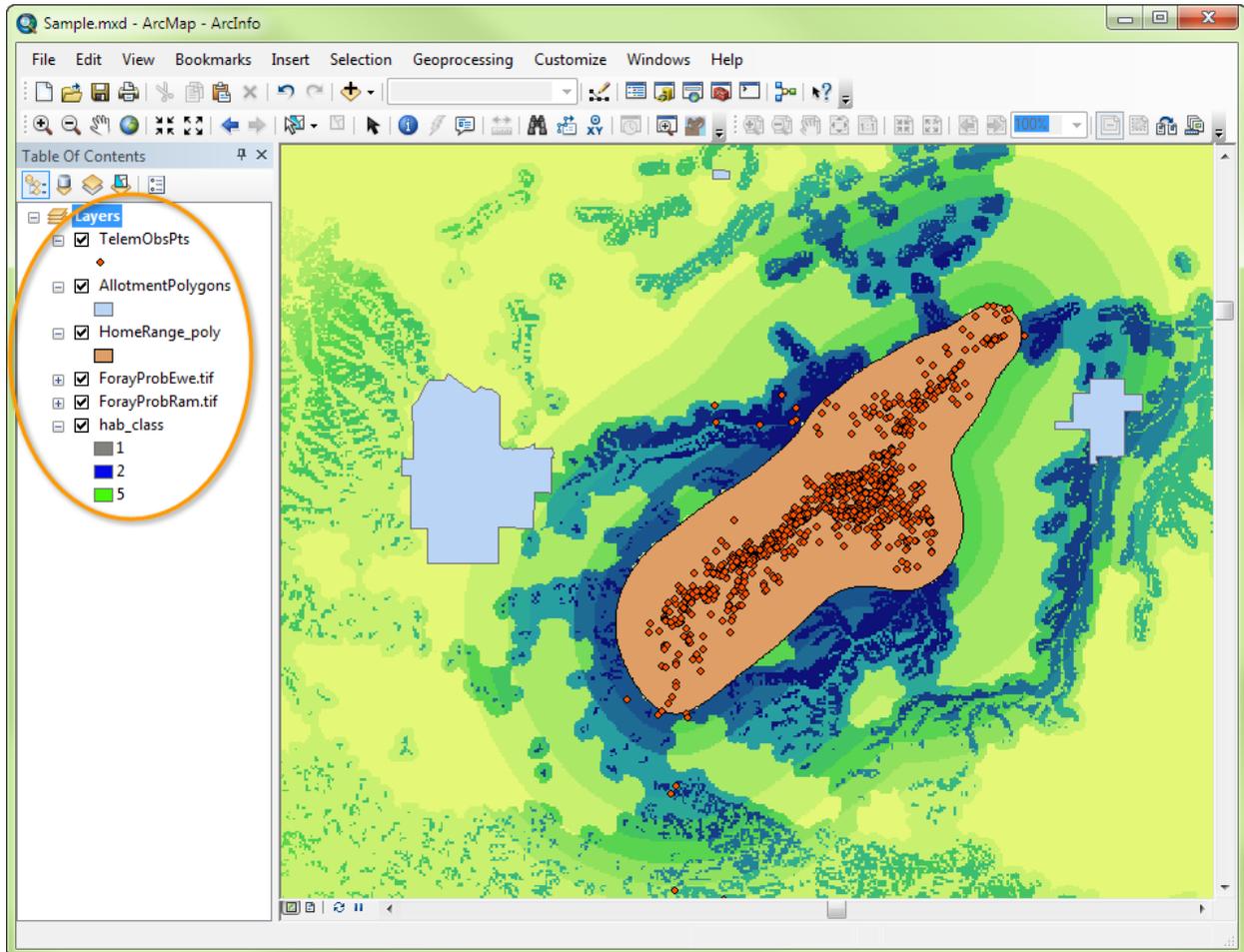


FIGURE 32. VIEW EXAMPLE ANALYSIS RESULTS AND BIGHORN SHEEP LOCATIONS



## 4.7 Create a Graph

The contact results table is a standard tabular \*.csv file (AllotmentResults.csv) written to the Contact Analysis output folder. The contents of the file can easily be processed and visualized in ArcGIS by selecting Create Graph from the Table Options drop-down menu. Alternatively, the file can be opened and processed using other computer programs such as Microsoft Excel.

The bar chart in Figure 33 was plotted using the ArcGIS "Create Graph Wizard". It displays estimated contact rates stored in the "Rate\_Hrd\_Cont" column of the AllotmentResults.csv file shown in Figure 30 above.

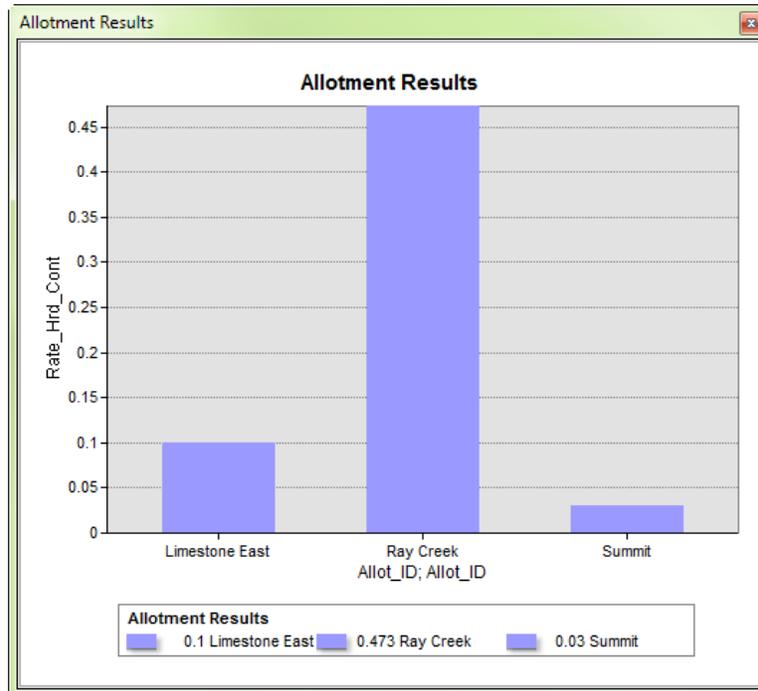


FIGURE 33. EXAMPLE GRAPH OF HERD LEVEL CONTACT RATE WITH THREE ALLOTMENTS



## 4.8 Project Output Folders and Files

All data generated during an analysis are saved in the working directory selected when the Tool was first opened. After all three of the Tool's interface components have been successfully run, the output folder will contain four subfolders (Figure 34):

1. HomeRange\_Output
2. ForayAnalysis\_Output
3. ContactAnalysis\_Output
4. logs

Each of the first three subfolders listed above contain intermediate files generated during the analysis, including a parameters log file which records the input parameter values selected by the user via the Tool interface.

**NOTE:** *The parameters log files constitute an essential record of the data and assumptions that went into an analysis and should be saved alongside any results of the analysis. For more details, see Appendix F.*

The “logs” subfolder contains several more detailed log files recording the calculations performed by each of the interface components. ArcGIS creates one log file each time any of the interface components is run. These log files contain copies of the commands sent to R and the ArcMap geoprocessing calls made by the Tool. In addition, the R package BHSkde outputs a log file of its own recording the progress of the CHHR calculations it performs. All of these log files are potentially helpful in diagnosing problems encountered when using the Tool.

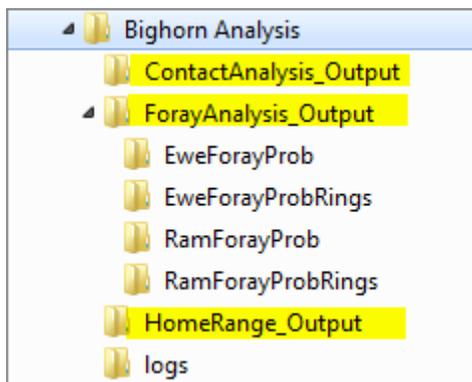


FIGURE 34. EXAMPLE BIGHORN OUTPUT FOLDER STRUCTURE



## Appendix A: Tool Installation Guide

This appendix details the steps needed to set up a computer so that it can be used to run the Bighorn Sheep Risk of Contact Tool. The Tool depends on a working installation of ArcGIS 10.1 Service Pack 1 equipped with the ArcGIS Spatial Analyst extension (Forest Service users see Section 3.1.1 on obtaining the software). Each item below links to the section of the same name:

- Obtain Administrative Privileges
- Download and Unzip the Tool Installation Zip File
- Install R-3.1.2
- Install the Bighorn Sheep Risk of Contact Tool Add-In

### A.1 Obtain Administrative Privileges

Administrative privileges are typically required to install the software. However, Forest Service computers run the PowerBroker Desktop (PBD) tool which provides the correct level of permissions for installation of software by simply double-clicking the installation executable. If prompted for an Administrator logon or if the User Account Control window pops up, click Cancel. Right-click the installation executable and select Run Elevated. For more information, visit <http://fsweb.wo.fs.fed.us/irm/security/powerbroker/index.php>. Bureau of Land Management personnel will need to contact the BLM National Help Desk (<http://1800blmhhelp.blm.gov/>) to install any software on their computer.

### A.2 Download and Unzip the Tool Installation Zip File

All of the software and documentation needed to use the Tool is bundled in a zip file that contains: (a) the R installer; (b) the Bighorn Sheep Risk of Contact Tool ESRI Add-in; (c) the Bighorn Contact Tool User Guide; and (d) a folder containing sample data used to demonstrate the Tool's use.

Forest Service users can download the zip file from the following location:

**O:\NFS\R02\Collaboration\WesternBHSheep2\BHS\_Tool\_ArcGIS\_10\_1**

For Bureau of Land Management personnel, software can only be downloaded/installed by submitting a remedy ticket to the BLM National Help Desk (<http://1800blmhhelp.blm.gov/>). In the remedy ticket, be sure to specify the exact software package name(s) as well as the version number(s).

Download the zip file and move it to a folder (e.g. a newly created folder C:\BighornROCTool) from which the Tool will be run. Unzip the file (e.g. by right-clicking on the file and selecting WinZip > "Extract here") and then follow the instructions below to install R and the Tool. If needed, Forest Service users can install WinZip from the Software Library accessed through the Chief Information Office (CIO) homepage (<http://fsweb.wo.fs.fed.us/irm/index.php>). Again, Bureau of Land Management personnel will need to contact the BLM National Help Desk (<http://1800blmhhelp.blm.gov/>) to install software on their computer.

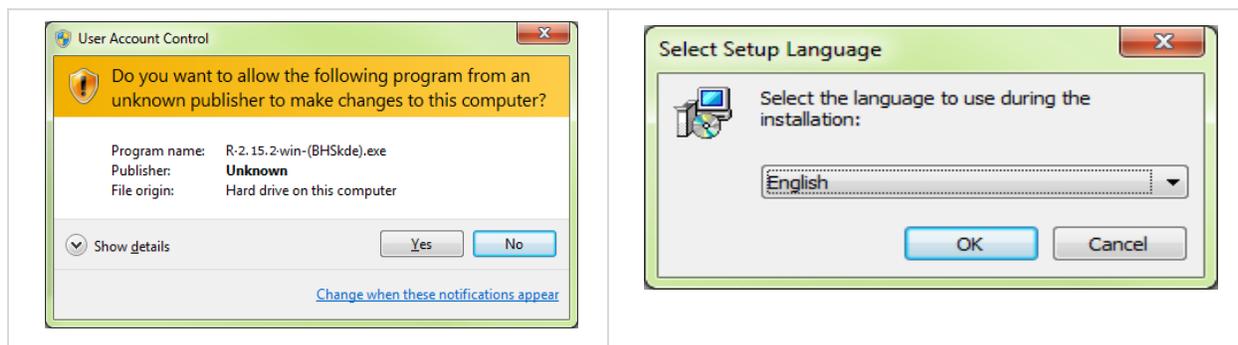


## A.3 Install R-3.1.2

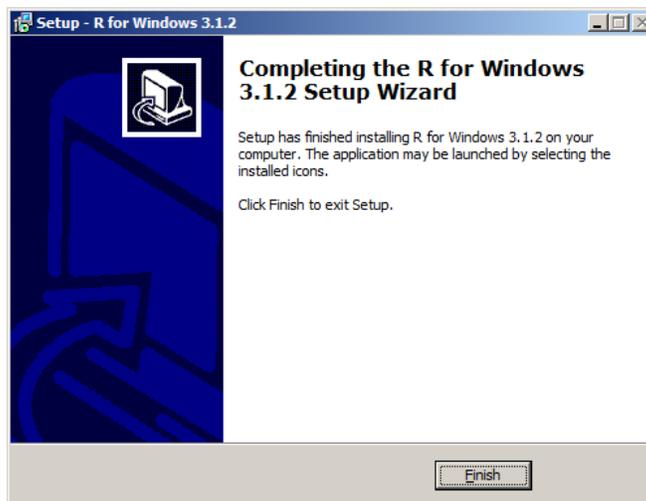
**NOTE:** Do not download and install R directly from the R Web site. The installer used in the steps below installs a customized version of R that has been set up to work with the Tool.

To install **R-3.1.2** and the required R packages, double-click on the customized R installer (R-3.1.2-win-(BHSkde).exe) provided with the Tool Installation zip file. If a prompt displays an “Open File – Security Warning” window, click **Run**. (If, as a Forest Service user, you are prompted for an Administrator logon or if the User Account Control window pops up, click **Cancel**. Right-click the installation executable and select **Run Elevated** and type “GIS” as justification in the PowerBroker Desktops Authorization window.) One or both of the following dialogue boxes will then appear.

**TABLE A-1. DIALOGUE BOXES LAUNCHED BY THE CUSTOMIZED R INSTALLER**



After clicking **OK** to accept English as the setup language, click **Next** eight times, accepting all of the default settings. When presented with the screen below (Figure A-1), click **Finish** to complete installation.



**FIGURE A-1. COMPLETING THE R WINDOWS SETUP WIZARD**

**NOTE FOR THOSE WHO USE R FOR OTHER PROJECTS/ANALYSES:**

The R executable and packages installed by running R-3.1.2-win-(BHSkde).exe will not interfere with any other versions of R installed on your machine.



## Install the Bighorn Sheep Risk of Contact Tool Add-In

To install the ESRI Add-In:

1. Double-click on the **BighornContact.esriAddIn** file provided with the Tool Installation zip file. The dialog shown in Figure A-2 will open.
2. Click the **Install Add-In** button.

