Transect Simulation System - Main Index

General

Extracts from the Manual

These are selected extracts from the printed materials which were provided with Version 0.9 Beta of WinTSS:

Creating a New Geographical Database

1. Choose **New** under the **File** menu, and choose a name for the new geographical database.

2. Click on the **Start** button.

3. Using the *left* mouse button to click where the vertices of the polygon are, start drawing the exterior most polygon. The colour of the polygon which you are working on is **White**.

4. When you approach the end of the polygon, click the *right* mouse button to complete the polygon. The completed polygon turns **Red** as the program calculates its area, and then it turns **Green.** If the polygon remains red for an excessive period of time (depending on the speed of the computer, and whether or not it has a co-processor), then most likely you have allowed two segments of the polygon to intersect, which will confuse the program. In this case, click on the **Abort** button and start over.

5. Start drawing a new polygon inside the green polygon. The program will not allow you to draw outside the green polygon. As before, use the *left* mouse button to draw the polygon, and the *right* mouse button to complete it. When the polygon is completed, it turns red for a short while, and then green.

6. If you do not wish to continue drawing additional polygons within the innermost **Green** polygon, click the *right* mouse button again, whereupon the innermost green polygon turns **Blue**. Now you can continue drawing additional polygons within the next innermost **Green** polygon, but not within the **Blue** polygon. In this way, you are able to create complex geographical structures.

7. When the outermost polygon turns blue after clicking on the right mouse button, the creation of the new geographical database is complete, and the program chooses a default colour scheme for the different regions. You may click on a region at this stage if you wish to change the colour or fill style of the region.

Setting the Scale

The scale is set by choosing the **Set Scale** item under the **Design** menu. This basically tells the program how to convert between screen coordinates and the actual coordinates of the geographical data. All densities and distances calculated by the program are calculated in terms of the real scale and the units which you choose here.

Click and hold the *left* mouse button down where you wish to start the line, and drag the line over to where you wish to stop. A small dialogue box pops onto the screen, in which you should enter the length of the line in the units you have in mind. For example, you could choose a line spanning the length of the entire geographical area, and you might decide that that line is ***1000*** meters long. So you would enter ***1000*** in the dialogue box, and ALL subsequent distances would be in terms of meters, areas in square meters, radii of plants in meters, etc. If you wish the change the scale at any time in the program, then hit the **Rescale** button.

NOTE: you have to remember which unit of length you use, because all the program does is make sure that all dimensional data are in terms of this unit. Choose a convenient unit, otherwise you may find yourself expressing the radii of plants in miles later in the program.

Setting Vegetation Densities

Select **Vegetation** under the **Design** menu to set the vegetation densities. To design the vegetation for a particular region, move the cursor over to that region use the *left* mouse button to click and bring up a dialogue box.

Press the **Set Radius Distribution** button. Then enter various radii, and frequencies corresponding to those radii. For example, if you enter

radius	freq
1	3
2	1

(where the units are chosen when you set the scale), then there will be approximately three times as many plants of radius 1 than of radius 2. When the program actually generates the plants for that region, it uses a smooth probability distribution for the radius, using the above table.Once you have completed the table, the program automatically calculates the min, max and mean radius, and also plots the smooth probability density function which it will use the generate the radii. Absolute magnitudes of the frequencies are unimportant; relative values are important only

Next, fill in a number for the **Number of Plants in Test Box,** and hit the **Test** button. It may be easier to change the magnification. Choose the number of plants for the test box until you are satisfied with the density of the plants.

Setting Animal Densities

Select **Critters** under the **Design** menu to set the vegetation densities. To design the animal populations for a particular region, move the cursor over to that region use the *left* mouse button to click and bring up a dialogue box.

