

Gopher Tortoise Line Transect Distance

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Sampling Workbook



Introduction

The gopher tortoise (*Gopherus polyphemus*) is legally protected in the six U.S. states where it occurs. Populations west of the Mobile-Tombigbee Rivers have been federally-listed as threatened since 1987 and those in the eastern portion of the range recently were found to warrant candidate status as threatened (U.S. Fish and Wildlife Service, 2011). Although threats to the species vary regionally, there is a critical need for information on the status and trends of populations across the range. This workbook outlines standardized methods for gopher tortoise surveys using line transect distance sampling methodology (Buckland et al., 2001) and builds upon methods described in the Gopher Tortoise Survey Handbook (Smith et al., 2009).

Line transect distance sampling (LTDS) is a widely-used method to estimate population size and density of wildlife species (Buckland et al., 2001). It is an efficient, statistically robust method that relies on counting objects observed from transects and measuring the distance from transects to each object. The method assumes all objects on the transect are detected but allows a proportion of objects to be missed, based on the fact that an observer's ability to detect an object decreases with distance from the transect (Buckland et al., 2001; Fig. 1). LTDS relies on five key assumptions: 1) all objects directly on the transect are found; 2) objects are detected at their initial location, prior to any response to the observer; 3) transect length is measured accurately; 4) distance from the transect to the object is measured accurately; and 5) transects themselves, or systematic placement of the transects, is random (Buckland et al., 2001). For a detailed explanation of how LTDS differs from spatially constrained survey methods like strip transect sampling see Buckland et al. (1993), Buckland et al. (2001), and Nomani et al. (2008).

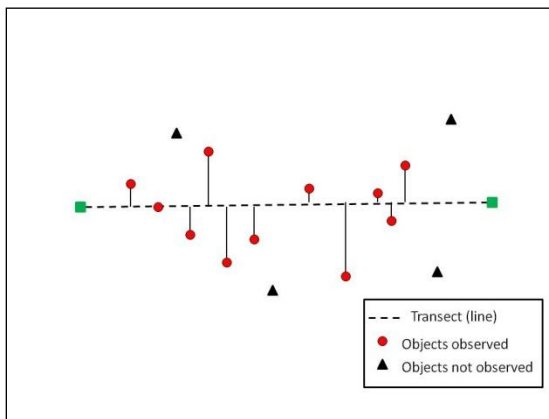
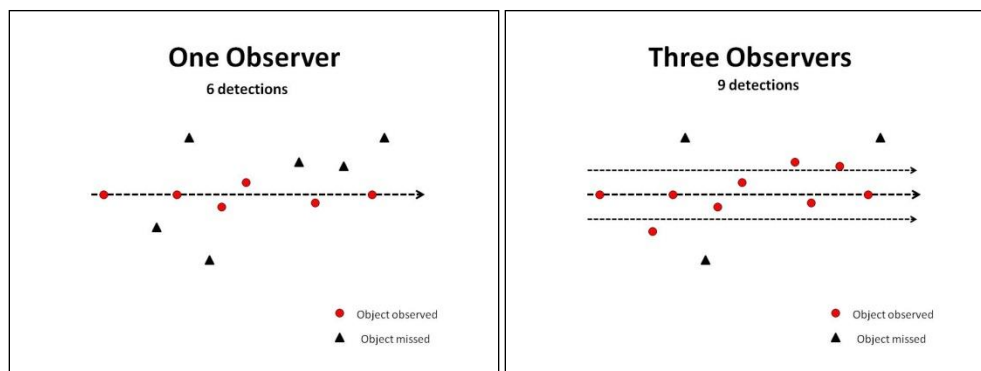


Figure 1. Representation of the results of distance sampling along a line transect. The method assumes all objects on the transect are detected, but allows for decreasing detection with increasing distance from the transect.

When using LTDS for gopher tortoises, the search objects are tortoises above ground and occupied burrows (as determined using a camera scope). The burrow entrance serves as the location of the individual, and the number of tortoises observed, either above ground or in burrows, is used to calculate a population estimate. Since burrow width varies with tortoise size, and the smallest burrows are difficult to detect, this method provides an estimate of subadult and

adult population size. We recommend using burrow width as a covariate in models to adjust for differences in detection probability. There is also a potential source of error associated with scoping burrows. For example, an observer may be unable to reach the end of the burrow with the camera scope because of obstructions (roots, debris, or presence of water), may fail to observe a second tortoise in a burrow, or may falsely classify an occupied burrow as unoccupied. The first two sources of scoping error are unavoidable with the current technology, but errors due to misclassification of occupancy can be minimized with proper training in use of a camera scope. Scoping error (percent of burrows for which occupancy was unknown) should be reported with survey results.

Gopher tortoises occur in low densities relative to many other wildlife species and their burrows are generally not evenly distributed across suitable habitat. Therefore, use of multiple observers can increase the number of observations over the typical one observer method (Buckland et al., 2001). With a three observer approach for gopher tortoise surveys, one observer navigates the transect searching for burrows and tortoises on or near the transect, and the other two observers search on either side of the transect to increase the total number of detections (Figs. 2a & b). Having three observers not only increases the number of detections, but also is helpful for carrying field equipment and scoping burrows. However, care must be taken to ensure objects between the center and outside observers are not missed.



Figures 2 a&b. Comparison of the number of detections using one versus three observers for distance sampling.

The open source software Program Distance ver. 6.2 (<http://www.ruwpa.st-and.ac.uk/distance/>, Thomas et al., 2010) can be used to create LTDS survey designs and to analyze data in a variety of ways. ArcGIS software can be used to create and manage spatial data [e.g., to define the survey area (sampling frame), transect, and tortoise locations]. The methods outlined in this workbook address the major steps to obtain population estimates for gopher tortoises under most circumstances using conventional LTDS. We present an example using

LTDS to estimate population size for a 222 ha site with a moderate density of tortoises. In special cases, e.g., large or very small sites where tortoise densities are extremely low, methods other than conventional LTDS may be appropriate. We assume that users of this workbook are familiar with ArcGIS, basic statistical principles, and have knowledge of the ecology of the gopher tortoise (including how to identify suitable habitat and burrows). We strongly encourage anyone using this workbook to review relevant chapters in the *Introduction to Distance Sampling* (Buckland et al. 2001) and *Distance Sampling* (Buckland et al. 1993) to gain an understanding of the theoretical and practical underpinnings of the method. Field technicians using this method must have an understanding of the importance of meeting the assumptions of LTDS described above, and should be proficient in field survey methods and use of all equipment. Quality control and oversight of data collection, management, analysis, and interpretation are critical.

The major steps in achieving a population estimate for gopher tortoises using LTDS are described below and are followed by examples in Appendix 1 that illustrate how to design a gopher tortoise survey and analyze survey data using Program Distance. Step-by-step worksheets for designing a survey and analyzing data, including how to interface between ArcGIS v.9.3, Microsoft Excel, and Program Distance ver. 6.2, are included in Appendix II. The latter material may become obsolete as software is updated.

