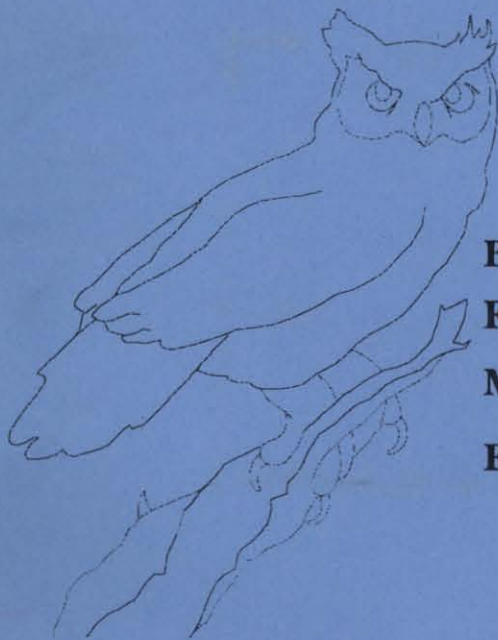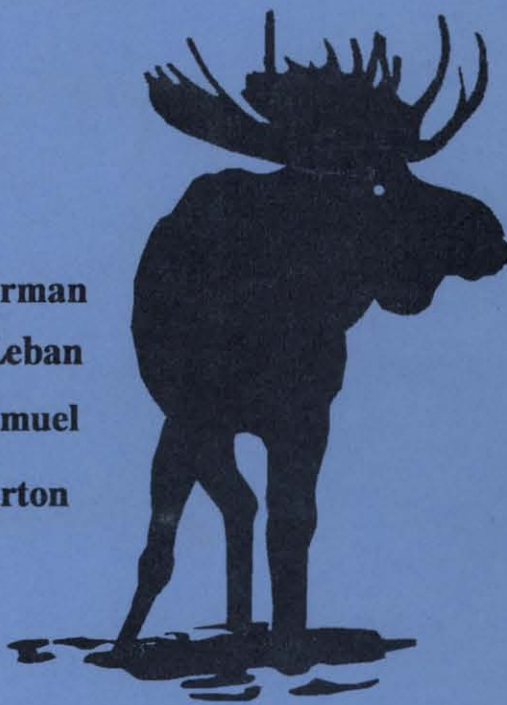# USER'S MANUAL FOR

PROGRAM HOME RANGE

Second Edition

Bruce Ackerman

Frederick Leban

Michael Samuel

Edward Garton

FOREST, WILDLIFE AND RANGE EXPERIMENT STATION

TECHNICAL REPORT 15

(REVISED MAY 1990)

University of Idaho

USER'S MANUAL

FOR

PROGRAM HOME RANGE

Second Edition

(REVISED MAY 1990)

by

Bruce B. Ackerman
Frederick A. Leban
Michael D. Samuel
Edward O. Garton

Technical Report 15

The material in this report has received internal processing
through the Department of Fish & Wildlife Resources and is issued
as a non-refereed publication of the Forestry, Wildlife and Range
Experiment Station, University of Idaho, Moscow.

Contribution No. 259

Forestry, Wildlife and Range Experiment Station
University of Idaho
Moscow, Idaho 83843

USER'S MANUAL FOR PROGRAM HOME RANGE, Second Edition

Technical Report 15

An example bibliographic citation of this manual is as follows:

Ackerman, B. B., F. A. Leban, M. D. Samuel, and E. O. Garton. 1990. User's Manual for Program HOME RANGE. Second Edition. Technical Report 15, Forestry, Wildlife and Range Experiment Station, University of Idaho, Moscow, Idaho, USA. 80pp.

This manual was produced with WordPerfect 5.1 and HP LaserJet III printer using the Math Elite (J) cartridge. Some illustrations were WordPerfect graphic images and some were produced with Applause II.

TRADEMARKS

Brand and product names mentioned in this document are trademarks or registered trademarks of their respective holders.

ABSTRACT

Program HOME RANGE calculates home range size using five different methods: convex polygon (Hayne 1949, Michener 1979, Bowen 1982), bivariate normal ellipse (Jennrich and Turner 1969), weighted bivariate normal ellipse (Samuel and Garton 1985), harmonic mean (Dixon and Chapman 1980), and Fourier transform (Anderson 1982). The program tests underlying assumptions such as independence of observations (Swihart and Slade 1985b), and fit to bivariate normal and uniform distributions (Samuel and Garton 1985). Harmonic mean core areas also can be identified (Samuel *et al*. 1985a, Samuel and Green 1988). Observations can be weighted to decrease the effect of outliers (Samuel and Garton 1985), to reduce serial correlation (Swihart and Slade 1985b), or to include proportion of time in different activities (Samuel and Garton 1987).