Press the **Set Group Size Distribution** button. Then enter various group sizes, and frequencies corresponding to those sizes. For example, if you enter

size	freq
3	3
10	1

then there will be approximately three times as many groups of size 3 animals than of size 10 animals. When the program actually generates the groups for that region, it uses a smooth probability distribution for the size, using the above table.Once you have completed the table, the program automatically calculates the min, max and mean group size, and also plots the smooth probability density function which it will use the generate the sizes. Absolute magnitudes of the frequencies are unimportant; relative values are important only

Groups of animals in this program are modelled by means of circles and ellipses. The animals within a group are distributed uniformly within a circle, the radius of which is entered as the **Group Radius**. Groups are kept apart by using a territorial ellipse. You can specify this territorial ellipse by giving a range for the **first radius** and the **second radius**, and the **orientation** of the ellipse. The radii and orientation of a given ellipse are chosen randomly from these ranges.

Next, fill in a number for the **Number of Groups in Test Box,** and hit the **Test** button. It may be easier to change the magnification. Choose the number of groups for the test box until you are satisfied with the density of the groups. Select the **Show Ellipses** option to see the ellipses which make sure that groups do not intersect.

Drawing Transects

Select **Transects** under the **Design** Menu. Press the **Start** button, and then the **Add Transect** button. Move the cursor to where you wish to start the transect, and click and hold the *left* mouse button, move the cursor to the end of the transect, and let go.

When the dialogue box pops up, enter in the half width of the transect, using the same units that you used for the scale.

Press the **Add Transect** button if you wish to draw more transects.

Generating the Animals and Plants

The animals and plant distributions are generated by choosing the **Vegetation** and **Groups** option under the **Generate** menu. The vegetation and animals must be designed before they can be generated.

If the plants and groups had been generated in a previous simulation, then you can choose not to regenerate them, in which case the plants and groups for the regions will be read in from disk.

Note that you can turn off the displaying of groups and/or vegetation as you generate them. This is recommended for slow computers.

Doing the Count

Once the groups and plants have been generated, you can do either an **aerial** count, or a **ground** count. In either case, the procedure is the same. Select either **ground count** or **aerial count** from the **Count** menu.

Then in the dialogue box which pops up, you can choose a stopping number for the Fourier series. The stopping number is the cutoff for the number of terms which are kept in the Fourier expansion used in the calculation of the densities. By default, the stopping rule as described in the Monograph is used; this automatically chooses which stopping number to use.

The other parameters which need to be specified are the sighting probabilities. For a description of what the sighting probabilities mean, look at the short description here which was in the printed manual provided with the first version.

Note that you can also use the built in Fourier analysis method to calculate densities from existing real data. Have a look at the release notes here which were also provided with the first version.

Results of the Count

The results can be displayed for each transect, or you can select **Total** from the **Current Strip** list, which displays the results as if the stips were really all part of one single transect, placed end to end.

You can also display the sighting function g(x) to check on whether the fourier series method is behaving the way you would expect, particularly for the ground count. Have a look at the short review here, which is a short extract from the printed manual provided with the first version. Also look at the release notes, which demonstrate how to test the internal calculation routines.

Release Notes for Version 0.9 BETA of WinTSS

(these are the release notes that were provided with the first version of the program)

The floppy diskette provided with these notes contains the following (please copy to a directory on your harddrive).

WINTSS.EXE: The MS-Windows executable. Install in your desktop manager (e.g. Program Manager) by creating a new item (see Window documentation).

SIM.DAT: Test data from **Wildlife Monograph on Line Transect Sampling** by Burnham, Anderson and Laake, Page 58

DEMO.GIS: Example database. See **Section 3** for details on how to use BWCC.DLL

BWCC.DLL: WinTSS needs this to display dialog boxes.

WINTSS.HLP: Help file.

1. A short description of the menu items

A more complete manual for the software will be provided with the final version once all the items have been finalized. Please provide a list of any changes to be made in the terminology used (e.g. the word "critters" will obviously be changed in the final version and has only been retained to distinguish the beta version from any subsequent final version).

1.1 File

New - Clears the current database and starts a new one.
Open - Retrieve a database from disk.
Save - Save the database to disk.
Save As - Save the database in a particular file.
Print - Print whatever is on the screen.
Quit - Quit.