Methodology

Delineation of Sampling Frame. The sampling frame is the area for which you wish to estimate the tortoise density and population size. For most purposes, the sampling frame is the extent of suitable tortoise habitat on a particular property as determined by soils, vegetation (land cover), and past and present land-use. In some situations, it may be desirable to stratify the sampling frame to determine tortoise density in different habitats within the same site (e.g., sandhill vs. flatwoods habitat, which might have different tortoise densities); in this case, systematic stratified sampling (e.g., by habitat type) can be used to minimize within-stratum variability. Once a decision is made on the extent of the sampling frame, ArcGIS can be used to create a shape file of the sampling frame.

Pilot Survey. The purpose of a pilot survey is to collect preliminary data on tortoise abundance to estimate the sampling intensity needed for the full LTDS survey. From the pilot survey data, the length of transect surveyed per tortoise observation, called the *tortoise encounter rate*, is calculated (Buckland et al., 2001, page 240). There is flexibility in the amount of effort required for a pilot survey and in selecting locations for pilot survey transects, but it is important that the pilot survey captures variation in habitat type, quality, and tortoise distribution within the sampling frame. Thus, we recommend random placement of pilot survey transects to minimize potential bias. We also recommend sampling a series of short transects, e.g., 10-20 transects that are 200 m long, across the sampling frame. Large sites or sites with very low tortoise densities

may require sampling additional pilot survey transects to ensure that you capture variation in tortoise distribution across the entire sampling frame. To increase efficiency, particularly on large sites, pilot survey transects can be configured in a “U-shape”, such that 500 m is sampled at each random location (see Appendix I, Example 1, Step 2). If no tortoises are observed on the initial round of pilot survey transects, it will be necessary to survey additional transects because at least one tortoise observation is required to calculate an encounter rate. Pilot surveys can also be used to assess the accuracy of the sampling frame, which can be adjusted if necessary.

Full Survey Design The full LTDS survey is designed using Program Distance and incorporates the sampling frame and tortoise encounter rate from the pilot survey. The tortoise encounter rate (meters of transect sampled per tortoise observed) is used to extrapolate the total length of transect necessary to observe enough objects (tortoises) to derive abundance estimates with reasonable precision (see Buckland et al., 2001, page 242; Buckland et al., 2004). As a general rule, to detect changes in population size over time, sampling should be intensive enough to detect >60 tortoises and produce a coefficient of variation (CV) of 15-20%, which is a practical expectation for most monitoring projects. If the CV exceeds 20%, the statistical power, confidence limits, and ability to detect trends in monitoring data are substantially reduced.

The survey design also takes into consideration some basic characteristics of the habitat within the sampling frame. In large areas of relatively homogeneous habitat, a systematic random survey is the most efficient design. In a systematic random survey, the beginning of the first transect is randomly placed, satisfying the statistical condition for a random sample, and transects are parallel and spaced a fixed distance apart. For large parcels of habitat (>10,000 ha), a systematic segmented grid or a systematic segmented trackline could be used to disperse the sample over a large area (Buckland et al., 2001). In either case, transects should be oriented perpendicular to topographic contours and parallel to any known gradient, if possible. For extremely small tortoise populations “repeated surveys” can be used to obtain sufficient observations of tortoises to estimate population size (Buckland et al., 2004). In repeated surveys, the same transects are re-sampled with independent observers and the data can be pooled to derive an abundance estimate. Alternatively, sample size can be increased by sampling two sets of perpendicular transects and pooling the data to derive an abundance estimate (Stober and Smith, 2009). In some circumstances, e.g., when there are fewer than 10 tortoises on a small tract of land (< 100 ha), a total count survey using a double-observer method should be considered (Nichols et al., 2000; Nomani et al., 2008).

Full Survey LTDS implementation:

Data collection. Data for long term gopher tortoise monitoring efforts will be collected infrequently and consistency in data collection is critical. Therefore, it is important to clearly define metadata associated with a project and to use pre-prepared datasheets (paper or electronic)

to ensure consistency in data collection. For conventional LTDS surveys, the minimum data collected in the field includes date/time, transect ID (unique to each transect), transect length, observations of tortoises (within and outside of burrows), perpendicular distances from the transects to burrows/tortoises, and burrow width or tortoise length. Transects can be delineated in the field using a compass and measuring tape. However, the best technology currently available for collection and management of spatial data is a field computer with a Global Positioning System (GPS) capable of real time data correction and an antenna with sub-meter accuracy, and with ArcPad and/or ArcGIS software. If a field computer/GPS is used for data collection, point data are collected at each observation and the perpendicular distances from transects to tortoises and burrows can be calculated later using ArcGIS. With a field computer, an electronic datasheet with pull down menus can greatly reduce data entry errors; however, prior to analysis all field data should be carefully reviewed for errors. For gopher tortoise population surveys using LTDS, we recommend collecting the following data listed below:

- **Date/Time**
- **Transect #:** Unique ID of transect.
- **Transect Length (m):** The total length of each transect. This can be calculated using ArcGIS if transect start and end points are collected in the field with a GPS unit with sub-meter accuracy.
- **Perpendicular Distance (m):** The perpendicular distance from any tortoise observed above ground (at location where they were first observed) or the burrow entrance to the transect. This can be calculated using ArcGIS, if locations are collected in the field with a GPS unit with sub-meter accuracy. Only data from occupied burrows or tortoises observed above ground will be used in analyses.
- **Burrow Width (cm):** a measurement of the width of each burrow taken approximately 50 cm inside the opening. If a tortoise is observed above ground, carapace length (in cm) should be entered in this field.
- **Burrow scoped (Yes or No):** Record whether you attempted to scope each burrow. If not, explain why in the “Notes” field.
- **Burrow occupancy (Yes, No, or Unknown):** Record occupancy as “Yes” if a tortoise is observed above ground or in a burrow; or “No” only if you are able to search to the end of the burrow and no tortoise is observed. Record occupancy as “Unknown” if you cannot clearly see the end of the burrow, and include an explanation in the “Notes” field. Be aware that tortoises can occupy flooded burrows or burrows packed with debris. It is important to record “Unknowns” as this is a source of potential error.
- **Commensals:** Record observations of other burrow inhabitants, such as Florida gopher frog.

- **Notes:** This field can be used to record why you did not scope a burrow; additional comments, or notes.

Field Sampling- single observer method. Line transect distance sampling typically involves one observer searching along a transect and recording all objects seen from the transect. When using a GPS/field computer as described above, the observer can navigate to the transect and take a GPS point at the starting point. While walking the transect, each time a burrow or tortoise is observed, a point is taken in the GPS, burrow width or tortoise length is measured, and if necessary, a camera scope is used to determine whether or not a tortoise is present in a burrow. Care must be taken if the observer leaves the transect so that no objects on or near the transect are missed. At the completion of each transect an endpoint is taken with the GPS; the actual length of transect sampled can be calculated later in ArcGIS. If a transect crosses unsuitable habitat, such as a wetland, this should be clipped out of the total length of the transect to avoid biasing the sample. When using a tape measure and compass for LTDS, the observer must measure the perpendicular distance from the transect to the burrow opening or above ground tortoise and transect length as accurately as possible (± 0.5 m).