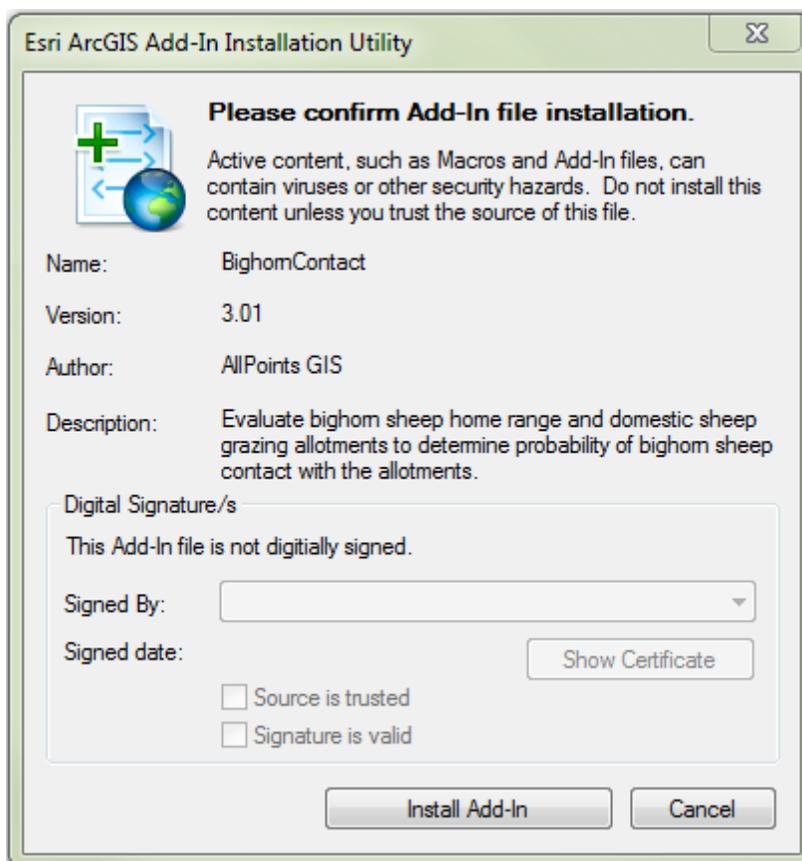


FIGURE A-2. ESRI ARCGIS ADD-IN INSTALLATION UTILITY

Depending on which version of Windows a computer is running, the Add-In application will be copied to one or the other of the default folders indicated below:

- **Vista or Windows 7:** C:\Users\\My Documents\ArcGIS\AddIns\Desktop10.1
- **XP:** C:\Documents and Settings\\My Documents\ArcGIS\AddIns\Desktop10.1



Once the installation is complete, the dialog box in Figure A-3 will display.

3. Click **OK**.

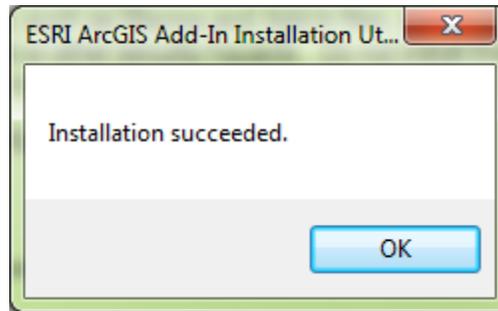


FIGURE A-3. ESRI ARCGIS ADD-IN INSTALLATION SUCCEEDED DIALOG BOX

#### A.4.1 Add Command Button to the Toolbar

1. Open ArcMap 10.1.
2. In ArcMap, click Customize > **Customize Mode** (Figure A-4).

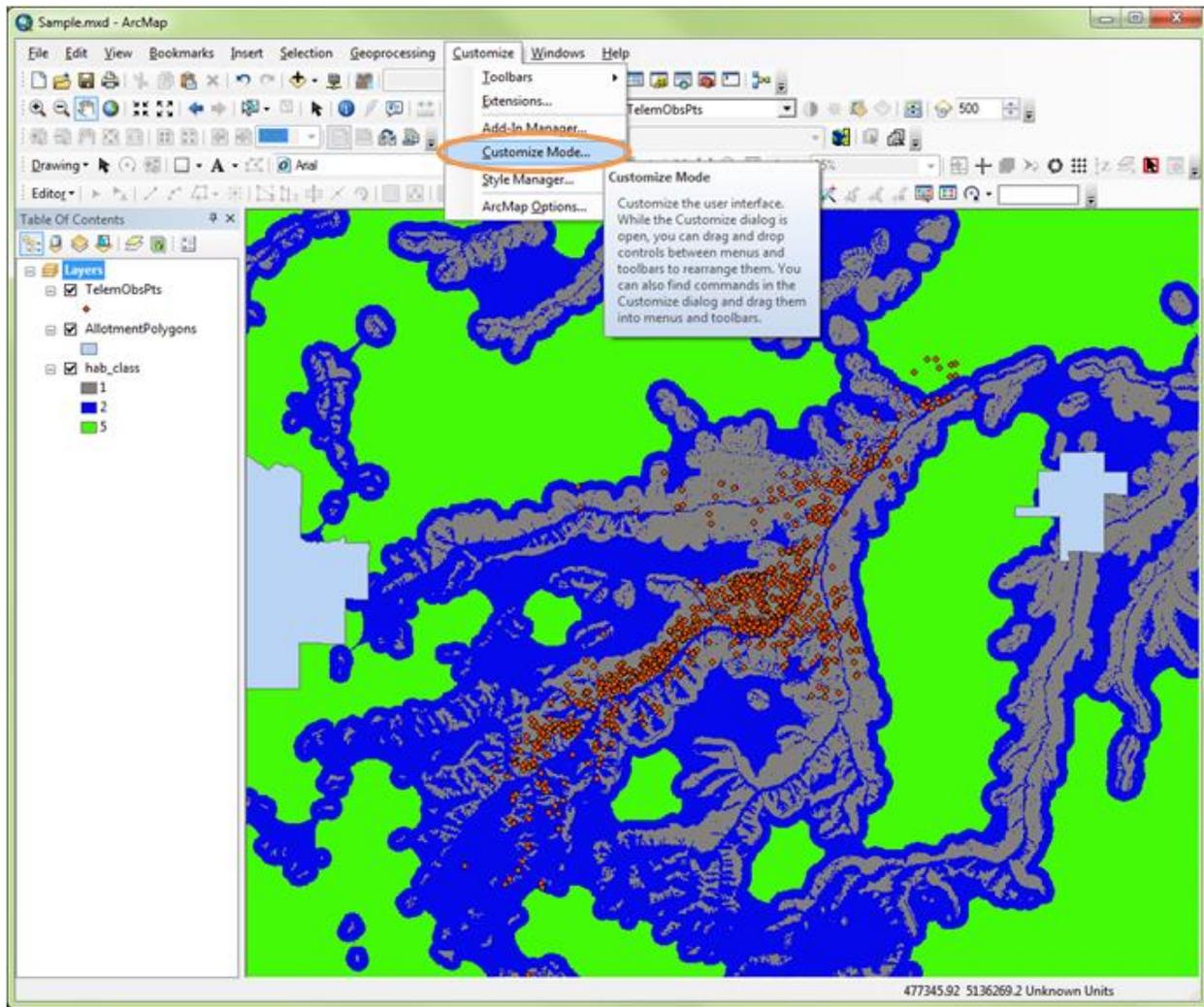


FIGURE A-4. CUSTOMIZE DROP-DOWN LIST



The **Customize** dialog box will open (Figure A-5).

3. Select the **Commands** tab.
4. Scroll down and click **Bighorn Sheep Tool**.
5. Select **Bighorn Sheep Contact Model** from the right pane.

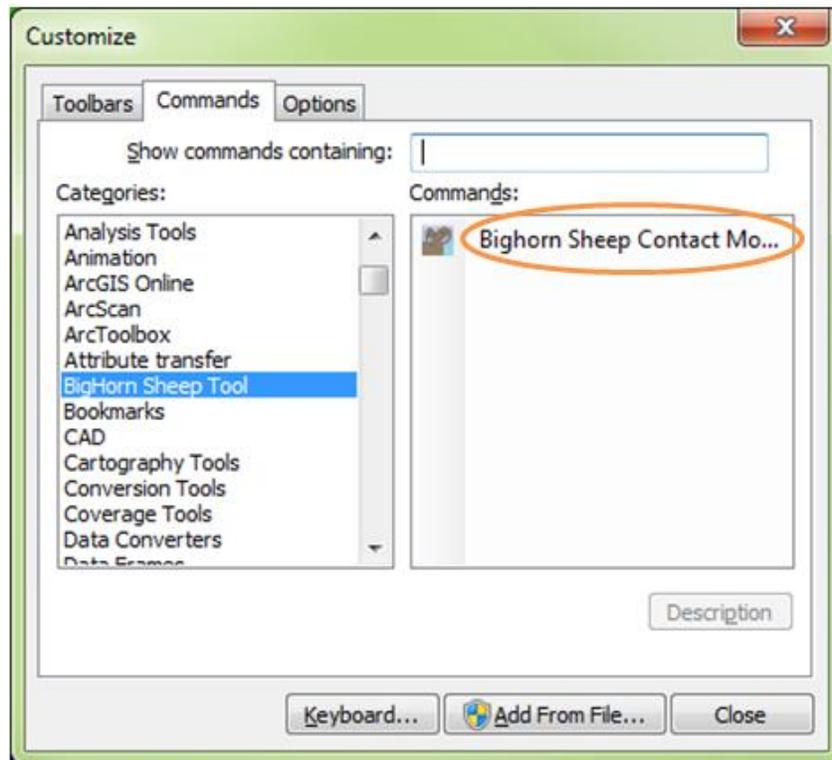
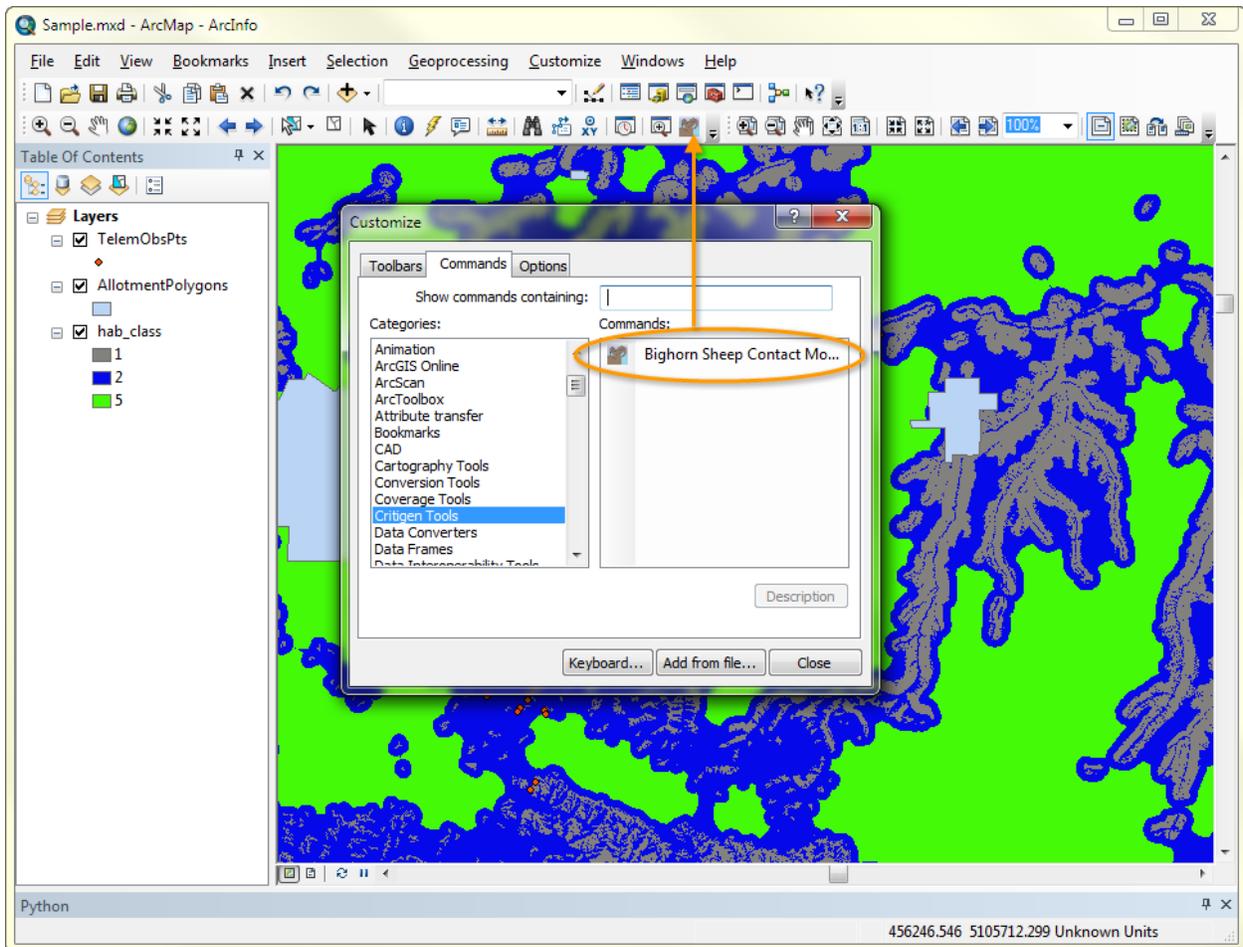


FIGURE A-5. CUSTOMIZE DIALOG BOX

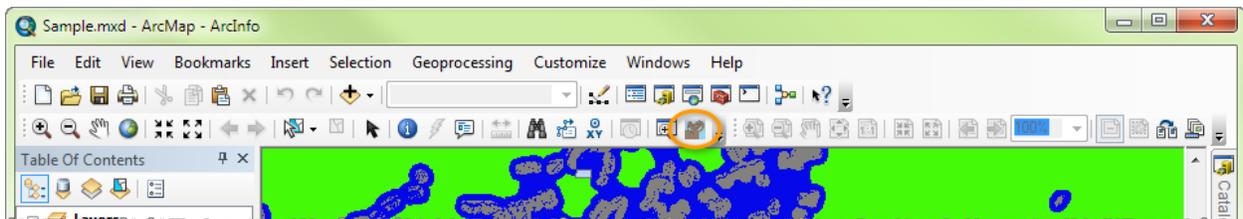


6. Drag the Tool to any **ArcMap toolbar** (Figure A-6).
7. Click **Close**.



**FIGURE A-6. ADDING TOOL TO ARCMAP TOOLBAR**

The Tool has been added to an ArcMap toolbar (Figure A-7).



**FIGURE A-7. BIGHORN SHEEP RISK OF CONTACT TOOL ADDED TO TOOLBAR**



## A.4.2 Uninstall the Bighorn Sheep Risk of Contact Tool Add-In

Both R-3.1.2 and the Add-In must all be installed for the Tool to work. However, each may be installed and uninstalled independently of the others, a feature that is especially helpful for updates and bug fixes. Uninstalling the Add-in uninstalls the Tool. (For more information on how ArcMap Add-Ins work and how to manage them, visit [ESRI ArcMap Resource Center](#), [ArcObjects Help for .NET developers](#).)

Below are instructions on how to uninstall the Add-in.