1.2 Edit

Copy to Clipboard- Copy whatever is on the screen to the clipboard.

1.3 Options

Generation Options

There are two main groups of options here: the **Interrupt** options and the **Display** options. When enabled, the interrupt options allow you to interrupt a long calculation and to obtain a status of the current operation. These options naturally slow down the computation process, and should be disabled if using a slow computer. By default, they are enabled. The Display options allow you to decide whether to show generated vegetation and animals on the screen. With a very large simulation on a slow computer, these options should be disabled to save memory and computation resources. By default, they are on.

Color Options

Specify the colour of the background (useful when printing).

1.4 Design

Create/Edit Regions - Draw the regions.
Choose Colors - Choose the appearance of the regions.
Set Scale - Set or change the current scale.
Vegetation - Design the vegetation characteristics for each region.
Critters - Design the animal characteristics for each region.
Transects - Specify the line transect.

1.5 Generate

Vegetation - Generate vegetation.
Groups - Generate animal groups.

1.6 Display

Vegetation - Toggles the display of the generated vegetation on the screen.

Note: the vegetation cannot be displayed if the Display option for vegetation was disabled in the Options menu.

Animals - Toggles the display of the generated groups on the screen.

Note: the animals cannot be displayed if the Display option for the animals was disabled in the Options menu.

Transect - Display the transects.

1.7 Count

Real Data - See below.
Ground count - Perform a ground count along the transect.
Aerial count - Perform an aerial count along the transect.

2. Testing the calculation routines

A means has been provided in this beta test version to test the internal routines. The following is a step-by-step explanation of how to perform the test:

2.1 Double Click on the **WinTSS** icon.

2.2 Under the **Count** menu, click on **Real Data (Optional)** and then on the **Calculate Density** popup menu item.

2.3 A dialogue box with the title **Fourier Estimate from Real Data** will appear. Click on the **Browse** button for a list of files. Double click on **Sim.dat** (provided with the programme). The number of data points should be 40.

2.4 Enter "1000" in the **Transect Length** box, and "65" in the **Effect Transect Width** box. Click on the **OK** button.

The estimated density in the strip is **0.0004859** +/- **0.0001909**, and the stopping number used is **1**. This data is actually taken from **Table 5** in the **Wildlife Monograph on Line Transect Sampling** by Burnham, Anderson and Laake, Page 58. There, Burnham et al calculate the density as 0.000486 +/- 0.000191, and determine the stopping number as m=1. The error was calculated assuming that the 40 objects were distributed randomly, which clearly is not a valid assumption in some cases.

2.5 Click on the **Graph** button.

The graph is of the Fourier series estimator of *f(x)*, which Burnham et al calculate in Fig.27 on page 59 (they did not do a good job of it!). Burnham et al actually produced the data using a half-normal underlying probability density function.

This process may be used with any data file containing perperndicular distances. The ground count simulation produces a ".cou" file, and the aerial simulation produces a ".aco" file. These files contain the perpendicular distances of the animals that were sighted, and can be used with other analysis packages.

3. Using DEMO.GIS

DEMO.GIS is a fairly complicated database to test how the software performs on your system. The following instructions detail how to run a sample simulation:

3.1 Start up the WINTSS software. It would be a good idea to disable screen savers, and (as with any beta software) save all other work.

3.2 Select the **Load** menu, and select DEMO.GIS to be loaded. If you wish, the current vegetation and animal group parameters for each region can be viewed by selecting the appropriate **Design** menu option.

3.3 Click on the **Options** menu, and select **Generation options**. A dialog box will appear. If your computer is limited by memory or speed, turn off the **Display generated vegetation** and **Display generated groups** options (there must be no tick mark). These options should only be used when testing, or for a once only viewing of very large distributions (such as in DEMO.GIS) because generating onto the screen as well as to the disk may require excessive amounts of the system resources.