If possible, we recommend using a second person to follow behind the primary observer and assist with scoping burrows. The second person can follow directly behind the first observer and search for burrows the first observer might have missed; observations should be recorded as either first or second observer. This is a double-observer approach can yield a more precise population estimate than a single observer approach (Nichols et al., 2000; Nomani et al., 2008)

Field Sampling- three observer method. The most efficient means of conducting LTDS surveys for gopher tortoises is to use three observers along with the GPS/field computer described above (Stober and Smith, 2009). Transect start and end points and observations of tortoises and burrows should be recorded as with the single observer method and all burrows should be scoped to determine whether a tortoise is present. But with a three observer approach, one observer navigates the transect using the GPS/field computer and observes tortoises or burrows on or near the transect. The other two observers walk on either side of the transect searching for tortoises and burrows from the transect outward. The outside observers should be sure to detect all tortoises and burrows between themselves and the transect centerline, but they may also detect objects to the outside. Thus, using three observers increases the number of observations and the effective strip width of the transect (Fig. 2b). The distance between the center line observer and two outside observers may vary slightly depending on the visibility within the habitat. But ideally outside observers should maintain a distance at which they are certain to see any burrows or tortoises between themselves and the centerline (3-5 m in most habitats).

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APPENDIX I

INSTRUCTIONS FOR LTDS SURVEY DESIGNS USING PROGRAM DISTANCE ver. 6.2

- **Creating a Conventional Design (Pages 11-16)**
- **Creating Designs for Special Cases**
 1. *Repeated Sampling Design (Pages 17-19)*
 2. *Systematic Segmented Grid Sampling Design (Pages 20-21)*

CREATING A CONVENTIONAL SURVEY DESIGN

A **conventional survey** design is the simplest approach to a LTDS survey and is appropriate for sites that are of moderate size with relatively homogeneous habitat and moderate to high numbers of gopher tortoises. Examples of more complex survey designs (e.g., for sites with low numbers of tortoises will follow).

There are a number of different ways to approach designing a survey using LTDS. We use ArcGIS to create and manipulate shape files needed for the design and data collection, and Program Distance to generate survey transects based on the pilot survey results. The methods below focus on the steps in Program Distance ver. 6.2, and provide limited guidance in ArcGIS, assuming the user has some familiarity with GIS software. Users with more experience in Program Distance and ArcGIS may elect to take a different, but equally valid, approach to designing a survey. Also, be aware that software versions may change rendering some of the steps in this workbook obsolete.

1. Preparing the Sampling Frame for import into Program Distance

To bring the sampling frame shape file into Distance, it must be given a specific name (“**study_ar**”) and the shape file must fit a very specific format. To do so, make a copy of the sampling frame shape file and name it “**study_ar**”. Since a shape file consists of multiple sub-files, it is easiest to copy and rename the file in ArcCatalog. Then go to the **Editor** in ArcGIS and select **Start Editing** the “**study_ar**” shapefile. Open the attribute table and select all rows in “**study_ar**”. In **Editor**, select **Merge** and then **Stop Editing** and **Save edits**. Open the attribute table again and add a field called “**LinkID**”, and specify the field **Type** as **Short Integer**, with **Precision** of “**0**”. Next, in the attribute table, delete all fields except “**FID**”, “**Shape**”, and “**LinkID**”. Next, right click on the “**LinkID**” field and select **Field Calculator**. You will get a warning message that “you are about to do a calculation outside of an edit session.” Select **Yes**

to continue. In the **Field Calculator** window, under “**LinkID**” =, enter a “**1**” and then select **OK**.

Your final attribute table for the study_ar shape file should look like this:

FID	Shape	LinkID
0	Polygon	1

2. How to create a Project in Program Distance

Once you have a study_ar shape file in the proper format, you need to create a new **Project** in **Program Distance** and specify where you wish to store the project files on your computer.

Open Program Distance. Select the **Tools** option on the task bar and then select **Preferences**. Under the **General** tab, select the **Browse** button to set the **Default project folder**. Once you have selected a location for the files, select the **OK** button at the bottom of the window. This returns you to the main menu.

From the main menu, select the **File** tab and select **New Project**. In the **Create Project** Window, enter your file name; for the purposes of this exercise, name the project “**Balfour_design**”. After naming your project and choosing a location to store it, check the box to “Save this folder as the default for Distance projects.” Then select the **Create** button. This opens a window with the **New Project Setup Wizard**. In **Step 1-Type of Project**: select **Design a new survey**, and then the **Next** button. This takes you to **Step 2- Setup for Designing Surveys**: select the **Finish** button. You need to close the project at this point so that Program Distance can create a folder to store your sampling frame shape file (“**study_ar**”). Close the project by selecting the **File** tab at the top of the screen and then selecting **Exit** and then **Yes**.

The next step is to copy your sampling frame shape file, “**study_ar**”, to the data folder called “**Balfour_design.dat**” that Program Distance automatically created for you. To do so, use **Windows Explorer**. Remember to copy all **6** of the “**study_ar**” files that make up the shape file (study_ar.dbf, study_ar.prj, study_ar.sbn, study_ar.sbx, study_ar.shp, and study_ar.shx). Copy and paste these files into the “**Balfour_design.dat**” folder. You will notice that there are already 3 files in “**Balfour_design.dat**” folder. These files are automatically created by the software when you created a new project and you will overwrite/replace all three of these files with your own files.

3. Creating a Map in Program Distance

Next you will create a map in your Distance Project using the “**study_ar**” shape file. This will display your sampling frame in Program Distance. Open your Distance project by double clicking on the project file in Windows Explorer (look for the Distance icon followed by your project name:  balfour).

Select the **Maps** tab within the Project Browser. If you slowly run your cursor across the icons on the tool bar under the **Maps** tab, text bubbles will pop up explaining what each icon does. Select the **New Map** icon. You will notice a **New Map**, highlighted in blue appears as the first row under **Name**. Then select the **View Map** icon. Select the icon to **Add Layer to Map**. This will open a window automatically allowing you to add your **Study area** (“**study_ar**” shape file). Select **OK**. Then close out of the **Maps** window by selecting the black **X** in the right corner of the screen (not the top red X, which closes the Project!). The **Confirm save map changes** window will appear, select **Yes**.

Go to the **Data** tab within the Project Browser to create a “**grid**” layer that will be used for transect placement. Right click on **Study area** located under the **Dater layers** window on the left side of the screen. Select **Data layer Properties**, then the **Geographic data** tab. This opens the

Coordinate System window. Select the **Change coordinate system** button in the lower right side of the window. Select the pull down tab to the right of **Geographic coordinate system**, scroll up and select **[None]**. Select the **OK** button to close this window and then select the **OK** button to close the **Data layer properties** window.