1. Open ArcMap and go to **Customize > Add-In Manager** (Figure A-8).

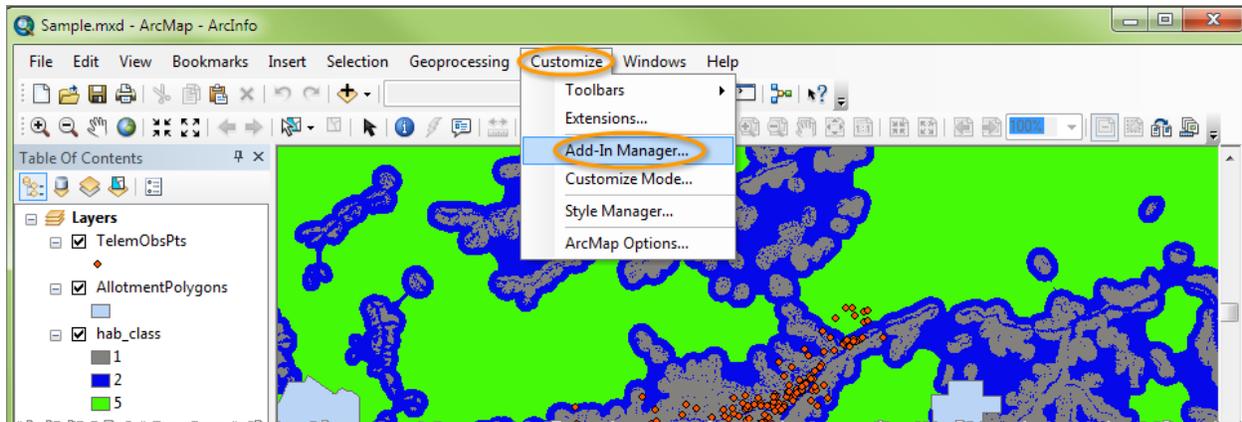


FIGURE A-8. ARCMAP ADD-IN MANAGER LINK



The **Add-In Manager** dialog box will open.

2. Select the **Add-In** and then press **Delete this Add-In** (Figure A-9).
3. Click **Close**, and the Add-In Manager dialog box will close.
4. Close **ArcMap**.
5. Reboot the computer.

The next time ArcMap is opened, the Add-in, and all of the commands, toolbars, and tools associated with it will be gone.

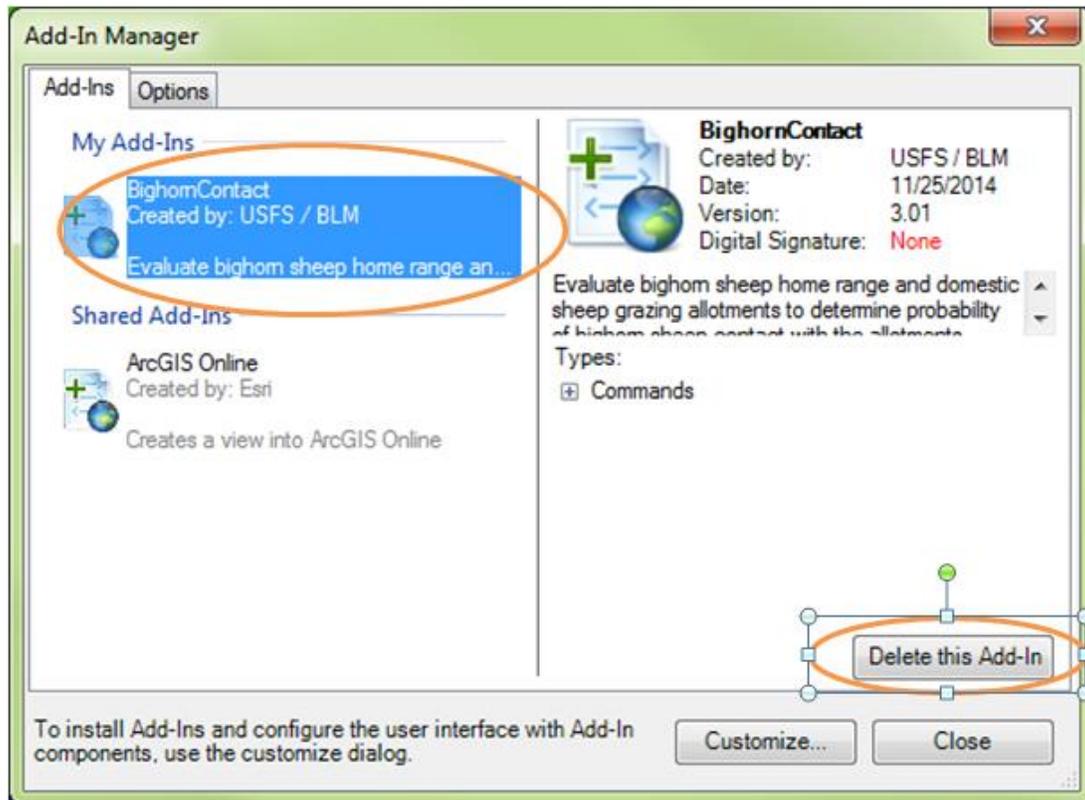


FIGURE A-9. ADD-IN MANAGER – ADD-INS TAB



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## Appendix B: Quick Start Guide

The purpose of this Quick Start Guide is to help users quickly set up their ArcMap 10.1 Service Pack 1 environment with the supplied sample data so they can become familiar with the Tool's functionality and verify that it is working properly. The directions in this section assume that ArcMap 10.1 Service Pack 1, R-3.1.2, and the Tool have already been installed as described in Appendix A: Tool Installation Guide.

All of the data files used in the examples below are located in the **Sample Data** folder (Figure B- 1) located in the same directory as the R installer provided with the Tool.

### B.1 Open the Sample ArcMap Project File

1. In Windows Explorer, navigate to the Sample Data folder (Figure B- 1).
2. Double-click the **Sample.mxd** file.

**NOTE:** Alternatively, first open ArcMap, then click **File**, select **Open**, and navigate to the folder in which the **Sample.mxd** project file is located. Double-click on it to launch the project.

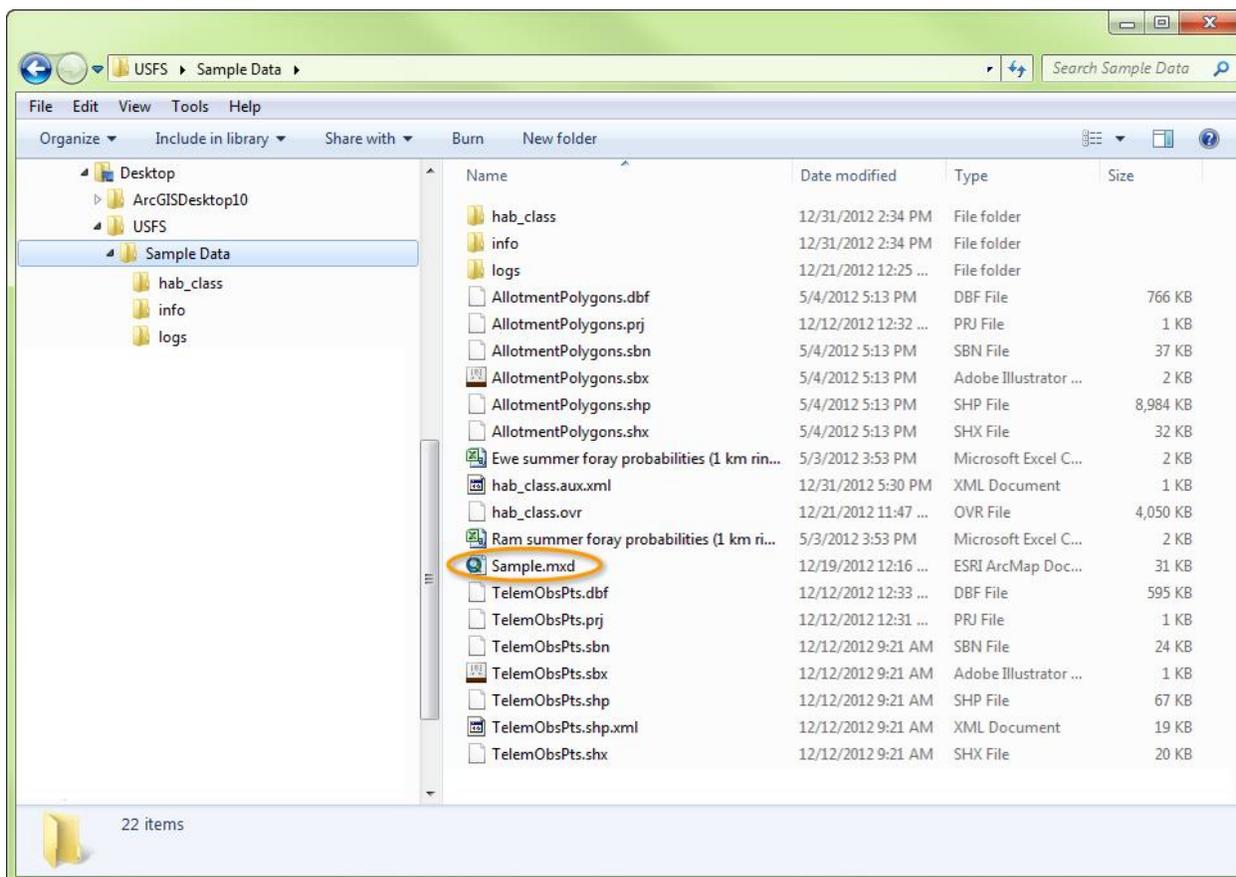


FIGURE B- 1. SUPPLIED SAMPLE DATA FOLDER



ArcMap will open with the sample map layers displayed in the Data Frame (right pane) of the ArcMap session window (Figure B- 2).

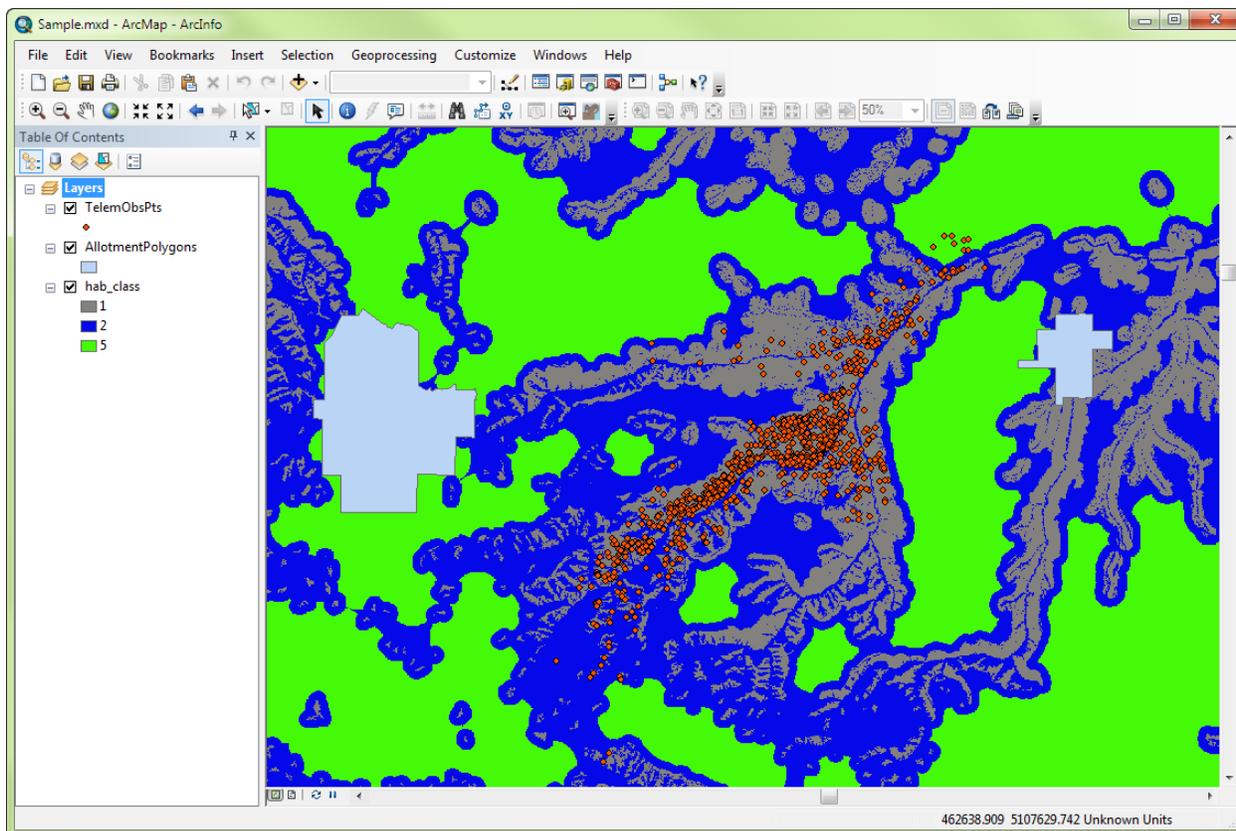


FIGURE B- 2. ARCMAP SESSION WINDOW



## B.2 Run the Bighorn Sheep Risk of Contact Tool

If the Tool is not already on a toolbar, refer to Appendix A: Tool Installation Guide.

**NOTE:** For more detailed instructions on how to run the Tool, refer to Section 4 Conduct a Risk of Contact Assessment.

1. Click on the Bighorn Tool icon from the ArcMap toolbar (Figure B- 3).

**NOTE:** The **Input Data** warning will open, reminding users to check that telemetry/observation points, the habitat raster, and allotment polygons are all formatted to the same projection and coordinate system. Click OK.