3.4 Select **Generate vegetation** in the **Generate** menu. On a 50 MHz 486DX, generating the vegetation took about 15 minutes (when **Display generated vegetation** was selected). Click on the Status button to see the current status of the computation. This procedure generates a 700K disk file called DEMO.V0 containing the coordinates and radius of every tree. If there is already a DEMO.V0 file on the disk, you will be prompted whether to use that file or to generate another.

3.5 Select **Generate groups** in the **Generate** menu. This procedure generates a disk file called DEMO.A0 containing the coordinates of the animals. If there is already a DEMO.A0 file on the disk, you will be prompted whether to use that file or to generate another.

3.6 Select **Ground count** in the **Count** menu to perform the count.

3.7 To conduct a count using another transect, select **Transect** in the **Design** menu, click on the **Transect** button, and draw a transect as described earlier. The vegetation and groups need not be regenerated, so go straight to the **Count** menu.

NOTE: To view a distribution file on the disk (e.g. DEMO.V0), do the following:

3.8 Load the DEMO.GIS database.

3.9 Click on the **Options** menu, and select **Generation options**. A dialog box will appear. Turn on the **Display generated vegetation** and **Display generated groups** options (there must a tick mark in both boxes).

3.10 Select **Generate vegetation**. When you are asked whether to regenerate or use the previous file, select **No** and the current distribution will be plotted on the screen. Note that this can a considerable amount of time for a complex distribution.

4. Reporting Errors

Since this is a beta version, there are bound to be problems which escaped our own testing. If you encounter any problems, please follow these general guidelines:

4.2 Try to reproduce the problem, and provide clear instructions on how we can reproduce the problem. If that is not possible, try to provide as full a description as possible on what you were doing when the problem occurred.

4.3. Please provide us with a list of any aspects of the interface which are confusing or badly worded. Please also make suggestions for what you would like to see in the final online help.

4.4. The easiest way to get in touch with us is through email at QUADLING@CS.UMN.EDU, or by snail mail to H.Quadling, c/o A. Starfield, 1614 Rosehill Circle, Lauderdale, MN 55108, USA.

Simulation modelling as a laboratory tool

(the following is an extract from the printed manuals which were provided with the first version; figures and diagrams are not included here)

1. Simulation as a means of evaluation

Suppose we have a monitoring technique which we wish to evaluate, i.e., we would like to know whether the technique produces useful results. The best way of doing this is to try the new method out on a sample area where we know the exact population density, and then to compare the actual density with replicated census results. Replicating the census is an expensive and usually impractical approach to the problem. In any case, it is not likely that we have access to an area where the exact population density is known.

Another approach would be to simulate an artificial population on a computer, and then to simulate the census exactly as it would be conducted in the field. By comparing calculated and actual densities, we could evaluate the accuracy of the method. However, we can only fully evaluate a monitoring technique by computer simulation if we manage to simulate reality perfectly. Since we could never realistically expect to create a perfect simulation, we should always be careful in the interpretation of results. The closer the simulation experiment is to reality, the easier it is to interpret, and the less likely it will lead to spurious conclusions. We stress that it is very easy to draw spurious conclusions if the simulation experiment is not designed properly, i.e, if the assumptions and the objectives are not compatible. At the same time, it is also easy to go hopelessly wrong if the simulation is too complex. We strive for as simple a simulation as possible, with as few assumptions as possible that will get the job done.

Another common use of computer simulation is to test the robustness of various monitoring methods with respect to some factor. For example, a line transect sampling model might assume a random homogeneous distribution of animals in order to make the mathematics tractable. A simulation model might be used to test how robust the statistical model is to departures from this rather restrictive assumption. In fact, as far as we can ascertain from the extensive literature, simulation (not necessarily in the computer medium) is the only technique used by researchers to test the robustness of a model. The following is an overview.