Next, right click on **Study area** again and select **Create Data Layer**. Change the **Layer name** to “grid”. Keep the default **Study area** under **Parent Layer**. Change the **Layer type** to **Coverage** using the pull down tab. Select the **Properties** button next to **Layer type** to open the **Grid Properties** Window. The **Projection for grid calculations** should be set to “[None]”, change the **Distance between grid points** from “100” to “40”. A rough rule of thumb is that grid spacing should be equal to the transect strip width (40 m for tortoise surveys). You may have to choose larger grid spacing for large sites because using transect width could create 10’s of thousands of grid points. In these cases, you would want to choose a larger grid spacing (Distance 6.2 Help Guide). The **Units of distance** should be set to “Meter”. Select **OK** and then **Yes** to confirm adding grid points.

The next step is to add the “grid” layer to your map. Go to the **Maps** tab on the Project Browser and select the **View Map** tab. Select the **Add Layer to Map** icon. Select **OK** to add the “grid” from the **Add Map Layer** window. Close out of the **Maps** window by selecting the black X in the right corner of the screen. Select **Yes** to save changes.

4. Creating a Conventional Design

Go to the **Designs** tab within the Project Browser (next to the **Maps** tab). Select the **New Design** icon and notice that a design named “New Design” appears in the first row in the main window (highlighted in blue). To set up your design, either select the **Show details for selected design** icon or double click the gray ball next to **ID**. Name this design “conventional”. Under the **Type of Design, Sampler**, select **Line** from the pull down menu. Below that, for the **Class** select **Systematic Random Sampling**. In these last two steps you are selecting a design based on **line transects** and transects will be created systematically (parallel and equally spaced), but placed at

a random starting point within the sampling frame, which satisfies the assumption of random placement of transects relative to survey objects.

Next, select the **Properties** button to the right. First go to the **Effort Allocation** tab. Under **Edge sampling**, select **Minus**. This forces transects to fall within the sampling frame and assumes objects are not biased toward the edge of the sampling frame. Alternatively, **Plus** sampling overlaps transects on the edge of the sampling frame to compensate for any potential bias of edge. If you use the **Plus** edge sampling, your design will include transects outside the sampling frame that must be edited out later. Next, under the **Allocation by stratum** tab select **Absolute values for “line length”**. Under **Length**, enter the total length (in meters) of sampling effort derived from pilot surveys for your desired degree of precision (CV). The default **angle** is “0”, which means that transects will be oriented **east-west**. If you prefer to have transects oriented differently, e.g., **north-south**, change the **angle** to “90”. We have found that orienting transects either east-west or north-south makes navigation in the field simple.

Next go to the **Sampler** tab. The default **Line sampler width units** should be **Meter**. Under the **By stratum properties**, replace the default **Width** of “1” with “20”. The 20 m **Width** is an approximation of half the width of a transect. Program Distance uses this value to calculate an estimate of the **coverage probability** for your survey (the expected proportion of the sampling frame you would survey using this particular design). Select **OK** to save the **Design properties**. Select **Run** on the top right side of the page and **OK** to generate the design. Close the **Design** page.

To create a shape file of the transects based on your design go to the **Surveys** tab to the right of the **Designs** tab. Under **Surveys**, select the **New survey** icon and you will see that a **New Survey** line has been added to the main screen. Double click the gray ball next to **ID** or select the **Show details for selected survey** icon. Name the Survey, “**transect**”. Under **Design**, select **Set 1 (the default)**, and **[1] conventional**. Select the **Run** button and **OK**. Page through the **Design output** by selecting **Next** at the top right of the **Design engine output** screen. These

screens provide a summary of the details of the design as well as a map showing the grid cells and a list of the X, Y coordinates of the start and end points for your transects. Close out of the **Surveys** page.

5. Displaying your transects in Program Distance

The next step is to add the “**transect**” layer to your map. Go to the **Maps** tab on the Project Browser and select the **View Map** button. Select the **Add Layer to Map** icon. Use the pull down tab on the **Add Map Layer** window and select “**transect**”. Then hit the **OK** button and close the **Maps** window. Select **Yes** to save changes. The “**transect**” shape file is automatically saved in the “**Balfour_design.dat**” folder. This shape file can be added to your ArcGIS project using the **Add Data** tool found within ArcGIS. You will need to define the projection if you use the shape file in an ArcPad project on a Nomad GPS.

Creating Designs for Special Cases

1. Repeated Sampling Design

A **repeated sampling** design is appropriate when you have a site with low tortoise density or a very small to medium-sized site where you might not have enough detections to obtain a population estimate with reasonable precision. With a repeated design, you can increase the number of detections either by 1) sampling the same transects more than once, using different survey crews to obtain independent samples or 2) sampling two sets of perpendicular transects, which would allow independent samples of each set of transects. As long as transects are sampled independently, it is acceptable to count the same tortoises twice.

Repeat steps 1-3 from the *Creating a Conventional Design* instructions above.

Start at Step 4 by designing a set of transects running east to west.

To do so, go to the **Designs** tab. Select the **New Design** icon and double click the gray ball next to ID or select the **Show details for selected design** icon and name this design “repeatEW”.

Under the **Type of Design**, **Sampler**, select **Line**. Below that, for **Class**, select **Systematic Random Sampling**. Select the **Properties** button to the right. First go to the **Effort Allocation** tab. Under **Edge Sampling**, select **Minus** or **Plus**. Next, under the **Allocation by stratum**, select **Absolute values for “line length”**. Under **Length**, enter **half the length** (in meters) of sampling effort derived from pilot surveys for your desired degree of precision (CV). The **angle** is the default, “0”, which means that transects will be oriented **east-west**.

Next go to the **Sampler** tab. The default **Line sampler width units** should be **Meter**. Under the **By stratum properties**, replace the default **Width** of “1” with “20”. The 20 m **Width** is an approximation of half the width of a transect. Program Distance uses this value to calculate an estimate of the **coverage probability** for your survey (the expected proportion of the sampling frame that you would survey using this particular design). Next, select the **Coverage Probability** tab. Under **Results Coverage grid**, use the default **Grid field name**, “repeatEW”. Select **OK** to

save the Design Properties. Select **Run** on the top right side of the page and **OK** to generate the design. Close the **Design** page.

Now you need to create a second design that includes transects that run north to south. Within the **Designs** tab, select the **New Design** icon and double click the gray ball next to ID or select the **Show details for selected design** icon. Name this design “repeatNS”. Under the **Type of Design, Sampler**, select “Line”. Below that, for the **Class**, select **Systematic Random Sampling**. Select the **Properties** button to the right. First go to the **Effort Allocation** tab. Under **Edge Sampling**, select **Minus** or **Plus**. Next, under the **Allocation by stratum**, select **Absolute values for “line length”**. Under **Length**, enter **half the length** (in meters) of sampling effort derived from pilot surveys for your desired degree of precision (CV). Change the default **angle** from “0” to “90”, so that transects will be oriented **north-south**.