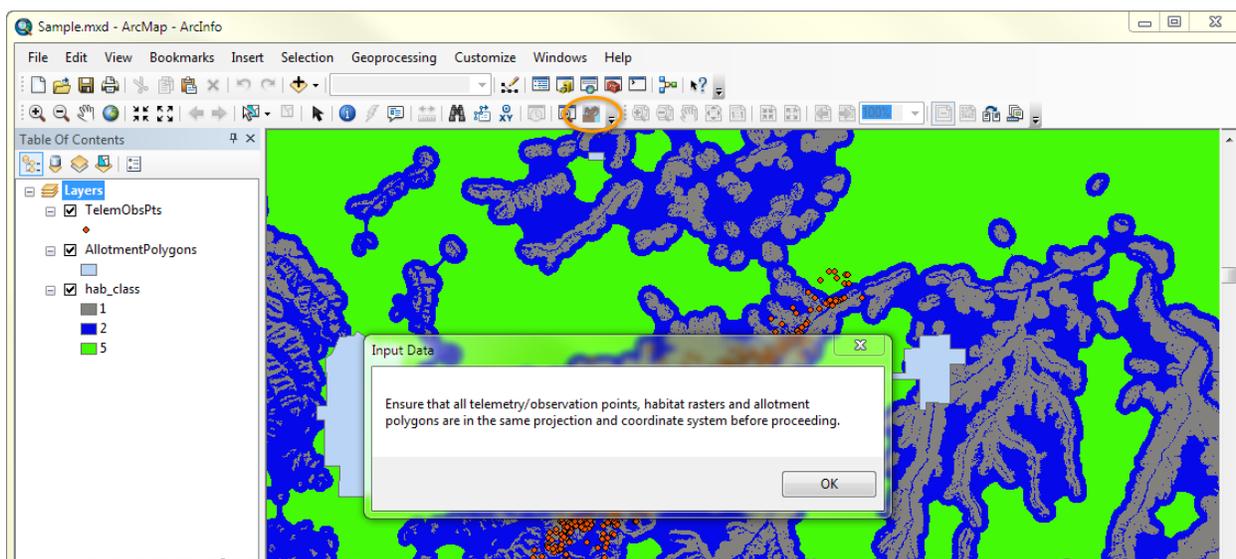


FIGURE B- 3. BIGHORN CONTACT ASSESSMENT TOOL (CIRCLED) IN ARCMAP TOOLBAR

2. The **Select working directory** dialog box will open (Figure B-4), click **No**.

**NOTE:** Select Cancel to close the Bighorn Tool without running an analysis.

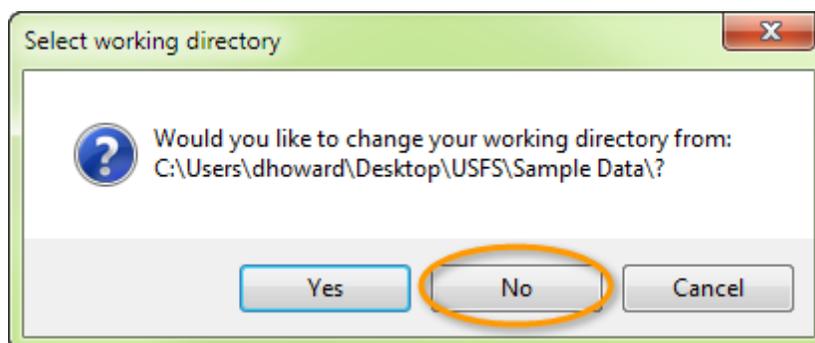


FIGURE B-4. SELECT WORKING DIRECTORY DIALOG BOX

3. Tool will open.



**NOTE:** The analysis results files will be saved in the Sample Data folder provided with the tool (Figure B-5).

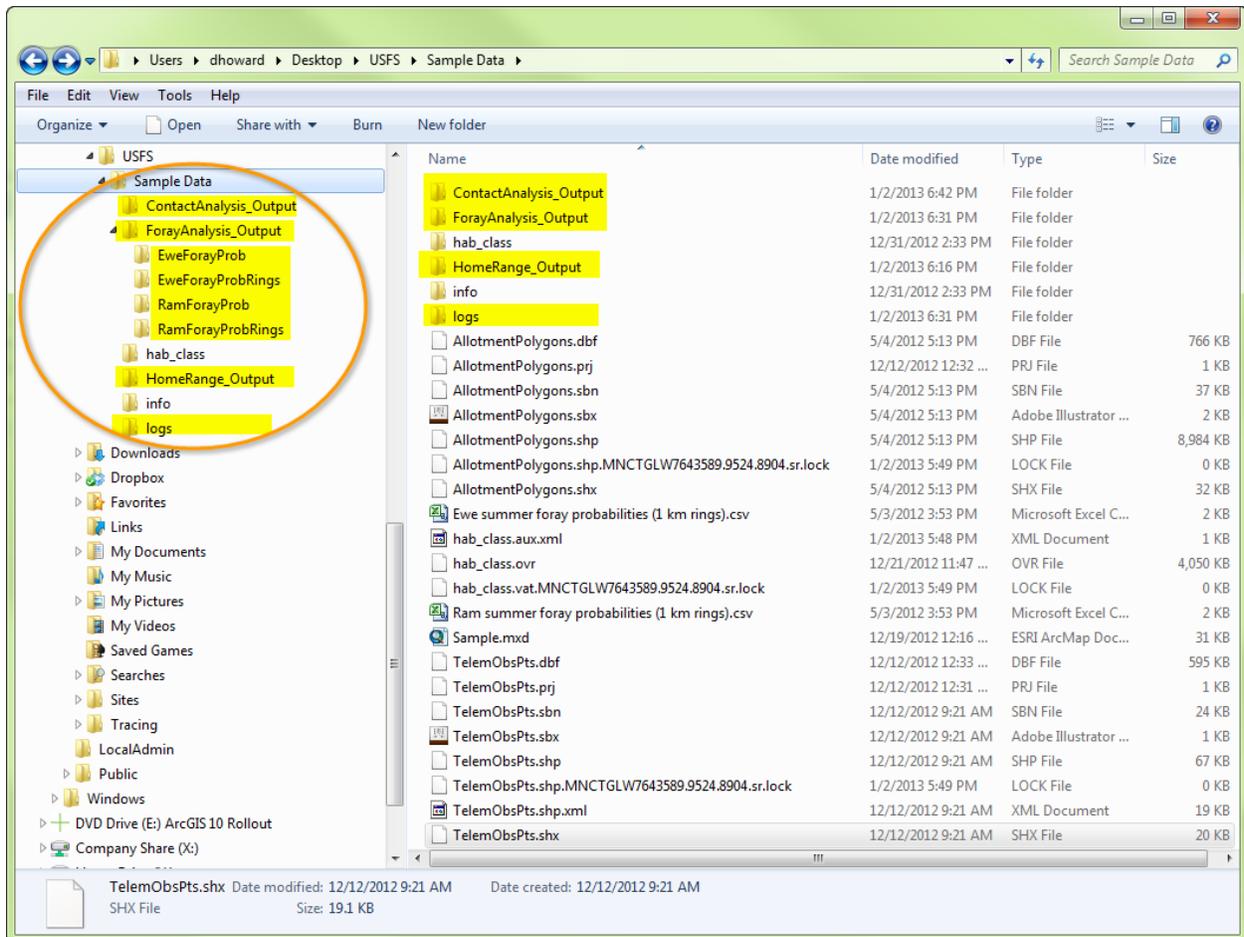


FIGURE B- 5. SAMPLE DATA FOLDER PROVIDED WITH THE TOOL



## B.2.1 Home Range Analysis

The first component of the Tool is used to perform the core herd home range (CHHR) calculation (Figure B- 6). Enter the information as described below:

FIGURE B- 6. HOME RANGE COMPONENT

1. **Core Herd Home Range Output Name:** Enter a name for the current Home Range analysis, in this case “HomeRange” with no space. Both the results folder and the home range polygon layer created by this calculation will be given names based on the value entered in this field:
  - **Folder:** \_output will be appended (e.g., HomeRange\_output)
  - **Layer:** \_poly will be appended (e.g., HomeRange\_poly)
2. **Telemetry/Observation Layer (Point):** The point layer used to generate the home range polygon. Use the drop-down list to select the “TelemObsPts” point layer loaded in the current ArcMap session.
3. **Animal ID Field:** The field used to identify the individual animals whose home ranges will be calculated and then combined to form the CHHR. Select the animal identifier field, in this case “Animal\_ID”, from the drop-down list that appears once the point layer has been chosen.
4. **Minimum Points Per Animal:** The minimum number of observations required for data from an animal to be included in the home range calculations. This cutoff is necessary because individual-level home range estimates based on too few points are less likely to be accurate. For this analysis, enter “21” minimum points per animal.
5. Leave the rest of the fields with the existing default values.
6. Click **Calculate**.

The **Calculation Progress** dialog box will open (Figure B- 7); the calculation will take a few minutes to finish. Once the calculation is complete, the **Calculation Progress** dialog box will close.

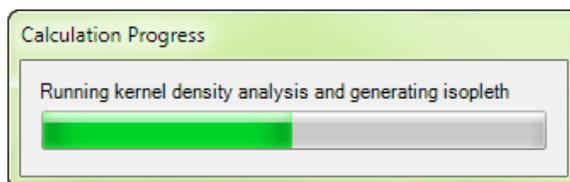


FIGURE B- 7. CALCULATION PROGRESS DIALOG BOX

After the calculation has completed, a new **\_poly** layer will be added to the ArcMap session (Figure B- 8) and the Tool should be left open. The new poly layer is the home range polygon required for the subsequent Foray Analysis.

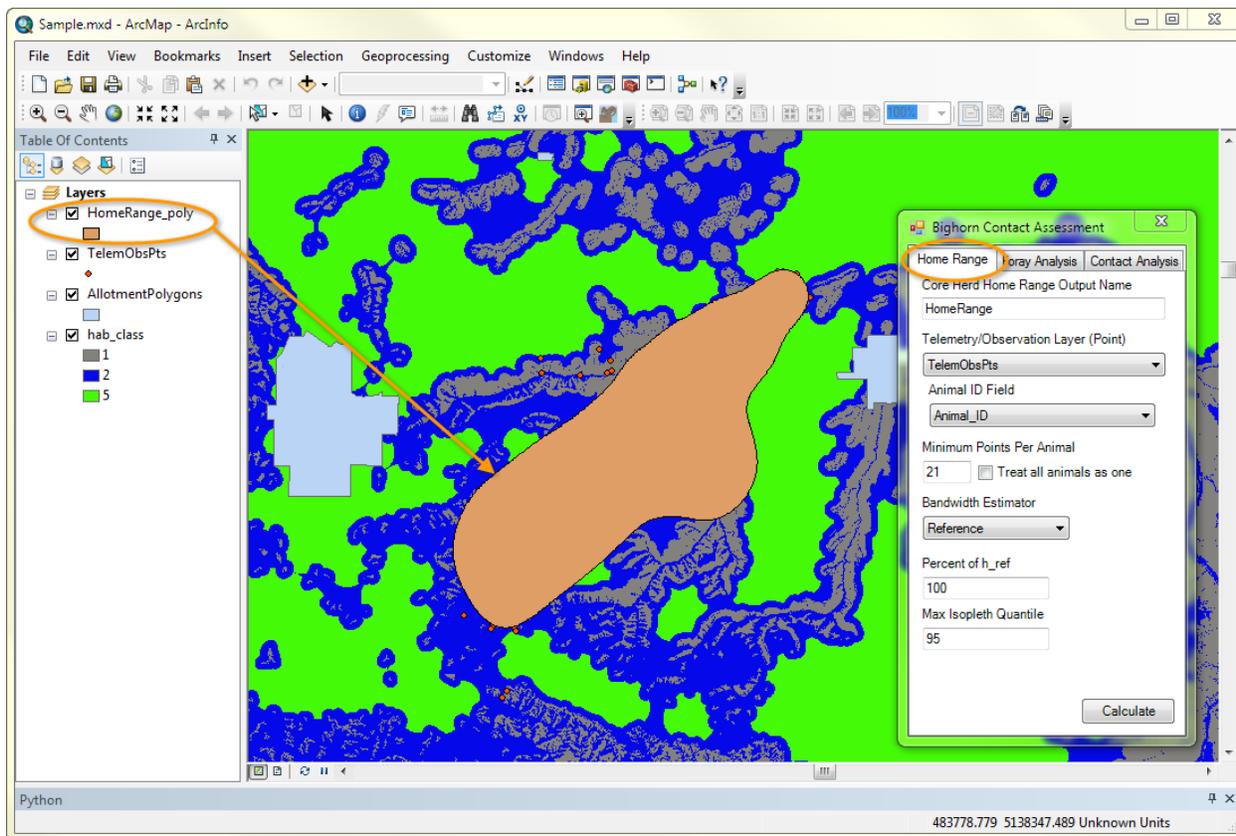


FIGURE B- 8. NEW HOMERANGE\_POLY LAYER



Habitat Class	Relative Preference
1	1
2	.177
5	.029

FIGURE B- 9. FORAY ANALYSIS COMPONENT

## B.2.2 Foray Analysis

The Tool's second component performs the Foray Analysis calculations (Figure B- 10). Its calculations **must be completed before** beginning the Contact Analysis. Enter the information as described below:

1. **Foray Analysis Output Name:** Enter a name with no spaces for the current Foray Analysis, in this case "ForayAnalysis". The value entered here will be used to name the folder to which Foray Analysis outputs are saved:
  - **Folder: \_output** will be appended (e.g., ForayAnalysis\_output)
2. **Core Herd Home Range Layer (Polygon):** Select the home range polygon layer created by the home range calculation from the drop-down list.
3. **Habitat Layer (Raster):** Use the drop-down menu to select a habitat class layer, in this case, hab\_class. The following three rows will be added to the grid:
  - Habitat Class 1: Denotes habitat
  - Habitat Class 2: Denotes connectors
  - Habitat Class 5: Denotes non-habitat
4. Enter the **Relative Preference** value for each habitat class as depicted in Figure B- 10.
5. **Ram and Ewe Distance Distribution Files:** The ram and ewe distance distribution files in the Sample Data folder automatically populate these fields. These files were derived from observations of Hells Canyon area radio-collared rams.
6. Once each field in the form has been populated, the **Calculate** button will be enabled. Click **Calculate** to start the calculation of the foray analysis which will take a few minutes to finish.



Once the calculation is complete, the foray probability layers — **<UserSelectedName>\_ForayProbEwe.tif** and **<UserSelectedName>\_ForayProbRam.tif** — will be added to the Foray Analysis output folder and ArcMap session (Figure B- 10).

**NOTE:** The **<UserSelectedName>\_ForayProbEwe.tif** and **<UserSelectedName>\_ForayProbRam.tif** layers will be added above the existing layers in ArcMap. In order to view the CHHR and Allotment polygon layers, both foray probability layers will need to be turned off or moved below the polygon layers in the Table of Contents.