2. Overview of simulation experiments from the literature

Several attempts have been made to evaluate monitoring techniques by means of simulation. For example, Watson *et al*7,8 (1969) described a serious attempt to simulate problems in East African aerial censusing by using actual scale models, but did not make any useful conclusions. A more recent simulation experiment conducted by Lake10 (1979) describes the placement of wooden stakes in a sagebrush meadow in Utah, in his investigation of the line transect sampling method. Lake's data has been used to demonstrate the validity of the Fourier series method*2*. A still more recent experiment by Burnham *et al* (1980) made use of a table top surface covered with circles of varying diameters, to simulate the flushing circles of animals located at the circle centres. By stretching a nylon string across the surface, animals were counted whose flushing circles intersected the string. This is an excellent example of how to model the detection problem, in this case using the flushing radius concept.

The simulation experiments discussed above have advantages and disadvantages over computer simulation experiments. A distinct advantage of the Lake stake simulation data over a similar computer simulation is that the human eye detects the animals in the Lake simulation, whereas in the computer experiment the detection process has to be modelled in some way. We remind ourselves that the main reason animals are difficult to detect is due to limitations of the human visual system (if we had a terminator cyborg's eyes, we would be in good shape). This is an important advantage that will always justify such experiments. We note however that the simple table-top experiment as described by Burnham *et al* does not have this advantage. The advantages of computer simulations are:

1. The cost of non-computer simulation experiments, in terms of time and resources, is much greater than that of a computer simulation.

2. Non-computer simulations are often plagued by the same measurement problems as in the actual census. A computer simulated census can be conducted without a single measurement error, and all calculations can be done exactly. This important advantage of the computer simulation makes it an ideal laboratory tool to investigate the robustness of various monitoring techniques to measurement errors. For example, the robustness of various line transect sampling schemes to errors in the angle and distance measurements can be investigated, simply by simulating known errors in the measurements and

comparing all calculated results with known values and the error-free calculated result. Computer simulations can be used to explore the effects of bias in the measurements.

3. Non-computer simulation experiments are usually easy to describe, but difficult to replicate. An important advantage of the computer simulation experiment is the ability of other researchers to repeat the same experiment.

Probably the first use of computer simulation to study line transect sampling estimators was by Gates9 (1969), who used a simulation study to explore the effects of varying true population density, line transect length, average flush angle, non-independent flushings, and sensitivities of the estimators to departures from the *assumed* detection function. We emphasize the word 'assumed', because Gates used an assumed form of the detection probability density function *f(x)* (see **1.14**) to generate his homogeneous population. Since the simulation experiment was designed to explore various aspects of line transect sampling theory which is absolutely based on the concept of the detection function, it is difficult to draw conclusions from Gates' simulation study. In this case, the problem is that the simulation experiment is too simplistic, and the structure of the simulation experiment is too similar to the structure of the theory of line transect sampling for comfort, and it is all too easy to make spurious conclusions.

Another more recent example of such a use of computer simulation is in the Monograph by Burnham et al2, who use computer simulated data in an example of the application of the Fourier series method, and to examine the bias in the method. In this experiment, perpendicular data is sampled from an *assumed* underlying truncated half-normal density function. Again, the simulation model is too simplistic, and not many useful conclusions can be made. The only real use of such a simulation model is to provide example data in learning how to use the method.

3. Simulation and design

Before a census can be successfully undertaken, it has to be thoroughly planned in advance. It is in this design stage of the census that computer simulation is indispensable as a laboratory tool. In this section, we consider the value of computer simulation in the design of a census, both as a technique and as a discipline.

3.1 Simulation as a 'crutch'

Computer simulation is an invaluable tool in the designing of a census. Suppose that we have clear objectives for the census. How do we use the resources at our disposal in order to meet those objectives? (See **figure 1**.) On the one hand we should design the census carefully to meet our goals because a census is a huge undertaking that usually cannot be repeated if botched. On the other hand, we would also like to know how a census can be bungled, so that we can avoid doing so. Computer simulation serves as a invaluable guide in this design stage, because a computer can explore so many different possible scenarios. Specifically, a computer simulation can highlight factors that influence the accuracy and reliability of the census. In addition to this, simulations can also be used for a practice, or final 'dress rehearsal', of the methods to be employed in the census.