Next go to the **Sampler** tab. The default **Line sampler width units** should be **Meter**. Under the **By stratum properties**, replace the default **Width** of “1” with “20”. Next, select the **Coverage Probability** tab. Under **Results Coverage grid**, change the **Grid field name** to “repeatNS”. Select **OK** to save the Design Properties. Select **Run** on the top right side of the page and **OK** to generate the design. Close the **Design** page.

Next, you need to run the survey for the east-west transects. Select the **Surveys** tab to the right of the **Designs** tab. Select the **New survey** icon and you will see that a **New Survey** line has been added to the main screen. Double click the gray ball next to ID or select the **Show details for selected survey** icon. Name the Survey, “EWtran”. Under **Design**, select **Set 1, [1] repeatEW**. Select the **Run** button and **OK**. Page through the Design output by selecting **Next** at the top right of the **Design engine output** screen. Close the survey page.

Next you need to run the survey for the north-south transects. Within the **Surveys** tab. Select the **New survey** icon and you will see that a **New Survey** line has been added to the main screen. Double click the gray ball next to ID or select the **Show details for selected survey** icon. Name

the Survey, “NStran”. Under **Design**, select **Set 1, [2] repeatNS**. Select the **Run** button and **OK**. Page through the Design output by selecting **Next** at the top right of the **Design engine output** screen. Close the survey page.

5. Displaying your transects in Program Distance

The next step is to add the **transect** layers to your map. Go to the **Maps** tab on the Project Browser and select the **View Map** button. Select the **Add Layer to Map** icon. Use the pull down tab on the **Add Map Layer** window and select “EWtran” followed by **OK**. Again, select the **Add Layer to Map** icon and use the pull down tab under the **Add Map Layer** window and select “NStran”. Then hit the **OK** button and close the **Maps** window. Select **Yes** to save changes. Both the “EWtran” and the “NStran” transect shape files are automatically saved in the “filename.dat” folder. These transect shape files can be added to your ArcGIS project using the **Add Data** tool. You will need to define the projection in ArcGIS if you use the shape files in an ArcPad project on a Nomad GPS.

2. Systematic Segmented Grid Sampling Design

A **Systematic Segmented Grid Sampling** design is appropriate for large sites (~10,000 ha) with somewhat heterogeneous habitat. This design randomly superimposes a systematic set of segmented parallel lines onto the sampling frame. More, shorter transect lines (samplers) yield more precise estimates of the encounter rate variance, and thus more precise population estimates than a design with few longer transects.

Repeat steps 1-3 from the *Creating a Conventional Design* instructions above.

Start at Step 4 by designing transects using **systematic segmented grid sampling**.

To do so, go to the **Designs** tab. Select the **New Design** icon and double click the gray ball next to ID or select the **Show details for selected design** icon and name this design “segmented”. Under the **Type of Design, Sampler**, select **Line**. Below that, for the **Class**, select **Systematic Segmented Grid Sampling**. Select the **Properties** button to the right. First go to the **Effort Allocation** tab. Under **Edge Sampling**, select **Minus** or **Plus**. Under **Sampler segment handling**, select **Allow split samplers**. Next, under the **Allocation by stratum**, select, **Systematic line spacing**, and check the box to the right for **Same spacing between segments and lines**. Where possible, it is best to create transects that are equally spaced between segments and lines, so that individual segments can be assumed to be independent when calculating variances. **It is important to note that on large sites, you will generally have to increase your sampling effort above what was calculated from the pilot survey, to obtain a reasonable Coverage probability.** Therefore, in the table at the bottom of the **Effort Allocation** tab, enter values under **Spacing** and **Segment** that produce a total **Length** (in meters) of the sampling effort that is equal to or greater than what was derived from pilot surveys for your desired degree of precision (CV). The default **Angle** is “0”, which means that transects will be oriented **east-west**. If you prefer to have the transects oriented **north-south**, change the angle to “90”.

Next go to the **Sampler** tab. The default **Line sampler width units** should be **Meter**. Under the **By stratum properties**, replace the default **Width** of “1” with “20”. The 20 m **Width** is an

approximation of half the width of a transect. Program Distance uses this value to calculate an estimate of the **coverage probability** for your survey (the area you would survey using this particular design). Select **OK** to save the design properties. Select **Run** on the top right side of the page and **OK** to generate the design. After generating the design, look at the **Design engine output** and decide if the **Approximated Coverage probability** is acceptable. If not, re-design the survey with increased Sampling Effort. Once you are satisfied with the design, close out of the **Design** page.

Next, you need to run the survey for the **Systematic Segmented Grid Sampling**. Select the **Surveys** tab to the right of the **Designs** tab. Select the **New survey** icon and you will see that a **New Survey** line has been added to the main screen. Double click the gray ball next to ID or select the **Show details for selected survey** icon. Name the Survey, “segtran”. Under **Design**, select **Set 1, [1] segmented**. Select the **Run** button and **OK**. Page through the Design output by selecting **Next** at the top right of the **Design engine output** screen. Close the survey page.

5.Displaying your transects in Program Distance

The next step is to add the “segtran” layer to your map. Go to the **Maps** tab on the Project Browser and select the **View Map** button. Select the **Add Layer to Map** icon. Use the pull down tab on the Add Layer window and select “segtran”. Then hit the **OK** button and close the **Maps** window. Select **Yes** to save changes. The “segtran” shape file is automatically saved in the “filename.dat” folder. This shape file can be added to your ArcGIS project using the **Add Data** tool. You will need to define the projection if you use the shape file in an ArcPad project on a Nomad.

APPENDIX II

INSTRUCTIONS FOR LTDS SURVEY ANALYSES USING PROGRAM DISTANCE 6.2

- **Conventional (CDS) Analysis (Pages 23-39)**
- **Multiple Covariate Distance Sampling (MCDS)
Analysis (Pages 30-35)**
- **Model Selection (Page 35)**

Conventional Distance Sampling (CDS) Analysis Engine

The Conventional Distance Sampling analysis engine is appropriate for surveys with up to one level of stratification (e.g., geographic stratification) and uses one covariate, observed distance, but does not allow additional covariates such as burrow diameter.

1. Data Management in ArcGIS

It is important to proof field data carefully. For data collected in ArcPad, carefully review the data within the attribute tables for the “**start_end points**” and “**tortoise_observation**” shape files. Check for missing start/end points on transects. Ensure that all points within both of these shape files correspond to the correct transect number.