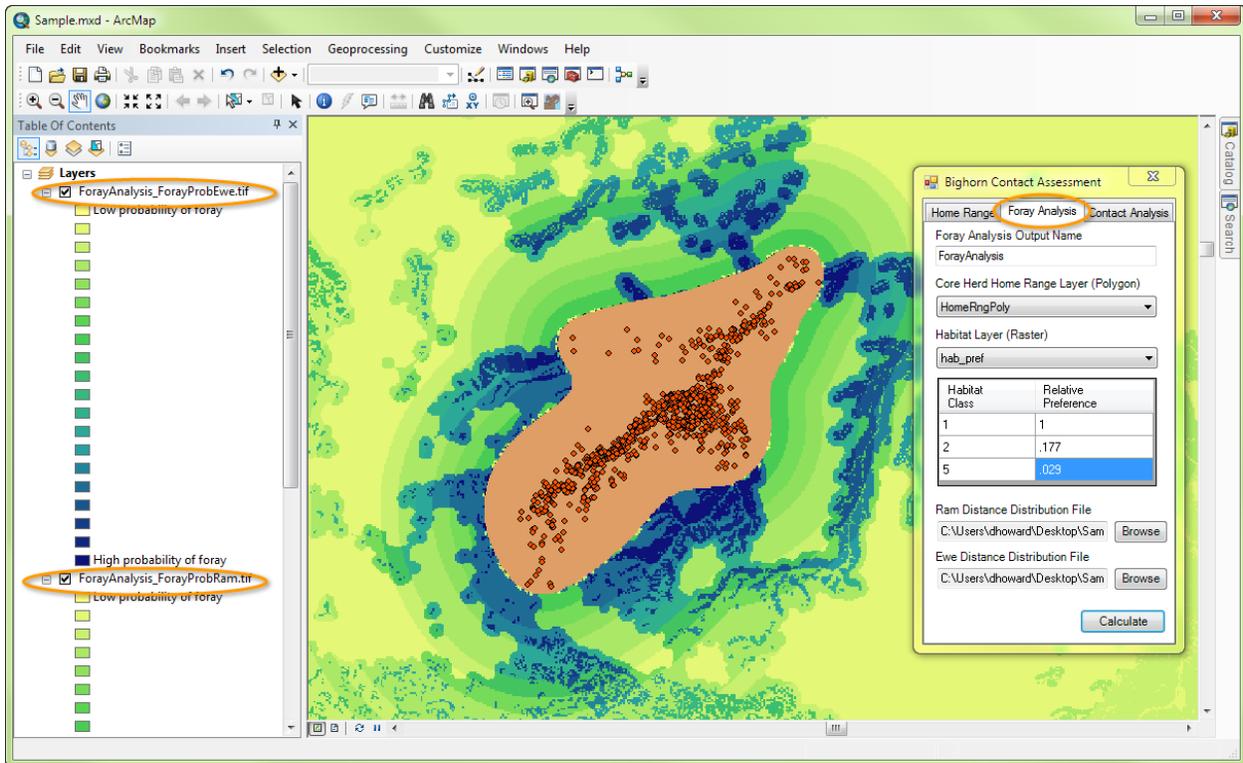


FIGURE B- 10. FORAY PROBABILITY LAYERS



## B.2.3 Contact Analysis

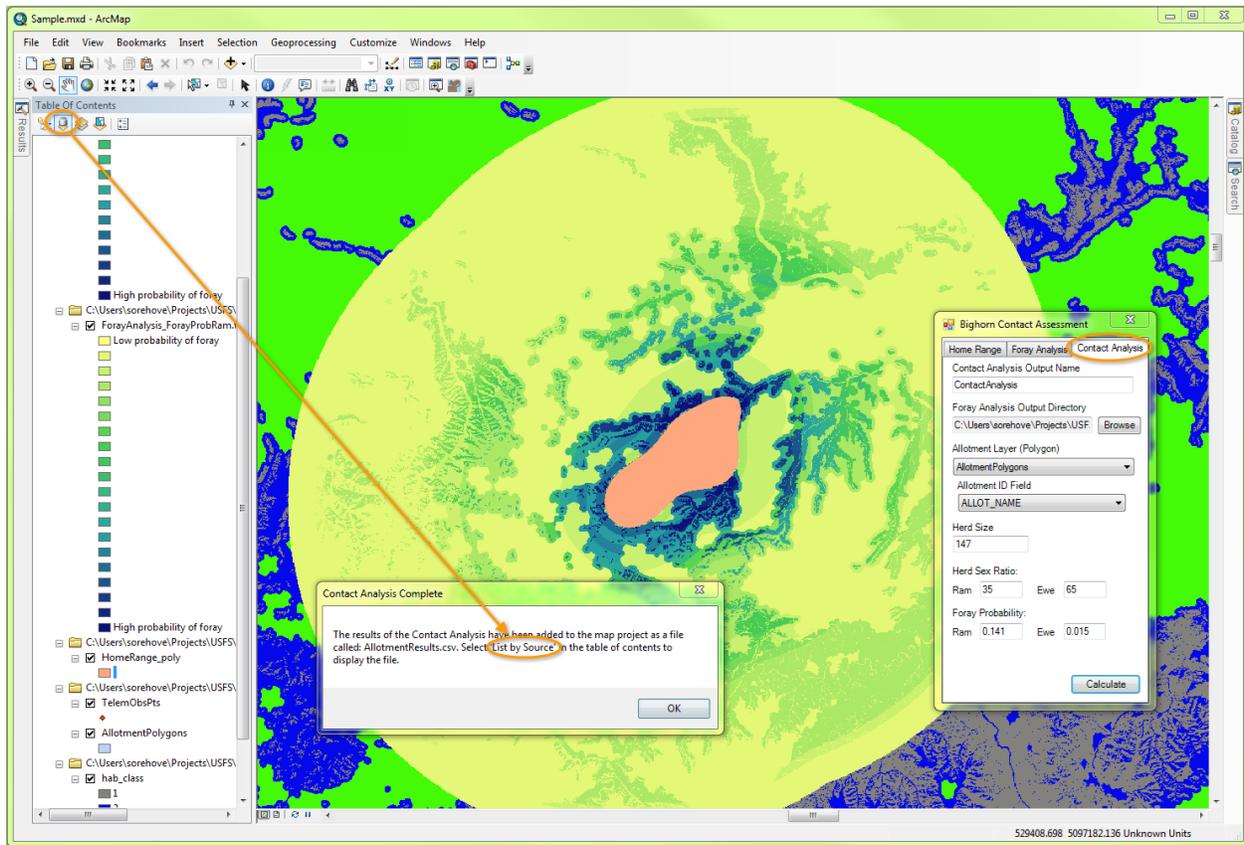
The third component performs the Contact Analysis calculations (Figure B- 13). Enter information in this tab as described below:

FIGURE B- 11. CONTACT ANALYSIS COMPONENT

1. **Contact Analysis Output Name:** Enter a name for the current Contact Analysis, in this case “ContactAnalysis” with no space. The Contact Analysis output folder created by this calculation will be named using the value in this field. The folder will contain an extension to the name as indicated below.
  - **Folder:** **\_output** will be appended (e.g., ContactAnalysis\_output)
2. **Foray Analysis Output Folder:** Browse to the Sample Data working directory (i.e., the directory selected when the Tool was launched [Appendix B.2, Step 2]) and select the **ForayAnalysis\_Output** folder.
3. **Allotment Polygons Layer:** From the drop-down list, select the **Allotment Polygons Layer** loaded in the ArcMap session. This layer contains the boundaries of each allotment to be evaluated for risk of contact.
4. **Allotment ID Field:** Select an allotment ID field; in this case, the ALLOT\_NAME field from the drop-down list. This field will be used to identify the allotment in the results table. The allotment ID must be unique to each allotment analyzed.
5. **Herd Size:** Enter the number of adult animals in the bighorn sheep herd, in this case 147.
6. Leave the rest of the fields with the existing default values.
7. Click **Calculate** to start the Contact Analysis calculation. Calculations will take a few minutes to complete.

Once the contact analysis calculations are complete, the Contact Analysis Complete dialog box will open with instructions on how to access the **AllotmentResults.csv** table by closing the Tool and clicking on the second icon in the Table of Contents to switch the view to **List by Source** (Figure B-12).

1. Click **OK** in the Contact Analysis Complete dialog box, and close the tool.



**FIGURE B-12. CONTACT ANALYSIS COMPLETE DIALOG BOX**



2. Select the **List by Source** icon in the Table of Contents.

The file **AllotmentResults.csv** will be added to the bottom of the ArcMap Table of Contents (Figure B-13).

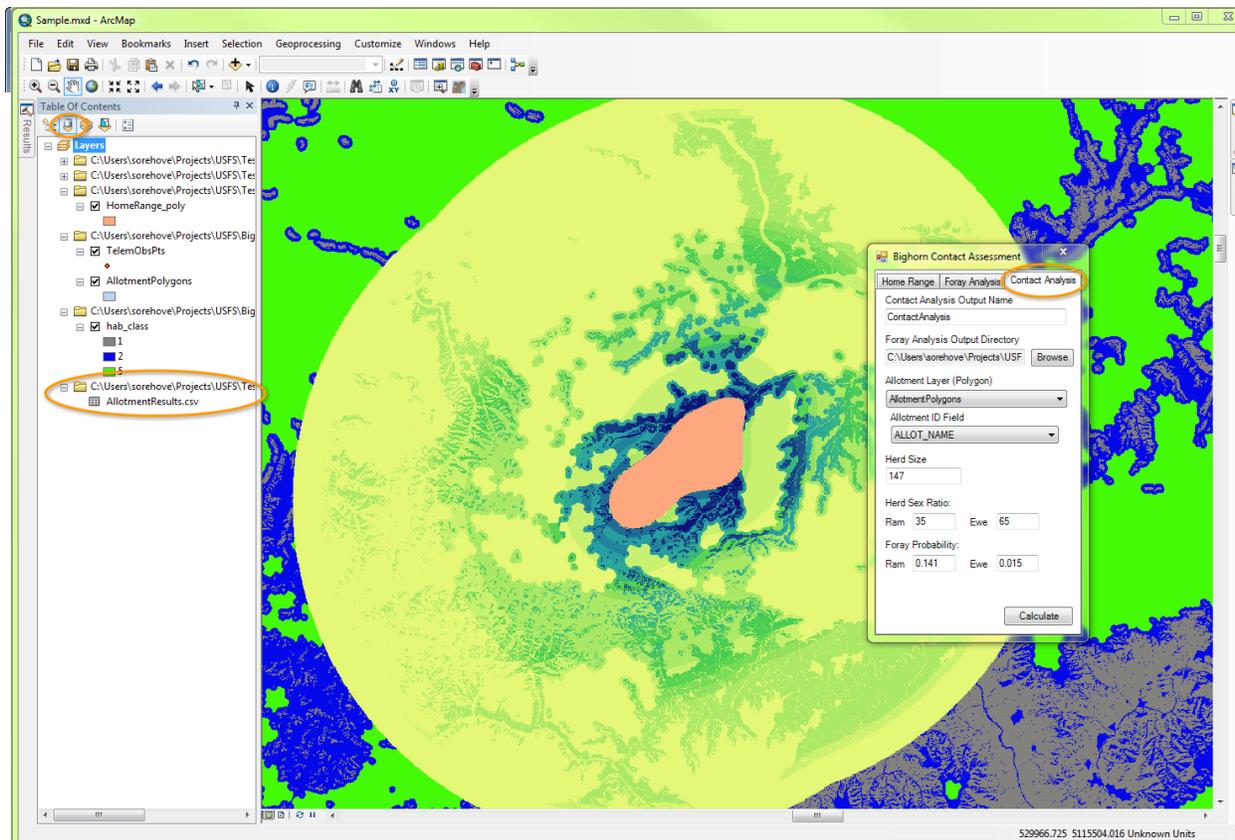


FIGURE B-13. ALLOTMENT RESULTS TABLE AND 'LIST BY SOURCE' ICON (BOTH CIRCLED)



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## Appendix C: Using ArcMap 10.1 SP 1 – The Basics

This section explains how to start ArcMap, describes the three main elements of the ArcMap window, and provides links to other basic usage tips. For newcomers to ArcMap, the following resources (all produced by ESRI) will likely prove helpful:

- A Quick Tour of ArcMap, for an overview of ArcMap
- Getting Started with GIS (for ArcGIS 10.1), a free on-line course
- ArcGIS Help Library for Desktop 10.1
- GIS Dictionary has a complete listing of GIS terms. Some of the GIS terms used in this user guide are included in Appendix G: Glossary
- ArcGIS Help 10.1.

Forest Service personnel may also access geospatial training provided at no cost to the user. For more information, visit the Forest Service Geospatial Training and Awareness website at <http://fsweb.geotraining.fs.fed.us/>. BLM personnel may also access geospatial training provided through DOlearn (<http://www.doi.gov/Doilearn/index.cfm>) or their state office training coordinator.

### C.1 Starting ArcMap

There are **two ways** to open ArcMap:

1. Go to **Start > All Programs > ArcGIS** and click on the ArcMap 10.1 icon.
2. Navigate to and then double-click on a previously saved ArcMap project file (.mxd). Just as an Excel (.xls or .xlsx) file may contain several saved worksheets, an ArcMap project file contains a list of layers and the spatial projection information for those layers as well as many more attributes for doing spatial editing and analysis. Opening it will launch an ArcMap session into which these layers are already loaded.

For additional information on starting ArcMap, refer to Starting ArcMap in ESRI's on-line help documentation.

### C.2 Adding Map Layers

Click the Add Data button  and navigate to the layer of interest. Select the layer and click **Add**.



## C.3 ArcMap Window

The ArcMap window is organized in three major sections (Figure C-1):

1. Table of Contents
2. Data Frame
3. Toolbars

For additional information, refer to the **Views in ArcMap** section in A Quick Tour of ArcMap in ESRI's on-line help documentation.

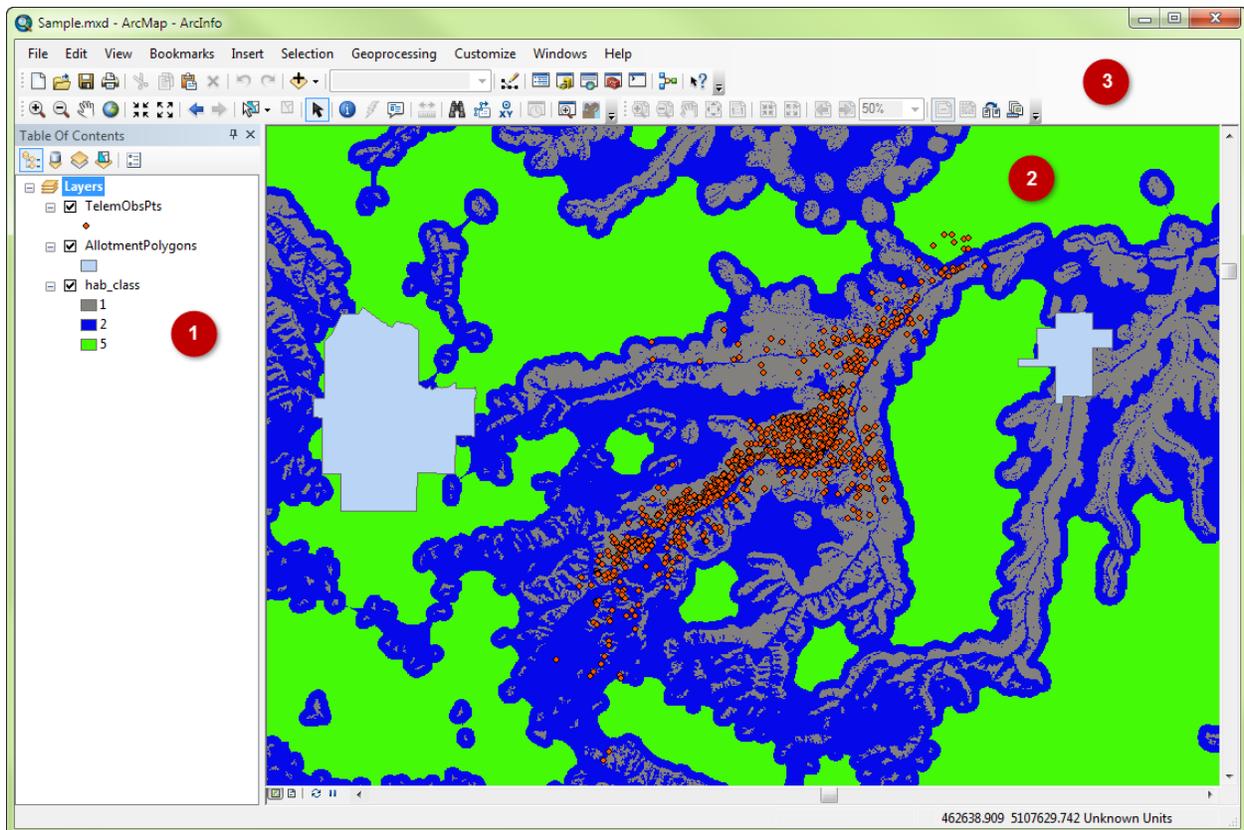


FIGURE C-1. ARCMAP WINDOW



## C.4 Table of Contents

The Table of Contents lists all layers in the current ArcMap session and shows the features represented in each layer. The Table of Contents allows users to manage the order in which the map layers and symbol assignments are displayed and to set the display and other properties of each map layer. Refer to Using the Table of Contents in ESRI's on-line help documentation for additional information.