3.2 Simulation as a means of experimentation

Simulation provides an inexpensive means of experimenting with many different techniques or ideas, that otherwise may have been too ambitious or expensive. Experimenting with a computer simulation model is an excellent way to look for patterns and anomalies, which is very often the first step in the understanding and interpretation of the results. Through experiment we can explore and discover scenarios that we may never have thought of, had we not been guided through the process by the simulation.

Another consideration emphasizes the relationship between simulation and experimentation is the total control the experimentalist has over the experiment. All measurements can be made with absolute accuracy, and there is never any ambiguity in any of the data. This is important since the experimentalist can always compare the results with some absolute 'truth'. For example, consider an experiment which consists of simulating a ground-based line transect survey, with vegetation as the factor which inhibits detection of the animals. In this case, the calculated density estimator and its confidence interval (or any other calculated parameter) can be compared with the actual value. If the experiment were to include the effects of distance and angular measurement errors (by introducing an element of uncertainty in the measurement process), then the experimental results could be compared directly with the actual results, since the corresponding actual measurements could be calculated exactly in the simulation model. For the spatial simulation model which is discussed in this report, the location of every animal and every plant and every spatial attribute can be determined exactly, with respect to any other point. This level of resolution may be much more than is required, but is easy to acquire on modern computer systems, and we may be sure that there are never systematic measurement errors that could result in spurious conclusions.

Another aspect of the design of the census which can be explored via simulation experiments is the question of which measurements should be recorded, and how they should be recorded, in order to meet the stated objectives. How data is recorded is an essential part of the design of the census. For example, we could conduct experiments in the investigation of how to group measurements (in an effort to facilitate the collection of data) and still meet our objectives. We could explore how much effort is worth expending in the measurements. We could explore the question of resolution, again always aiming for the objectives of the census that we decide on right at the beginning. Simulation is an indispensable tool in our quest to minimize the effort in the pursuit of the objectives which must be met.

3.3 Simulation as a means of evaluation

The use of computer simulation as a procedure of evaluating monitoring techniques is not entirely obvious. The only way a statistical monitoring technique can be properly evaluated is through controlled experiments. However it is possible to evaluate certain aspects of the method being considered. An example of such an aspect would be the evaluation of the robustness of a method to various factors, such as the robustness of a line transect method to inhomogeneously distributed spatial populations. Another example would the use of computer simulation to determine rough estimates of the variances of the estimated parameters, as done by Gates9 in his computer simulations that we have already discussed.

3.4 Simulation as a discipline

We could also consider computer simulation as a discipline for defining objectives and checking to see whether designs really do meet the stated objectives. This might be the most important role simulation can play. The difference between estimating the total population or determining whether the population size is in some range might not appear important when one talks about a census. Similarly, it might show up major differences between these two objectives.

The Estimation of Animal Population Density: a Review

(this is an extract from the printed manual which was provided with the first version of the software; figures and equations are not included)

1. Introduction

Monitoring of animal populations is an important activity not only for ecological reasons, but also because the proper management of animal populations depends on accurate census estimates, or estimates that can be interpreted in some meaningful way. Vast sums of money are spent every year on monitoring, and there is a large literature on the statistics of the problem.

Several excellent reviews of monitoring methods are available, and this chapter serves as a brief review of the statistical results pertinent to our study. Most of the material may be found in the book by Seber1 and the wildlife Monograph on line transect sampling by Burnham et al2. There are also good reviews by Gates3, Eberhardt4 and Kovner et al5.

2. An overview of censusing techniques

2.1 The single total count

The most obvious way to determine population density is to survey the entire area in an attempt to count all the animals in it. There are however many problems associated with this 'brute force' approach. Clearly a serious problem is the expense of such an undertaking, particularly if the area in which the census is conducted is large. In many cases, the expense that this technique entails cannot be justified.