Each transect must be uniquely identified, including fragments of transects that may have been separated by unsuitable habitat or fell within disjunct polygons in the sampling frame. Transects and transect fragments can be uniquely labeled in the field, or you can add a new field for unique labels in the “**start_end points**” shape file. To do so, open the attribute table for “**start_end points.shp**”, sort by **transect ID**, select the **Options** at the bottom right of the window. Select add a new field named “**tran_segment**”. Next, start editing “**start_end points.shp**” and enter a unique segment ID for each pair of consecutive points [e.g. $\text{tran_segment} = (1.1, 1.1); (1.2, 1.2); (1.3, 1.3)$; for 3 pairs of consecutive points taken while surveying transect #1].

Next, create a new **transect** shape file that represents the actual length of transects surveyed. This step is necessary if you designed the survey using **Plus** sampling, where the ends of transects that fell outside the sampling frame were surveyed, or if sections of transects that passed through unsuitable habitat within the sampling frame were clipped out in the field. To do so, in ArcGIS, convert **features** from a points shapefile (“**start_end points**”) to a line shapefile (name it “**actual_transects**”) and group by the field, “**tran_segment**”. Calculate the transect lengths and export as “**transect_lengths.dbf**”.

Next, assign the appropriate “**tran_segment**” ids to observations within the “**tortoise_observations**” shapefile.

Next, calculate the perpendicular distances from “**tortoise_observations.shp**” to “**actual_transects**” using the **NEAR** tool in the Arctoolbox and export data as “**tortoise_observations.dbf**” (unoccupied burrows are not included for tortoise density estimates and you will edit these out in the next step). 85° to 95° is an acceptable range for angles calculated from the NEAR analysis; angles outside this range indicate that burrows were outside the sampling frame and they should be excluded from the analysis.

2. Data Management in Excel

In Excel, create “**distance_input.csv**” that combines data from “**transect_lengths.dbf**” and “**tortoise_observations.dbf**” (remember to delete unoccupied burrows from this csv file) and format data following the example below:

Example

Label	Area (ha)	Transect ID	Length (m)	Perpdistance (m)
Ichauway	12000	1.1	1284.8	5.6
		1.2	568.2	
		1.3	854.3	19.2
				15.2
		2.1	525	2.3

*Note: Transect ID 1.3 had 2 tortoise observations. One at 19.2 m from the transect and one at 15.2 m.

“**Label**” = Site name

“**Area**” = Area of sampling frame (ha)

“**Transect ID**” = tran_segment IDs (include all transects, even those with no tortoises)

“**Length**” = tran_segment lengths (m)

“**Perpdistance**” = Perpendicular distance (m) from tran_segments to tortoise_observations (Leave blank if no tortoises observed on transect; remember to delete all unoccupied burrows)

3. Data Import into Distance

To import your data into Program Distance for analysis, you first need to create a new **Project**. A **New Project Setup Wizard** will guide you through the following steps to ensure that your data (“**distance_input.csv**”) is read into the program properly.

Open Program Distance. From the main menu, select the **File** tab and select **New Project**. In the **Create Project** Window, enter your file name. After naming your file and choosing a location, select the **Create** button. Use the **New Project Setup Wizard** to complete project setup; **Step 1- Type of Project**: select “**I want to: Analyze a survey that has been completed**”, select **Next** button.

Step 2- Setup for Analyzing a Survey: select the **Next** button.

Step 3- Survey Methods: under **Type of survey**, use the default “**Line transect**”, under **Observer configuration**, choose the default “**Single observer**”. Choose this option if you are using only one group of observer(s) recording observations. A double observer configuration would be chosen if you had a second group of observer(s) independently recording the observations that were missed. Under **Distance measurements**, use the default “**Perpendicular measurements**” (type of distances measured to tortoises). Under **Observations**, use the default “**Single objects**” (observations of single individuals). Select the **Next** button.

Step 4- Measurement Units: Specify the following measurement units for your data: under **Distance**, select “**Meter**”. Under **Transect length**, select “**Meter**”. Under **Area**, select “**Hectare**”. Select the **Next** button.

Step 5- Multipliers: Multipliers are constants used to scale the final density estimate (Distance 6.2 Help Guide), i.e. if only one side of the transect was surveyed, you would add a sampling fraction of 0.5. For most cases, no multipliers are needed. Select the **Next** button.

Step 6-Finished: Under Destinations, select “**Proceed to Data Import Wizard**” to import data from an external file. Select the **Finish** button. This will open a new window. Navigate to the location of the “**distance_input.csv**” file containing data to import (**Note:** you must select “**All files**” under **Files of type** to list .csv files in window). Select **OK**. The **Import Data Wizard** will open automatically to **Step 3** after choosing your “**distance_input.csv**” file.

Step 3-Data Destination: Next, you need to tell Distance where to store the imported data. Under **Destination data layers**, use the default **Lowest data layer**, “**Observation**”. This layer is the most specific or finest-scaled data layer (i.e., **tortoise observations**). Under the **Highest data layer**, select “**Region**”. This layer is your most general or largest scale data layer (i.e., **Site name**). Under **Location of new records**, select the default “**Add all new records**”. Under the **Creation of new records in lowest data layer**, select the default “**Create one new record for each.....**” Choosing these options will allow distance to format your data similarly to your distance_input.csv file. Select **Next**.

Step 4- Date File Format: Here, you tell Distance what delimiters were used to separate the columns of your data (Distance 6.2 Help Guide). You can check that columns are being recognized correctly by looking at the preview of the table. Under **delimiter**, choose “**Comma**”. Tick the box under **Ignore Rows** to allow distance to ignore the first row of your “**distance_input.csv**” file. This step is necessary if the first row of data in your .csv file contains column labels. Select the **Next** button.

Step 5- Data File Structure: Here, you tell Distance which columns in your data file correspond to fields in the Distance database (Distance 6.2 Help Guide). **Check** the box under **Shortcuts:** “**Columns are the same order.....**” This will populate the proper **Layer names**, **Field names**, and **Field types** for each column. **Layer name** refers to the scale of the data, highest data layer (Region) to lowest data layer (observation). **Field name** can be a **Label** (Site name or transect ID), **Area**, **Line Length**, or **Perp distance**. **Field type** can be a **Label** (character) or **Decimal**

(numeric). Alternatively, you can also manually assign columns to fields, by clicking on the first and second row of grey boxes (Distance 6.2 Help Guide). Select the **Next** button.

Step 6- Finished: under **Existing data**, select the default “**Overwrite existing data**” and then the **Finish** button to import your data into the **Distance database**. Select the **Data** tab. Under **Data layers**, select “**Observation**”. This will allow you to see the contents of the Distance database. Verify that the data were imported correctly (i.e. correct number of tortoise observations, transects etc).

4. Defining models in Distance

The next step is to define a series of models to tell Distance how to analyze the data. **Model Definition** options include the analysis engine to use, in this case, **Conventional Distance Sampling**, the type of detection function model (e.g., half-normal with cosine adjustments) and the method of estimating variance (analytic vs. bootstrap), among other things. The model definitions outlined below are those that are those most likely to fit an appropriate detection function for gopher tortoise survey data.