There are **four options** for viewing the listed layers in the Table of Contents (Figure C-2):

- **List by Drawing Order:** Use this option to edit the contents of the Data Frame (map display area), changing the order of the layers, renaming or removing layers, and creating or managing group layers.
- **List by Source:** Use this option to show the layers organized by the folders or databases in which the data sources referenced by the layers can be found. This view will also list tables that have been added to the ArcMap session.
- **List by Visibility:** Use this option to see a dynamic listing of the layers currently displayed in the active Data Frame. As a user pans and zooms, interacts with the map, selects features, and turns layers on and off, this list of visible layers is continuously updated.
- **List by Selection:** Use this option to group layers automatically by whether or not they are selectable and have selected features. A selectable layer means that features in the layer can be selected using the interactive selection tools, such as those on the Tools toolbar or the Edit tool, when in an edit session.

The List by Drawing Order and List by Source options will be the primary options used for conducting the analysis.

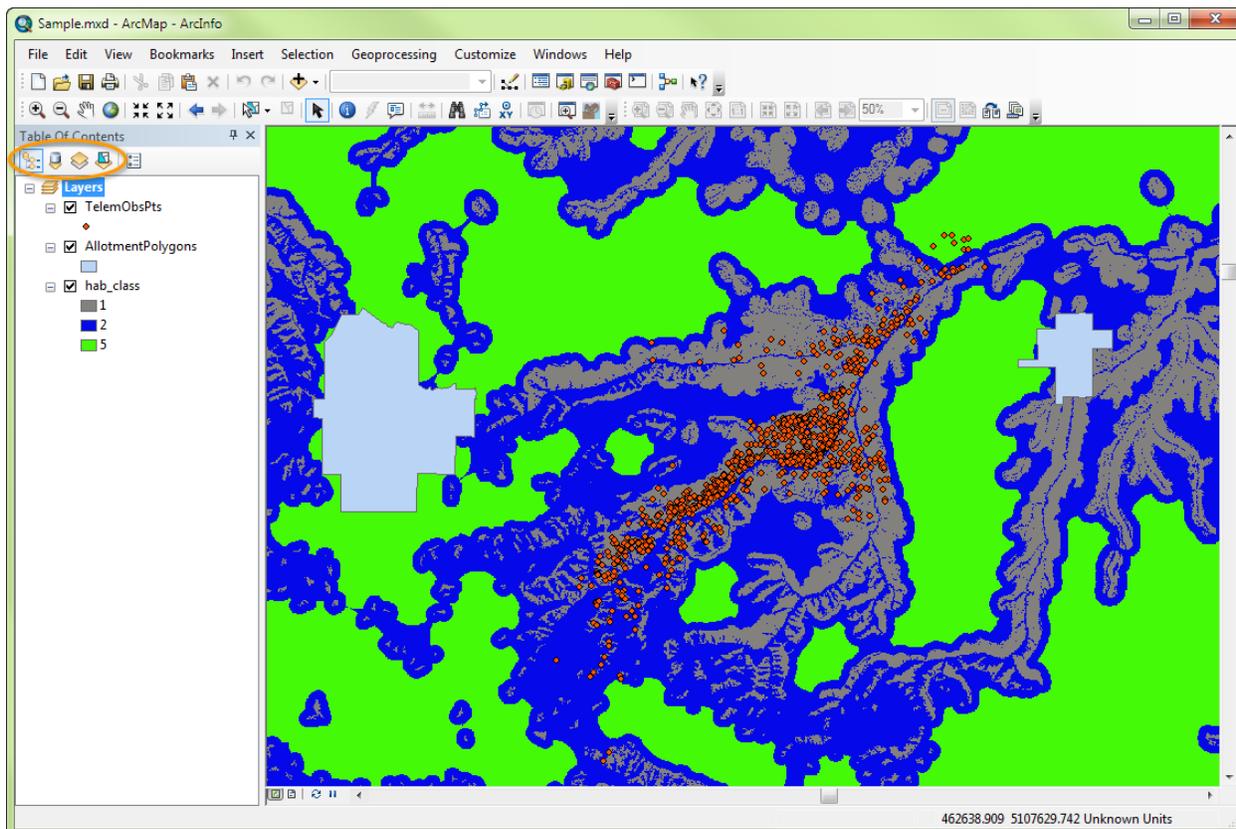


FIGURE C-2. TABLE OF CONTENTS



## C.5 Data Frame

Map layers are geographically displayed in the Data Frame. Refer to *Displaying Maps in Data View and Layout View* in ESRI's on-line help documentation for additional information on the Data Frame of the ArcMap window.

There are **two options** for viewing a map in the ArcMap Data Frame:

- Data View
- Layout View

### C.5.1 Data View

Data View displays the map layers in the Data Frame in the order they appear in the Table of Contents (Figure C-3). It provides a geographic window for exploring, displaying, and querying the data contained in a map. This view displays data in real-world coordinates and measurements.

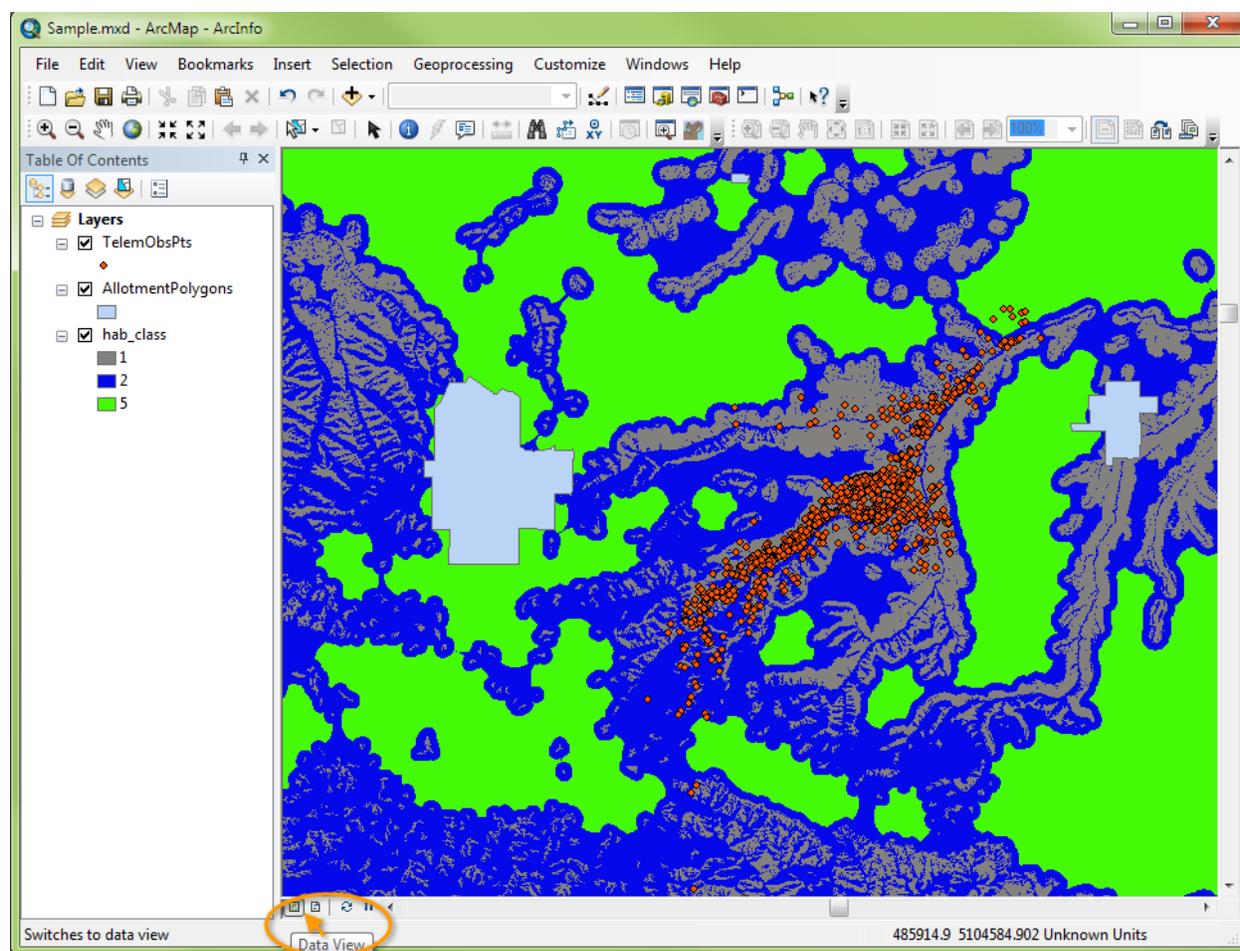


FIGURE C-3. DATA VIEW



### C.5.2 Layout View

Layout View shows a printable page layout of the map (Figure C-4). It allows users to add legends, change the page orientation, and to print or export a completed map.

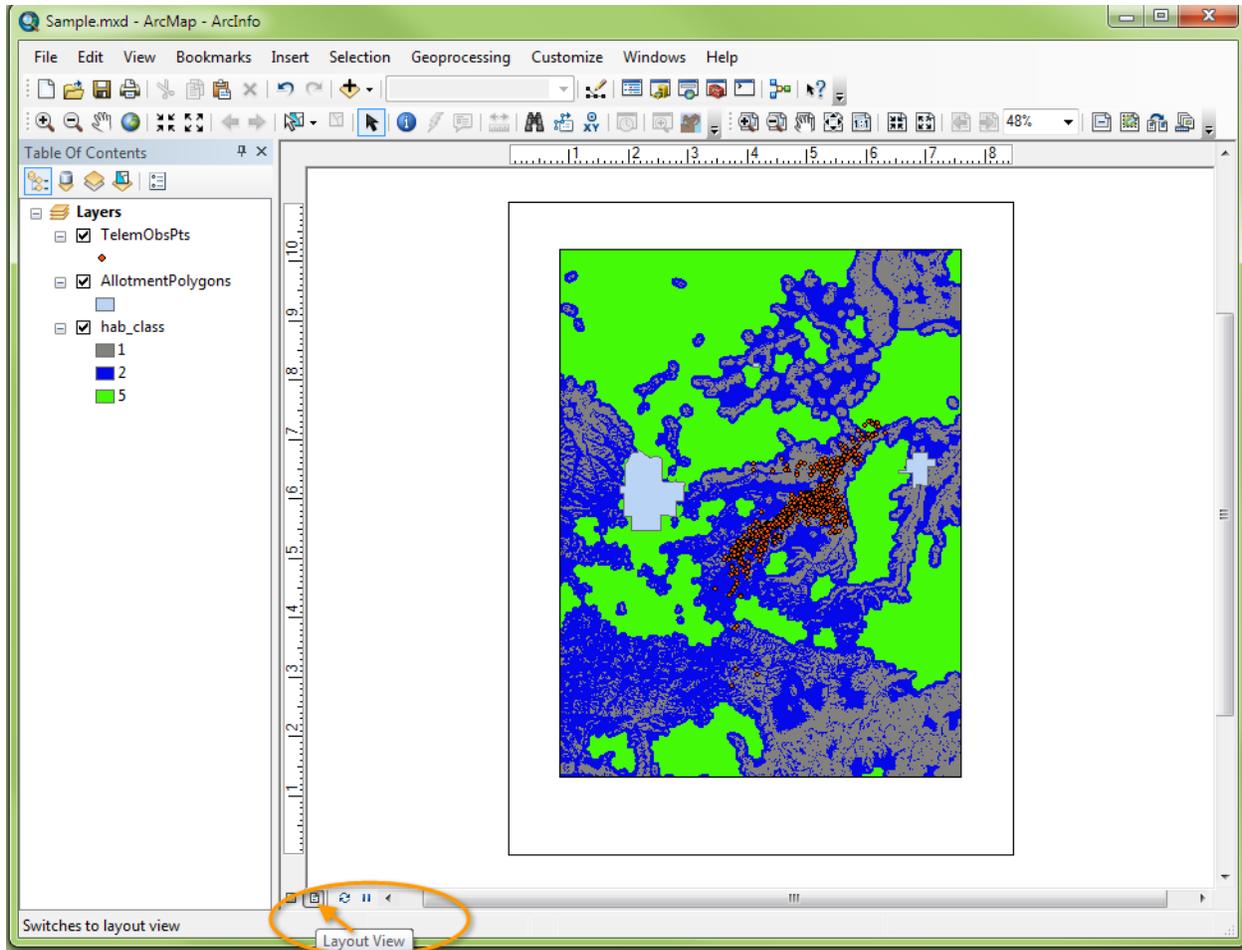


FIGURE C-4. LAYOUT VIEW



## C.6 Toolbars

Two toolbars are used to navigate within a map:

- Tools toolbar
- Layout toolbar

Refer to *Displaying Map in Data View and Layout View* in ESRI's on-line help documentation for a list of all tools and their functionality.

### C.6.1 Tools Toolbar

The **Tools** toolbar (Figure C-5) is used to move around the map while viewing it in the **Data View**. This toolbar is active while viewing the map in both Layout and Data Views. For more information on a tool's functionality, hover over its icon.

**NOTE:** In the example below, the *Bighorn Tool* icon was added to the Tools toolbar, but the icon can be added to any other toolbar.



FIGURE C-5. TOOLS TOOLBAR

### C.6.2 Layout Toolbar

The **Layout** toolbar (Figure C-6) is used in **Layout View** to format a map so that it can be used in a report or slide presentation. Maps can be exported as PDFs or in one of several other image formats (i.e., jpg, png, eps, bmp). Hover over a tool for more information on its functionality.



FIGURE C-6. LAYOUT TOOLBAR

## C.7 Quick Ways to Navigate a Map

Refer to *Quick Ways to Navigate Data Frames and Layouts* in ESRI's on-line help documentation for additional information on how to quickly navigate maps and layout pages.

## C.8 Print a Map

Print a map by using **File > Print** in the main menu. Maps can be printed from either the Data View or the Layout View. Refer to *Printing a Map in ArcMap* in ESRI's on-line help documentation for additional information on how to print a map.

## C.9 Saving a Map

Save a map to an ArcMap project file (.mxd) by using **File > Save** or **File > Save As** in the main menu. Refer to *Saving a Map* in ESRI's on-line help documentation for additional information on how to save a map.



## Appendix D: Distance Distribution File Example

This appendix displays one of two distance distribution files supplied as defaults for the Tool. Column 1 contains distances in kilometers. Column 2 gives the proportion of bighorn rams on summer-season forays who reach rings at each distance from their CHHR. Both distributions were derived from a 12-year record of telemetry observations from 444 radio-collared animals in 12 Hells Canyon area bighorn herds.