The accuracy of the total count depends on the visibility of the animals, and that is the crux of the problem. The only animals that are included in the count are the ones that are actually seen, i.e., there is a systematic under count. This systematic error is impossible to avoid, and makes all density estimates suspect. As a consequence of these possible errors (the magnitude of which we have no idea), it is difficult to justify a single total count, and alternative methods should be explored.

2.2 Total counts in sample areas

Another way of estimating the population density in an area is to select sample areas, and perform a total count in each of the sample areas. One of the main reasons for doing this is usually a lack of resources for an undertaking as described in the paragraph above, and the possibility of doing repeated counts to estimate errors. The choice of size and shape of the sample areas is governed by many factors, including the specific species being counted, the terrain, the vegetation, etc. Usually, the most important factor which determines the shape of the sample area is the ease with which the sample area can be marked out, and the ease at which the sample area can be covered. For aerial surveys, and indeed for most ground based censuses, the easiest sample area to navigate is a long thin rectangular strip. In this study, we consider our sample areas to be strips. We define a 'strip' as a rectangular sample area which is oriented in some arbitrary fashion in the total area.

The estimation of population density using sample plots is a well established technique which is well covered in the literature. As a simple example, we consider a total population of size N which is randomly distributed in an area A1. The probability p of finding an animal in the sample area is the ratio of the sample area to the total area. In this simple case, the number n of animals in the sample area pA follows a binomial distribution

These equations can be used to provide a very rough idea of what proportion of the total area must be covered in order that the variance be within a specified tolerance, given a rough lower bound estimate of N. Of course, it is seldom (if ever) valid that the population being surveyed is randomly distributed, but many of the statistical methods in use today do not insist on this assumption, as described later.

A more ambitious scheme would be stratified random sampling in which the total area is divided into different strata. Each stratum would have a randomly distributed population, but the strata would not necessarily have the same densities. Stratified random sampling is one way of avoiding problems with inhomogeneous spatial distributions (Siniff).

2.3 Density estimates from line transects

One of the most important censusing methods in use today is the line transect method, which consists of traversing a straight line transect and recording data in a systematic manner. This can be carried out from the ground, or by air.

2.3.1 Detection

The idea central to the line transect method is that the probability of detecting an animal changes with perpendicular distance from the transect. The animals are detected in one of two modes: either they are simply seen, or they are detected because they flush. The actual mode of detection is irrelevant to the theory as reviewed by Burnham *et al*2, in contrast to other authors for whom the detection mode is important1,3. For example, some authors describe methods in which the animals that do not flush are not counted. Such theories associate a flushing radius with a particular species; an observer within the flushing radius of an animal would cause the animal to flush and to be seen by the observer, who would then record the necessary data.

The reason that animals are difficult to count is due to limitations of the human eye, as well as obstructions such as vegetation, rocky outcrops etc. Modelling how obstacles affect sighting probabilities is not difficult, but modelling how the physiology of the human eye affects detection is practically impossible. In view of this, we realize that it is impossible to evaluate monitoring methods fully by means of computer simulations, and likewise it is impossible to build these human factors into a statistical model. We strive to build a simple model that is useful and that we can interpret easily. In the immediate context of line transects, our simple model is based on the idea of a detection function, as described later.

The theory as reviewed below deals with 'objects'. These objects may be individual animals, or entire groups as is the case with clustered populations. If (as usually is the case) the objects being counted in the line transect survey are groups, then the location of the object is the centre of mass of the group, and the number of animals in the group has to be estimated along with the distance and angle measurements. There is of course the additional question of how the group size affects the detection probability.

2.3.2 Conventions

We use the standard notation in the line transect theory literature. The perpendicular distance of the object to the line transect is denoted by *x*. The relationship between *x* and the sighting distance *r* is shown in **figure 1**, the sighting angle being , i.e.,

It is generally assumed in line transect models that these errors are negligible, an assumption which may not be valid.   If the error in the angle is relatively large, then that is where most of the error in x is going to come from.