In Distance, a model is composed of 2 parts: 1) **Key functions**: Half-normal, Uniform, and Hazard-rate and 2) **Series Expansion functions**: Cosine, Simple polynomial.

It is important to add a **data filter** to the models that will discard outliers. We typically filter (discard) the largest 5% of distances. The model naming convention includes the **Key function** and **data filter truncation** (i.e. HN 5%).

To define models in Distance, navigate to the **Analyses** tab in the Project Browser. Double click on the gray ball or **Show details for selected analysis**. First, you need to set up your data filter. Under **Data filter**, select the **Properties** button and navigate to the **Truncation** tab. Under **Truncation of exact measurements/Right truncation**, choose **Discard the largest “5” percent of distances**. Under **Left truncation**, use the default “**No left truncation**”. Left truncation is

used to truncate (remove) observations close to the transect that might be biased by observer presence (e.g. when conducting deer spotlight counts along a road and deer avoid the road [transect] because of the presence of a vehicle). Under **Truncation for cluster size estimation/Right truncation**, choose the default “**Same as that specified above**”. This option only applies to observations of clustered groups. Change the **Name** to “**discard 5%**” and select **OK**. The next step is to define models.

Analysis 1 (HN): under **Model definition**, select the **Properties** button. Under **Analysis Engine**, choose the default “**CDS-Conventional distance sampling**”. Navigate to the **Detection function** tab and select the **Models** tab. Under **Detection function models**, use the defaults for **Key function** (Half-normal) and **Series expansion** (Cosine). Select the “**plus**” sign next to **Series expansion** and add **Model 2: Key function** (Half-normal), **Series expansion** (Simple polynomial). Select the **Constraints** tab, under **Constraints on fitted function** and select “**weakly monotonically non-increasing**.” Change the **Name** to “**HN**” and select **OK**.

Analysis 2 (UN): under **Model definition**, select the **New** button. Under **Analysis Engine**, keep the default “**CDS-Conventional distance sampling**”. Navigate to the **Detection function** tab and select the **Models** tab. Under **Detection function models**, For **Models 1** and **2**, change the **Key function** to “**Uniform**”. Keep the **Series expansion** set as “**Cosine**” for **Model 1** and “**Simple polynomial**” for **Model 2**. Change the **Name** to “**UN**” and select **OK**.

Analysis 3 (HR): under **Model definition**, select the **New** button. Under **Analysis Engine**, keep the default “**CDS-Conventional distance sampling**”. Navigate to the **Detection function** tab and select the **Models** tab. Under **Detection function models**, change the **Key function** to “**Hazard-rate**” Keep the **Series expansion** set as “**Cosine**” for **Model 1** and “**Simple polynomial**” for **Model 2**. Change the **Name** to “**HR**” and **OK**.

5. Running Models in Distance

You will run the following 3 analyses:

- HN 5%
- UN 5%
- HR 5%

To run the first analysis, change the **Name** at the top of the Analysis Browser to “**HN 5%**”. Under **Data filter**, select “**discard 5%**”. Under **Model definition**, select “**HN**”. Select the **Run** button next to **Name**. Page through the **Results** by clicking the **Next** button in the top right corner. Close the **Results** browser by selecting the bottom “**X**” in the top right corner.

To run the second analysis, select the **New Analysis** icon. Double click the gray ball or select the **Show details for selected analysis** icon. Change the **Name** at the top of the Analysis Browser to “**UN 5%**”. Under **Data filter**, keep “**discard 5%**”. Under **Model definition**, change to “**UN**”. Select **Run**. Page through the **Results** and close the **Results** browser.

To run the third analysis, select the **New Analysis** icon. Double click the gray ball or select the **Show details for selected analysis** icon. Change the **Name** at the top of the Analysis Browser to “**HR 5%**”. Under **Data filter**, keep “**discard 5%**”. Under **Model definition**, change to “**HR**”. Select **Run**. Page through the **Results** and close the **Results** browser.

6. Model Summary

The **Model Summary** is formatted like a spreadsheet, with one row for each model analysis and columns that give you useful information about the analyses (Distance 6.2 Help Guide).

Columns of default parameters summarize the results (i.e. **AIC**, **D**). Additional parameters (i.e. **N**, **P**) can be added using the **Add, remove, and arrange columns** icon.

Multiple Covariate Distance Sampling (MCDS) Analysis Engine

This analysis is appropriate to use when you have additional covariates that might influence detection of objects, e.g., the size of a burrow. This analysis engine contains (almost) all the features of the CDS engine, but also allows additional covariates to be included in the detection function model, in addition to observed distance. These covariates are assumed to influence the scale of the detection function, but not its shape (User's Guide Distance 6.2, Release 1, Chapter 9).

Repeat step 1 from the *Conventional (CDS) Analysis* instructions above.

2. Data Management in Excel

In Excel, create “**distance_input.csv**” with data from “**transect_lengths.dbf**” and “**tortoise_observations.dbf**” and merge and format data similarly to the following example:

Example

Label	Area (ha)	Transect ID	Length (m)	Perpdistance (m)	Diameter (cm)
Ichauway	12000	1.1	1284.8	5.6	35
		1.2	568.2		
		1.3	854.3	19.2	26
				15.2	25
		2.1	525	2.3	15

*Note: Transect ID 1.3 had 2 tortoise observations. One at 19.2 m from the transect and one at 15.2 m.

Label = Site name

Area = Area of sampling frame (ha)

Transect ID = tran_segment IDs (include all transects, even those with no tortoises)

Length = tran_segment lengths (m)

Perpdistance = Perpendicular distance (m) from tran_segments to tortoise_observations
(leave blank if no tortoises observed on transect)

Diameter = burrow diameter (cm)

3. Data Import into Distance

To import your data into the Distance program, you first need to create a new **Project**. A **New Project Setup Wizard** will guide you through the following steps to ensure that your data (“**distance_input.csv**”) is read into the program properly.

Open Program Distance. From the main menu, select the **File** tab and select **New Project**. In the **Create Project** Window, enter your file name. After naming your file and choosing a location, select the **Create** button. Use the **New Project Setup Wizard** to complete project setup; **Step 1- Type of Project**: select “**I want to: Analyze a survey that has been completed**”, select **Next** button.

Step 2- Setup for Analyzing a Survey: select the **Next** button.

Step 3- Survey Methods: under **Type of survey**, use the default “**Line transect**”, under **Observer configuration**, choose the default “**Single observer**”. Choose this option if you are using only one group of observer(s) recording observations. A double observer configuration would be chosen if you had a second group of observer(s) independently recording the observations that were missed. Under **Distance measurements**, use the default “**Perpendicular measurements**” (type of distances measured to objects). Under **Observations**, use the default “**Single objects**” (observations of single individuals). Select the **Next** button.

Step 4- Measurement Units: Specify the following measurement units for your data: under **Distance**, select “**Meter**”. Under **Transect length**, select “**Meter**”. Select the **Next** button.