Distance	ForayProb
1	1
2	0.9511509
3	0.9019131
4	0.8519672
5	0.8011736
6	0.7496466
7	0.6977936
8	0.6463024
9	0.5960646
10	0.5480446
11	0.5031165
12	0.4619105
13	0.4247026
14	0.3913743
15	0.3614454
16	0.3341694
17	0.3086657
18	0.2840673
19	0.2596598
20	0.2349892
21	0.2099244
22	0.184658
23	0.159647
24	0.1355072
25	0.1128867
26	0.092346
27	0.074272
28	0.0588345
29	0.0459911
30	0.0355299
31	0.0271359
32	0.0204613
33	0.0151823
34	0.0110316
35	0.0078033
36	0.0053408
37	0.0035164
38	0.0022158
39	0.0013303
40	0.0007579
41	0.0004081
42	0.0002066
43	9.73E-05
44	4.17E-05
45	1.50E-05
46	3.07E-06



## Appendix E: Configuration File

The configuration file is stored in the .esriAddIn archive and can be edited using a program called Winrar, which is available for download from <http://www.win-rar.com>. Winrar will open the archive file, allowing its values to be edited and then recompressed into the .esriAddIn archive.

```
<?xml version="1.0" encoding="utf-8"?>
<configuration>
<appSettings>
<addkey="MaxKilometerRings" value="35" />
<addkey="DefaultPercentHRef" value="100" />
<addkey="DefaultMaxIsoplethQuantile" value="95" />
<addkey="DefaultRamDistanceDistributionFileName" value="" />
<addkey="DefaultEweDistanceDistributionFileName" value="" />
<addkey="DefaultProbabilityOfOutbreak" value="0.5"/>
<addkey="DefaultRamRatio" value="35"/>
<addkey="DefaultEweRatio" value="65"/>
<addkey="DefaultRamForayProbability" value="0.14" />
<addkey="DefaultEweForayProbability" value="0.02" />
<addkey="AddIntermediateFilesToMap" value="false" />
<addkey="AllotmentRasterCellSizeMeters" value="100" />
<addkey="HomeRangeRasterCellSizeMeters" value="100" />
<addkey="HomeRangeRasterBufferSizeMeters" value="20000" />
<addkey="HomeRangeInputMaxExtentAreaKilometers" value="160000" />
<addkey="MinimumNumberOfPointsForAnimal" value="1" />
</appSettings>
</configuration>
```



## Appendix F: Parameter Log File Examples

Each time one of the three Bighorn Sheep Risk of Contact Tool (Tool) components is run, the parameters selected by the user are written to a log file. The parameters log files constitute an essential record of the data and assumptions that went into an analysis and should be saved alongside any results of the analysis.

Each of the log files is written to the relevant subfolder (Section 4.8) of the working directory selected when the Tool was first opened (Section 4.2). The log files are text (.txt) files named as indicated below, including a unique value generated from the date and time the log file was created. The unique value is included in the log file name to prevent duplicate names from being generated. To find the latest log file, look at the date and time the file was created.

- **CHHR\_Parameters\_<unique-integer-id>**: Core Herd Range **Parameter Calculations**
- **FA\_Parameters\_<unique-integer-id>**: Foray Analysis **Parameter Calculations**
- **CA\_Parameters\_<unique-integer-id>**: Contact Analysis **Parameter Calculations**

### F.1 Core Herd Home Range Parameter Calculations Log File

Bighorn Version 2.0

Start Core Herd Home Range Calculations at 1/4/2013 9:14:19 AM

Output path: C:\Users\dhoward\Desktop\Bighorn Analysis\HomeRange\_Output

Telemetry/Observation Point Layer Name: TelemObsPts

Bandwidth Estimator: Href

Home Range Raster Buffer Size Meters: 20000

Home Range Raster Cell Size Meters: 100

Isopleth Quantile: 95

Animal ID Field: Animal\_ID

Percent HRef: 100

Min Points Per Animal: 21

Output File Name: HomeRange

Treat All Animals as One: False

Output file: C:\Users\dhoward\Desktop\Bighorn Analysis\HomeRange\_Output\HomeRange\_poly.shp

End Core Herd Home Range Calculations at 1/4/2013 9:14:55 AM

### F.2 Foray Analysis Parameter Calculations Log File

Bighorn Version 2.0

Start Foray Analysis Calculations at 1/4/2013 9:19:06 AM

Output path: C:\Users\dhoward\Desktop\Bighorn Analysis\ForayAnalysis\_Output

Home Range Polygon Layer Name: HomeRange\_poly

One Kilometer Buffer Ring Count: 35

Habitat Raster Layer Name: hab\_class

The habitat raster provided contains integer values and therefore the user must provide a preference value for each habitat class.

Habitat Class:1 Habitat Preference:1



Habitat Class:2 Habitat Preference:0.177

Habitat Class:5 Habitat Preference:0.029

Ram Distance Distribution File: C:\Users\dhoward\Desktop\USFS\Sample Data\Ram summer foray probabilities (1 km rings).csv

Ewe Distance Distribution File: C:\Users\dhoward\Desktop\USFS\Sample Data\Ewe summer foray probabilities (1 km rings).csv

End Foray Analysis Calculations at 1/4/2013 9:33:05 AM

### **F.3 Contact Analysis Parameter Calculations Log File**

Bighorn Version 2.0

Start Contact Analysis Calculations at 1/4/2013 9:36:02 AM

Output path: C:\Users\dhoward\Desktop\Bighorn Analysis\ContactAnalysis\_Output

Foray Analysis Output Folder: C:\Users\dhoward\Desktop\Bighorn Analysis\ForayAnalysis\_Output

Allotment Polygon Layer Name: AllotmentPolygons

Allotment ID Field: ALLOT\_NAME

Herd Size: 147

Sex Ratio Rams: 35

Sex Ratio Ewes: 65

Foray Probability Rams: 0.141

Foray Probability Ewes: 0.015

One Kilometer Buffer Ring Count: 35

End Contact Analysis Calculations at 1/4/2013 9:48:42 AM



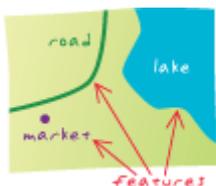
## Appendix G: Glossary

Below are definitions for terms used in this document. For a complete listing of GIS terms, refer to the on-line ESRI GIS Dictionary.

**dataset** Any collection of related data, usually grouped or stored together.

**extension** In ArcGIS, an optional software module that adds specialized tools and functionality to ArcGIS Desktop. ArcGIS Network Analyst, ArcGIS StreetMap, and ArcGIS Business Analyst are examples of ArcGIS extensions.

**feature** A representation of a real-world object on a map.



**floating points** Numbers that contain floating decimal points. For example, the numbers 5.5, 0.001, and -2,345.6789 are floating point numbers.

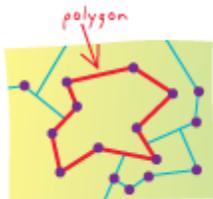
**integer** A whole number (not a fraction) that can be positive, negative, or zero.

**isopleth** An isoline drawn according to known values that can only be recorded for areas not points. Examples include population per square mile or the ratio of residential land to total land for an area.



**.mxd** In ArcMap, the file that contains one map; its layout; and its associated layers, tables, charts, and reports. Map documents can be printed or embedded in other documents. Map document files have a .mxd extension.

**polygon** On a map, a closed shape defined by a connected sequence of x,y coordinate pairs, where the first and last coordinate pair are the same and all other pairs are unique.

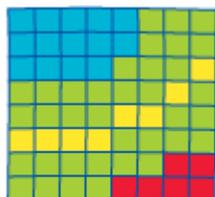


**quantile** In a data distribution, a value representing a class break where classes contain approximately equal numbers of observations. The p-th quantile, where p is between 0 and 1, is that value that has a proportion p of the data below the value. For theoretical distributions, the p-th quantile is the value that has p probability below the value.

**raster** A spatial data model that defines space as an array of equally sized cells arranged in rows and columns and composed of single or multiple bands. Each cell contains an attribute value and location coordinates. Unlike a vector structure, which stores coordinates explicitly, raster coordinates are contained in



the ordering of the matrix. Groups of cells that share the same value represent the same type of geographic feature.



**shapefile**

A vector data storage format for storing the location, shape, and attributes of geographic features. A shapefile is stored in a set of related files and contains one feature class.

**telemetry**

A technology that allows data measurements to be made at a distance.

**vector**

A coordinate-based data model that represents geographic features as points, lines, and polygons. Each point feature is represented as a single coordinate pair, while line and polygon features are represented as ordered lists of vertices. Attributes are associated with each vector feature, as opposed to a raster data model, which associates attributes with grid cells.





## Appendix H: Frequently Asked Question (FAQs)

### H.1 Model structure

**Q: Does the Tool model attraction between bighorn sheep (BHS) and domestic sheep (DS)?**

No. The Tool only models the probability that foraging bighorn sheep will reach allotments. It does not model the possible role of DS in attracting BHS to occupied allotments, nor does it model the interaction between BHS and DS occupying those allotments. Also, the probability of contact with an allotment is based solely on the habitat suitability and distance of the allotment from the Core Herd Home Range (CHHR). The presence or absence of domestic sheep in an allotment plays no role (in the model) in the probability that bighorn sheep will reach that allotment. This does not mean that managers shouldn't consider the known attraction of the species for one another.

**Q: How does the Tool take into account the amount of time BHS and DS are within contact of each other?**

As explained in the previous answer, the Tool models the probability that foraging bighorn sheep will reach allotments. It does not directly model their interactions with domestic sheep occupying those allotments, nor the amount of time they spend in them.

However, if it is known that an allotment is only occupied by domestic sheep during a limited but definable period, the analysis should specify that period and the model inputs should be adjusted accordingly. The May-October "summer season" model reflected the period when domestic sheep were on NFS lands, and the 14% ram foray probability was based on that time window.

**Q: What about the possibility of disease transmission from straying domestic sheep?**

Stray domestic sheep have been implicated in several die-off's, and in many settings may pose a risk of transmission as large as or greater than do foraging bighorn sheep. Although the Tool does not model this factor, managers should also consider the risk of transmission due to straying domestic sheep.

**Q: Did you investigate cost-surface models?**

Cost-surface models of animal movement attempt to represent a landscape's permeability (or resistance) to animal movements. Each pixel of the landscape is assigned a resistance value: preferred habitat types have low resistance values, while high values are given to areas that are not preferred or are actively avoided. Locations that can only be reached by long journeys through non-habitat will have the highest path costs, and the lowest probabilities of being reached.

During the early model-development phase, the possibility of using cost-surface models was explored. Although a well-parameterized cost-surface model might be more realistic, the available data were not sufficient to adequately parameterize such a model. Even among the 1300+ animal years of data in the Hell's Canyon telemetry data set, just 44 ram forays were observed, and in those, observations were typically at two week intervals, so the actual paths travelled by foraging animals were simply unknown. Given that sheep on forays do seem to exhibit different behavior and habitat preferences than they do while inside the home range, there were simply not enough data to support a cost-surface analysis.

### H.2 Data inputs and default parameter values

**Q: What is the cell size of the draft habitat class raster layer developed by the Forest Service?**



The habitat layers produced by the Forest Service for each of the western states are composed of 30 meter by 30 meter grid cells.

**Q: How many animals (and how many points per animal) are needed to estimate a CHHR?**

A cutoff of 21 points per animal was used in the Payette NF analysis, but there is no hard rule. Like the rest of the model, the CHHR delineation should not be carried out in a vacuum, and the reasonableness of its estimated boundaries should be examined by an informed wildlife biologist.

Also, the number of points in a telemetry dataset is only one measure of its quality. Just as important is how representative of whole-year (or whole-season) use patterns those points are. In general, it's better to have a smaller number of records well distributed through the year than it is to have many "non-independent" points collected over a short time interval.

**Q: Where do the default habitat preference values come from? Were they arbitrary ("just SWAGs" in the words of one questioner)?**

The values (shown in the Tool training PowerPoint slides 18, 27 and 28, and User Guide Figures 18 and B-10) were derived from the Hells Canyon Bighorn Sheep Restoration Committee telemetry data set (approximately 54,000 data points). Preference values were based on a use/availability model which compares the proportion of telemetry points falling within a given habitat type to the proportion of the landscape composed of that habitat type (See Payette FSEIS Appendix L, p. L-32).

For example, while outside of the CHHR, Hells Canyon bighorn sheep exhibited relative habitat preferences of 1.00 for habitat and 0.177 for connectivity habitat. This implies that a given acre of habitat is nearly 6 times more likely to be visited or occupied by a bighorn sheep than the same area of connectivity habitat. Likewise, an allotment completely composed of habitat will be estimated to have nearly 6 times the contact rate as it would were it fully composed of connectivity habitat.

**Q: How should habitat preferences be adjusted based on the amount of habitat and non-habitat? Do you recommend using the habitat preferences in the User Guide?**

Use/availability habitat preferences are expressed on a per area basis, so they may be applied without modification in landscapes with differing amounts of habitat and non-habitat.

The habitat preferences in the User Guide were based on actual observations of habitat use by Hells Canyon-area animals. In areas where enough telemetry data exist, it is possible (and maybe advisable) to calculate observed preferences of local bighorn sheep.

The Tool is also set up to use regionally appropriate habitat preference models wherever they are available. The Tool's habitat layer input field will accept any integer or real-valued \*.GRD, \*.ASCII, or \*.TIFF raster file. (See Section 3.2.2 of the User Guide for more details.)

**Q: Is the risk of contact sensitive to herd size? Do users need to have good quality information about herd size and sex ratios?**

The estimated risk of contact is sensitive to herd size. In fact, the relationship between the two is linear, meaning that, e.g., doubling the number of animals in a herd will double the herd's expected annual contact rates with surrounding allotments.

Because rams are much more likely than ewes to leave the CHHR (i.e., to engage in foray movements), and tend to travel farther from the CHHR when they do, a herd's sex ratio also plays an important role in determining estimated contact rates. For a good first approximation, a herd's rate of contact is determined by the number of rams it contains.



In the prior analyses, estimates of herd size and sex ratio were primarily based on annual counts conducted by the three State wildlife agencies responsible for the area's bighorn sheep. In some cases, herd-specific counts were available, while in others, counts were at the level of hunting units. Observed ram:ewe ratios clustered tightly around 35:65 (see page L-41 of the Technical Appendix), forming the empirical basis for the Tool's default value. Sex ratio data for other areas (e.g., state census data) can be used if available.

**Q: Can all BHS on a forest be analyzed at once, or does each BHS herd need to be analyzed separately? Is there a minimum distance between distinct herds?**

The Tool is designed to calculate risk of contact on a herd-by-herd basis. The CHHR should delineate the area typically used by members of a herd, from the borders of which any animal in the herd might make a foray movement. Forests or Districts encompassing several distinct herds should thus run the Tool several times, once for each identifiable herd. Where delineating the boundaries between herds is difficult or impossible, we advise consulting with both state and federal wildlife biologists and the bighorn sheep working group, who have some experience with this issue.

### H.3 Scope/range of model's applicability

**Q: What about seasonality of the model? (e.g., what to do in a desert setting where considerable variation in movement patterns between breeding and non-breeding seasons is known to exist?)**

Knowledge of local bighorn sheep's behavior and/or domestic sheep grazing patterns will lead to the choice of different seasons of analysis. The recommended workflow is to run the Tool once for each season of interest and to then aggregate the estimated rates of contact during each season. (Care should be taken to adjust foray probabilities to match the length of each season: all else being equal, foray probabilities will be higher during a six-month period than during a one-month period.)

**Q: Can the Tool be used to model interactions between bighorn and cattle (or any animals other than domestic sheep)? Are there any known cases of disease transmission from cattle to sheep?**

Yes and yes. The Tool certainly could be applied to contact with other species. The Tool models probability of forays reaching different parts of a landscape, irrespective of what activities are occurring there. It could just as well be used to model probability of contact with cattle-occupied allotments (or roads, or areas of ORV use) as it can be used to model probability of contact with domestic-sheep occupied allotments. The management implications of these "other types" of contacts would clearly be very different.