We denote the length of the transect by *L* and its half width by *w*. The number of objects counted is denoted by *n*. The area of the strip is denoted by *A*.

2.3.3 Assumptions underlying the line transect method

In earlier reviews of the line transect methods, it was often stated that an assumption of randomness was necessary, i.e, that the animals are homogeneously and isotopically distributed throughout1. In recent years however, it has come to be generally accepted that this severely restrictive assumption is not necessary, provided that the line transects are randomly located2,6. We shall discuss the validity of this and the other assumptions later. The following four assumptions are considered important for accurate density estimates2:

1. Objects on the actual transect line are seen with certainty.

2. All objects are stationary before they are sighted, and are not counted more than once.

3. There are no errors in either angle or distance measurements.

4. All object sightings are statistically independent events.

A full analysis of how violations of these assumptions affect the density estimates has not yet been conducted, nor has there been a satisfactory investigation of the assertion that homogeneity is not required.

2.3.4 Detection function g(x)

The detection function, usually denoted by *g(x)*, relates the perpendicular data *xi* to the estimators that we are looking for, such as density. Quoting the definition given in Burnham *et al*2, the detection function *g(x)* is defined as the conditional probability of observing an object given that the object is located at a perpendicular distance *x* from the line:

We also expect the probability of sighting an object to decrease with increasing *x*, and so we expect *g(x)* to be a decreasing function of *x*.

Many factors influence the sighting probability of objects, including weather and habitat conditions. It would be wrong to suppose that *g(x)* has the same form over the duration of the census. It is fortunate that there are analytical methods which are not affected by these factors, such as the

Fourier series method described later. In addition, it is claimed in the literature that *g(x)* is completely unrelated to the spatial distribution of the objects in the strip2.

Using the GIS simulation system: A Simple description.

The windows application wintss.exe provides a quick and easy way of creating a simple coordinate-free geographical database, on which to conduct monitoring experiments.

5.1 A short description

The user enters in a geographical database, by defining regions which are bounded by polygons. The user assigns each region the following attributes:

(1) A plant density
(2) A probability density function for the plant radius distribution.
(3) A group density
(4) A probability density function for the group size distribution.
(5) Various parameters which determine the minimum distance between groups, how the groups are distributed spatially, and how the individual animals are scattered spatially within the group.

The scale is also set by drawing a line segment, and then specifying the length of the line in any units. All calculations such as areas and densities will calculated in terms of those units.

A single transect which has a beginning and an end and a width is also entered.

The user is then able to perform either a ground count or an aerial count. The densities are calculated using the Fourier series method (described in Chapter 1), and all the information neccessary to compare the estimated and observed parameters with the actual parameters is provided.

It is also possible to use the built-in Fourier series routines to calculate densities and approximate errors on real data (perpendicular sighting distiances from the base line).

5.2 How the animals are counted.

For the ground count:

It is assumed that an animal has a certain fixed probability of being detected if it is behind a plant. If the animal is behind n plants, then the probability is raised to the nth power. There is another fixed probability of the animal being observed even if it is not obstructed by any plants. These probabilities are specified by the user before conducting the count. This is the simplest way to model how the probability of detecting an animal falls off with the perpendicular distance from the transect baseline. It should be kept in mind that this is a model, and that these probabilities along with the vegetation cover chosen should be used to simulate the problems associated with a census in a simple way.

According to these probabilities, if the animal is detected, the perpendicular sighting distance is recorded. The density is estimated using the Fourier series method, and a 95% confidence interval is also calculated. The confidence interval is based on a Poisson distribution (which is not a good assumption, especially for groups) and should not be taken as an accurate figure, but merely as a guide to the errors involved.

For the aerial count:

The aerial count is quite similar to the ground count, except that in this case there is a fixed probability of the animal being detected if it is under a plant. Again, using two probabilities to determine whether or not the animal is detected is the simplest way of modelling the situation of how some animals are missed.

In both cases, the estimated underlying probability density function f(x) (the 'detection' or 'sighting' function) can be displayed.

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