Step 5- Multipliers: Multipliers are constants used to scale the final density estimate (Distance 6.2 Help Guide), i.e. if only one side of the transect was surveyed, you would add a sampling fraction of 0.5. For most cases, no multipliers are needed. Select the **Next** button.

Step 6-Finished: Under Destinations, select “**Proceed to Import Data Wizard**” to import data from an external file. Select the **Finish** button. This will open a new window. Navigate to the location of the “**distance_input.csv**” file containing data to import (**Note:** you must select “**All files**” under **Files of type** to list .csv files in window). Select **OK**. The **Import Data Wizard** will open automatically to **Step 3** after choosing your “**distance_input.csv**” file.

Step 3- Data Destination: Next, you need to tell Distance where to store the imported data. Under Destination data layers, use the default **Lowest data layer**, “**Observation**”. This layer is the most specific or finest-scaled data layer (i.e **tortoise observations**). Under the **Highest data layer**, select “**Region**”. This layer is your most general or largest scale data layer (i.e. **Site name**). Under **Location of new records**, select the default “**Add all new records**” Under the **Creation of new records in lowest data layer**, select the default “**Create one new record for each.....**” Choosing these options will allow distance to format your data similarly to your distance_input.csv file. Select **Next**.

Step 4- Date File Format: Here, you tell Distance what delimiters were used to separate the columns of your data (Distance 6.2 Help Guide). You can check that columns are being recognized correctly by looking at the preview of the table. Under **delimiter**, choose “**Comma**”. Tick the box under **Ignore Rows** to allow distance to ignore the first row of your “**distance_input.csv**” file. This step is necessary if the first row of data in your .csv file contains column labels. Select the **Next** button.

Step 5- Data File Structure: Here, you tell Distance which columns in your data file correspond to fields in the Distance database (Distance 6.2 Help Guide). **Tick** the box under **Shortcuts:** “**Columns are the same order.....**” This will populate the proper **Layer names**, **Field names**, and **Field types** for each column. **Layer name** refers to the scale of the data, highest data layer (Region) to lowest data layer (observation). **Field name** can be a **Label** (Site name or transect ID), **Area**, **Line Length**, or **Perp distance**. **Field type** can be a **Label** (character) or **Decimal**

(numeric). **Covariates** will not automatically populate the **Data File Structure**. Therefore, for “**Diameter**”, you must manually assign “**Observation**” under **Layer name**, type in “**Diameter**” under **Field name**, and select “**Integer**” for **Field type**, by clicking on the first and second row of grey boxes. Select the **Next** button.

Step 6- Finished: under **Existing data**, select the default “**Overwrite existing data**” and then the **Finish** button to import your data into the **Distance database**. Select the **Data** tab. Under **Data layers**, select “**Observation**”. This will allow you to see the contents of the Distance database. Verify that the data were imported correctly (i.e. correct number of tortoise observations, transects etc).

4. Defining models in Distance

The next step is to define the models that will be used for the analysis. In Distance, a model is composed of 2 parts: 1) **Key functions**: Half-normal, and Hazard-rate and 2) **Series Expansion functions**: Cosine, Simple polynomial. It’s important to add a **data filter** to the models that will discard outliers. Notice that only 2 key functions are available in MCDS models. We typically filter (discard) the largest 5% of distances. The model naming convention includes the **Key function**, and **data filter truncation** (i.e., HN 5%).

To define models in Distance, navigate to the **Analyses** tab in the Project Browser. Double click on the gray ball or **Show details for selected analysis**. First, you need to set up your data filter. Under **Data filter**, select the **Properties** button and navigate to the **Truncation** tab. Under **Truncation of exact measurements/Right truncation**, choose **Discard the largest “5” percent of distances**. Under **Left truncation**, use the default “**No left truncation**”. Left truncation is used to truncate (remove) observations close to the transect that might be biased by observer presence (e.g. when conducting deer spotlight counts along a road and deer avoid the road [transect] because of the presence of a vehicle). Under **Truncation for cluster size estimation/Right truncation**, choose the default “**Same as that specified above**”. This option only applies

to observations of clustered groups. Change the **Name** to “**discard 5%**” and select **OK**. The next step is to define models.

Analysis 1 (HN): under **Model definition**, select the **Properties** button. Under **Analysis Engine**, choose “**MCDS-Multiple covariates distance sampling**”. Navigate to the **Detection function** tab and select the **Models** tab. Under **Detection function models**, use the defaults for **Key function** (Half-normal) and **Series expansion** (Cosine). *Note that the MCDS analysis engine does not allow constraints. Select the **Covariates** tab. Under **Detection function covariates**, select the **Plus** button. Under **Layer type containing covariate**, select “**Observation**”. Under **Field name of covariate**, select “**Diameter**”. Change the **Name** to “**HN**” and select **OK**.

Analysis 2 (HR): under **Model definition**, select the **New** button. Under **Analysis Engine**, keep “**MCDS-Multiple covariates distance sampling**”. Navigate to the **Detection function** tab and select the **Models** tab. Under **Detection function models**, Change the **Key function** to “**Hazard-rate**”. Keep the **Series expansion** set as “**Cosine**”. Change the **Name** to “**HR**” and select **OK**.

5. Running Models in Distance

In MCDS, there are only two key functions available. You will run the following 2 analyses:

- HN 5%
- HR 5%

To run the first analysis, change the **Name** at the top of the Analysis Browser to “**HN 5%**”. Under **Data filter**, select “**discard 5%**”. Under **Model definition**, select “**HN**”. Select the **Run** button next to **Name**. Page through the **Results** by clicking the **Next** button in the top right corner. Close the **Results** browser by selecting the bottom “**X**” in the top right corner.

To run the second analysis, select the **New Analysis** icon. Double click the gray ball or select the **Show details for selected analysis** icon. Change the **Name** at the top of the Analysis Browser to “HR 5%”. Under **Data filter**, keep “discard 5%”. Under **Model definition**, change to “HR”. Select **Run**. Page through the **Results** and close the **Results** browser.

6. Model Summary

The **Model Summary** is formatted like a spreadsheet, with one row for each analysis and columns that give you useful information about the analyses (Distance 6.2 Help Guide). Columns of default parameters summarize the results (i.e. **AIC**, **D**). Additional parameters can be added using the **Add, remove, and arrange columns** icon (i.e. **N**, **P**).

7. Model Selection

Program Distance uses an information theoretic approach to model selection (Burnham and Anderson 2002). The model summary table includes both Akaike's Information Criterion (AIC) and Delta AIC values for the suite of models. Generally, the model with the lowest AIC is considered the best model, but all models with an AIC < 2 units from the best model are competitive. However, be sure to review all output pages for each competing model. In particular, check for error warnings, which would appear under “Log messages.” Among competing models, we generally select the model with the lowest CV. However, we strongly recommend reviewing Burnham and Anderson (2002) and Buckland et al. (2001; Chapter 8) for information on model selection in Program Distance.