Although there are a few documented cases of disease transmission from cattle to bighorn sheep, contact with cattle is normally not a concern. Bighorn sheep and domestic sheep are attracted to one another and have behavioral and physiological similarities, unlike the situation with cattle. The few known instances involved extreme circumstances such as drought or hard winters that brought the two in close proximity. These unusual events can be prevented by not watering or salting near bighorn sheep.

**Q: Could the model be used to evaluate relative suitability of different potential reintroduction sites in a landscape containing numerous private domestic sheep flocks?**

Yes, that would be an excellent setting in which to use the model.

**Q: What about impacts of domestic sheep on private/State/other non-Federal lands?**



The Tool can be used to calculate the risk of contact with any polygon defining an area within which domestic sheep are found. The risk of contact with private sheep and goat farm flocks, as well as with other adjacent federal or State land located near CHHRs should be considered as a part of cumulative effects analysis.

## H.4 Management Implications

**Q: *What is the suggested size of a single analysis area? Allotment? Ranger District? Field Office? District Office? State? Region?***

This may vary by agency regulatory requirements and the purpose of the individual analysis. The model could be applied to any of these. For Forest Planning (i.e. viability-related issues at Forest Plan scale) the National Forest might be an appropriate analysis area. For analyses of possible allotment management plan revisions, the allotment scale might be more appropriate. While carrying out allotment-level analyses, it is important to keep in mind that what matters, biologically-speaking to a bighorn sheep herd is its overall, landscape-level, rate of contact with domestic sheep. That landscape-wide rate, not its rate of contact with a single allotment, is what will determine the frequency of interspecies disease transmission and the herd's long-term prospects for viability.

The National Forest Management Act (NFMA) and the Forest Service's interpretive regulations require that habitats be managed to support viable populations of species at a Forest scale. Hence, the analysis area incorporated bighorn sheep populations potentially affected by management at the Forest scale.

For BLM administered lands, The Federal Land Policy and Management Act of 1976 (FLPMA) states "the Secretary (of Interior) shall by regulation or otherwise, take action necessary to prevent unnecessary or undue degradation of the (public) lands." FLPMA also requires the BLM to manage its lands for multiple use and sustained yield. According to the Act, sustained yield means "the achievement and maintenance in perpetuity of a high-level annual or regular periodic output of the various renewable resources of the public lands consistent with multiple use" (43 USC § 1701 Sec. 103(h)).

For both the Forest Service and the BLM, the National Environmental Policy Act (NEPA) also prohibits the agencies from making an irreversible or irretrievable commitment of resources until those recognized risks are analyzed. See 42 U.S.C. § 4332.

**Q: *How should users deal with allotments that intersect the CHHR?***

The Risk of Contact model focuses on the risk of contact due to relatively infrequent forays by bighorn sheep forays outside of their CHHR. Where an allotment directly overlaps the CHHR, it may be contacted by any adult or juvenile bighorn sheep using that part of the CHHR, not just those engaged in infrequent and relatively brief forays. Although the model doesn't quantify the rate of interspecies contact expected with allotments intersecting the CHHR, the rate is likely to be quite high. Barring strong evidence to the contrary, users should assume multiple contacts per year with allotments that overlap the CHHR.

Users can use the CHHR to clip the allotment so that only parts of it lying outside of the CHHR are considered. A knowledgeable wildlife biologist should be consulted before this type of manipulation is carried out.

**Q: *What is an acceptable level (probability or rate) of contact? Do you have any suggestions about how to translate the output of the Tool into management recommendations? What are recommended courses of action?***

Obviously, the greater the rate of contact, the more likely that contact will result in a disease transmission event, and potentially a disease outbreak in a bighorn sheep population. In the Payette NF analysis, the rate of contact with allotments was used as one element in a complex



disease model which estimated extirpation probabilities for various herds.

The FSEIS also estimated disease return intervals (in years) under risk scenarios that varied in the likelihood of a disease outbreak given contact with an allotment (see Payette EIS Table W-29). Estimated disease return intervals help managers assess the possible impacts of outbreaks on bighorn sheep populations. Chapter 3 of the Payette EIS discusses the ramifications of various disease return intervals. We recommend that model users refer to the Payette EIS for examples of how this and other metrics may assist decision makers in interpreting the model's results.

The development team is considering next steps for how the probability and rates of contacts from the Risk of Contact Model can be used for near-term management recommendations. One step is to develop an output table that converts contact rates to estimated disease outbreak intervals given various risk assumptions that a contact with an allotment will result in a disease outbreak event. This information, along with other metrics used for the model, can be used to inform decision-makers on risks associated with different alternative management actions.

**Q: Will using a Payette-style analysis lead to Payette-type conclusions?**

The model is an adaptation of the Payette-style analysis that will be executed using site-specific information to derive site-specific results. It is one tool, in addition to other biological, social and economic factors, used by line officers in making an informed, science-based decision.

**Q: Is the model “conservative” with respect to estimating the risk of contact?**

The model is intended to be neither conservative, nor liberal, in its risk of contact estimate. It provides a realistic framework for characterizing likely bighorn sheep movements across landscapes given what we understand about their behavior and habitat suitability. Obviously, the more data one has on populations and movement patterns and distances, the more accurate the model will be. The Hell's Canyon telemetry data points fit the habitat model with 92% of the telemetry points within modeled suitable habitat. The telemetry data points supplied by the State of Colorado had similar results after modification of canopy closure levels. The probabilities that sheep will reach each point on the landscape are mathematically derived using observed foray frequencies and distances and habitat preferences. Hence, the risk of contact model is likely not an overreach. The additional factor of known attraction between the two species is not modeled so from that perspective, it might be considered conservative.

Estimating the probability that contact with an allotment will result in a disease outbreak is a different question. Obviously, the more contacts, the more likely a disease transmission and subsequent outbreak will occur. One can evaluate the rates of contact, relative to the risks of a contact resulting in a disease outbreak. One approach to quantifying disease transmission risk is addressed in the response to the previous question “What is an acceptable level (probability or rate) of contact?”

**Q: How should managers account for risk of contact with domestic sheep occupying areas that are not administered by their agency? What does the model imply about the likely persistence/viability of disjunct “island” populations surrounded by domestic sheep that are not grazing on NF lands, but are within easy foray distance of the bighorn sheep?**

Federal and state agencies need to consider the contributions of all land ownerships to bighorn sheep recovery. The private and state lands with domestic sheep are a disease transmission concern to be addressed with state, federal and NGO partners to minimize interspecies contact.

Agencies are responsible for management on their own lands. The courts have usually ruled that regardless of threats to species on other ownerships, agencies still must demonstrate management that is consistent with their regulations (e.g. viability). The management of salmon/steelhead populations on NFS lands is a good example: even though the vast majority of



impacts occur off NFS lands, there is still a clear responsibility that agencies must provide conservation measures for habitats on public lands.

**Q: What do the rates in the contact model’s output table represent, and how can they be described in narrative form?**

This frequently asked question does not ask for direction on the management actions that should be taken based on the results in the output table. Instead, it seeks clarification regarding the precise meaning of the values in the table.

The Payette NF’s FSEIS’ discussion of alternatives (especially the section beginning on its page 3-55) provides one example of how the model’s contact rate and probability estimates may be described in narrative form. Another example is included below, in the text following Table H-1.

Table H-1 displays estimated contact rates from a single bighorn sheep herd (“Herd S15”) to two nearby domestic sheep allotments. Herd S15 consists of 200 adult animals — 70 rams and 130 ewes. Its columns have been renamed and reformatted, as they might be in a report, but the values in them directly correspond to those in the **AllotmentResults.csv** output by the Tool’s Contact component (see, e.g., Figure 30).

The columns “Single ram” and “Single ewe” (corresponding to columns “**Single\_Ram**” and “**Single\_Ewe**” in **AllotmentResults.csv**) display the annual/seasonal probability that a given ram or ewe **will leave the CHHR and then go on to contact an allotment**. These per-individual contact rates for ewes are much lower than those for rams, largely because ewes are much less likely to make any foray movement in a year than are rams. (The default annual/seasonal foray probabilities are 14.1% for rams, and 1.5% for ewes.)

The columns “All rams” and “All ewes” (corresponding to “**All\_Rams**” and “**All\_ewes**” in **AllotmentResults.csv**) display the expected annual/seasonal number of rams and ewes that will foray outside of herd S15’s home range and contact each of the allotments. For both rams and ewes, the total contact rate is equal to the per-individual contact probability multiplied by the number of animals. Looking just at the Fisher Mountain Pasture, for example, the number of expected contacts for all rams is 0.009308 contacts/ram/yr \* 70 rams = 0.651553 contacts/yr. Similarly, for all ewes, the number is expected contacts 0.000472 contacts/ewe/yr \* 130 ewes = 0.06139 contacts/yr.

The final column (corresponding to the column “**All\_Herd**” in **AllotmentResults.csv**) gives the total herd contact rate, the sum of the rates for all rams and all ewes. For the Fisher Mountain allotment, the total rate is 0.651553 + 0.06139 = 0.712944 contacts/yr.

**TABLE H-1: ESTIMATED ANNUAL CONTACT RATES OF HERD S15 ANIMALS (70 RAMS AND 130 EWES) WITH IVY CREEK AND FISHER MOUNTAIN PASTURES.**

	Estimated annual contact rates via foray.				
Pasture	Single ram	Single ewe	All rams	All ewes	All animals (Herd)
Ivy Creek	0.002446	0.000138	0.171236	0.017934	0.189169
Fisher Mtn	0.009308	0.000472	0.651553	0.06139	0.712944

The following bullets give one example of how the rates in Table H-1 might be described in narrative form.

- **Single Ram Contact Rate:** Annual/Seasonal probability that a typical ram will leave its Core Herd Home Range (CHHR) and contact this pasture.



*Fisher Mtn. Example:* There is an estimated 0.93% probability that any given ram will leave the S15 herd's CHHR and contact the Fisher Mtn. pasture in any given year/season.

- **Single Ewe Contact Rate:** Annual/Seasonal probability that a typical ewe will leave its Core Herd Home Range (CHHR) and contact this pasture.

*Fisher Mtn. Example:* There is a 0.047% probability that any given ewe will leave its CHHR and contact this pasture each year/season.

- **All Rams Contact Rate:** Expected number of rams contacting the pasture each year/season.

*Fisher Mtn. Example:* Based on the number of rams (70) and their individual contact probabilities (0.93%), it is estimated that Herd S15 rams will foray from the CHHR and make contact with this pasture at a rate of 0.65 times per season ( $= 70 * 0.93\%$ ). In other words, one ram contact with the Fisher Mtn. pasture is expected every 1.5 ( $= 1 / 0.65$ ) years/seasons.

- **All Ewes Contact Rate:** Expected number of ewes contacting pasture each year/season.

*Fisher Mtn. Example:* Based on the number of ewes (130) and their individual contact probabilities (0.047%), it is estimated that Herd S15 ewes will foray from the CHHR and make contact with this pasture at a rate of 0.06 ( $= 130 * 0.047\%$ ) times per year/season. In other words, one ewe contact with the pasture is expected to occur every 16 ( $= 1 / 0.06$ ) years/seasons.

- **Total Herd Contact Rate:** Average number of adult bighorn sheep (rams plus ewes) expected to foray from the CHHR and contact this pasture each year/season.

*Fisher Mtn. Example:* Based on the aggregate ram and ewe contact rates (0.65 and 0.06 contacts/year respectively), it is expected that a bighorn sheep will foray from the core herd range and make contact with this pasture at an average rate of 0.71 times per year/season equating to a rate of approximately 7 contacts every 10 years.

If a conservative assumption that one in four contacts results in disease transmission and a subsequent outbreak is used, a disease outbreak would be expected to occur every 10 years if not sooner. Even if just one in 10 contacts results in an outbreak, disease outbreaks would be expected every 14 years, on average. Outbreaks at this level would mean that the population is consistently exposed to ongoing disease transmission and resultant outbreaks. The population would likely be extirpated as a result of consistent exposure to interspecies contact.

**Q: Is there a realistic minimum viable population size for bighorn herds?**

The model does not recommend a minimum population. Our planning regulations definition for a viable population is: "A population of a species that continues to persist over the long term with sufficient distribution to be resilient and adaptable to stressors and likely future environments". The literature suggests a range from 100-188 animals to provide for bighorn sheep population persistence.

**Q: What other considerations go into interpreting contact rates and their possible impacts on bighorn sheep persistence?**

The Risk of Contact Model provides outcomes that reflect contact rates between bighorn sheep and domestic sheep allotment boundaries. This may, or may not, equate to interspecies contact. Nothing in the available literature provides an estimate of bighorn sheep contacts with an allotment and real interspecies contact rates in wildland environments. To account for this uncertainty an array of probabilities that contact with an allotment would result in actual interspecies contact that would in turn result in disease transmission and a subsequent disease outbreak can be evaluated. The Payette analysis defined a "moderate" rate of contact with an allotment resulting in a disease outbreak at 0.25, or that 1 in 4 contacts with an allotment would result in interspecies contact, disease transmission, and a disease outbreak. Scenarios with probabilities above and below this value were evaluated; i.e. from 0.05 (1 in 20) and 1.0 (every)



contacts with an allotment resulting in a disease outbreak event. This approach allows the relative comparison of alternatives while recognizing uncertainties associated with these assumptions.

Although the mechanisms of disease transmission and resulting disease outbreaks in bighorn sheep following interspecies contact are not fully understood, there is compelling evidence from the literature indicating the need to prevent interspecies contact and associated management guidance that these species be kept separate (WAFWA 2012). The Risk of Contact model does provide the probability and rates of contact between bighorn sheep and allotments where they potentially can contact domestic sheep. This is a logical surrogate to address separation.

The effects of respiratory disease outbreaks on bighorn sheep populations are often severe (see Besser et al. (2012a), Table 1 and Besser et al. (2012b), Table 1). Controlled pen experiments identified in Besser et al. (2012a) resulted in complete or nearly complete die-offs of bighorn sheep following contact with domestic sheep. Besser et al. (2012b), Coggins and Matthews (1992), and Foreyt (1990) also document that disease perturbations can affect lamb recruitment for several years following severe population declines resulting from disease epizootics. Hence, when bighorn sheep disease die-offs occur, there is a substantial immediate mortality (population decline) and subsequent delayed population recovery due to poor lamb recruitment, that follows in the aftermath for many years.

Although there is no guidance on the number of decades required to recover from a disease outbreak, observations of herds that have experienced pneumonic events indicate it likely requires many decades, if the herd recovers at all. Given the severity of respiratory die-offs and the potential link to domestic sheep as a causal factor in outbreaks, management scenarios should allow for long periods of time without interspecies contact. Population recovery is unlikely where interspecies contact, potentially resulting in disease transmission and subsequent disease outbreaks, occurs within a few decades of each other.

As an example, if the model output is 0.08 contacts (combined ram and ewe) with an allotment per year, and the assumed probability of a contact with an allotment resulting in an interspecies disease transmission and outbreak event is one in four (0.25), the average disease outbreak period would be 50 years. Although we still lack empirical data to make recommendations on the periodicity of outbreaks and the effects on bighorn sheep, this might be a good benchmark to ensure population persistence until better data are available.



## H.5 Citations

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