This user's manual contains a discussion of the philosophy of home range estimation and a brief review of the estimation methods including their assumptions. It provides instructions for using program HOME RANGE, the options which can be requested, and a description of input/output formats. Menu-driven utility programs are also described for displaying two- and three-dimensional graphs of animal home ranges in a variety of formats.

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF FIGURES

PREFACE TO THE SECOND EDITION

Since the first edition of this manual was produced (1983), then revised (Samuel *et al.* 1985b), there have been extensive changes. Most are in response to the tremendous proliferation of microcomputers in that short time. Not only are microcomputers now widely available and used extensively (even in wilderness research sites without electricity!), but the variety of CPU's, disk drives, monitors, graphics displays, printers and plotters is staggering. The speed of high-end microcomputers now approaches that of mainframe computers a few years ago and accuracy is better! With this in mind, the program has been modified in three major directions: 1) minor changes to the home range estimation procedures——correcting errors, refining procedures, and adding a few recently-described techniques; 2) numerous changes to the program which should allow it to run on almost any midrange IBM compatible microcomputer; and 3) extensive program changes and development to allow menu-driven access to most graphics display units, printers, and plotters, for production of good quality 2- and 3-dimensional displays of home range information.

Because computation time and cost are less important on microcomputers than on mainframe computers, little attention has been directed toward streamlining calculations. In contrast, we now routinely recommend methods which would have been prohibitive recently——large arrays and grids, multiple runs using many estimators, etc. Bootstrap and jackknife methods with 100's and 1000's of repeated sub-sampled runs will probably be routine before long. However, in spite of the advanced features, the attractive display procedures and graphics, the goal of this work is still only to provide a tool to obtain better biological understanding of the home range. The availability of "high-tech" hardware, programs, and statistical methods does nothing to alter the fact that the "science" of home range analysis far outstrips the biological use that it is put to on the average research project. We encourage users to use this tool to hypothesize and evaluate meaningful biological question related to space use patterns of animals. Not until home range analysis is routinely used for this purpose will this program have served its purpose.

Our philosophy has been, and remains, that:

1) Researchers should know why they are asking home range questions. Why is it important to estimate the home range size? What biological question is being evaluated? There are numerous ways to draw a line around animal locations on a map (area enclosed by observed locations; area likely to be used by an animal in a day, a year, an entire lifetime; areas with special importance). Each method has a different meaning, different assumptions, different consequences. With the development of this and similar programs, no one method is substantially easier or cheaper to calculate, thus the choice between methods should be based on more important biological factors.

2) Before the data are collected, the researcher must develop a reasonable sampling strategy. This strategy must consider, at a minimum, temporal movement patterns, randomization, animal activity patterns, serial correlation, and sample size. The days when haphazard data collection was acceptable have past. These factors may be different for every species, in every environment, and for different age/sex/dominance classes.

3) All of the home range estimators are biased low at very small sample sizes, some worse than others. Results will be inaccurate and imprecise if sample sizes are too low for a given method. Results may not even be comparable between animals that have different numbers of observations, even within one season, one species.

4) Serial correlation in the data (observations which are collected too closely together in time) causes most methods to produce estimates that are too small. (The effect is that of artificially inflating sample size). If possible, the correct timing of observations ("time to independence", Swihart and Slade 1985b) should be determined, and observations too close together pooled or deleted.

5) Observations must be randomly obtained throughout the entire season of interest and around the clock.

6) Once collected, data should be tested to see whether they fit the underlying distributions appropriate for each method. If not, the method should not be used without overwhelming justification. Some methods are more sensitive to violations of various assumptions than others.

7) After testing, the most appropriate method should be used. If none is strictly appropriate, the most appropriate or most general method should be used.

In summary, there is still no shortcut to "reliable knowledge" (Romesburg 1981), or good science.

Bruce B. Ackerman[1]
Fred A. Leban
Michael D. Samuel[2]
Edward O. Garton

University of Idaho
Moscow, Idaho
May 3, 1990

[1] Present address: Marine Research Institute, Florida Department of Natural Resources, 100 Eighth Ave., S. E., St. Petersburg, FL 33701. Phone: (813) 896-8626.

[2] Present address: U. S. Fish and Wildlife Service, National Wildlife Health Research Center, 6006 Schroeder Road, Madison, WI 53711. Phone: (608) 271-4640.
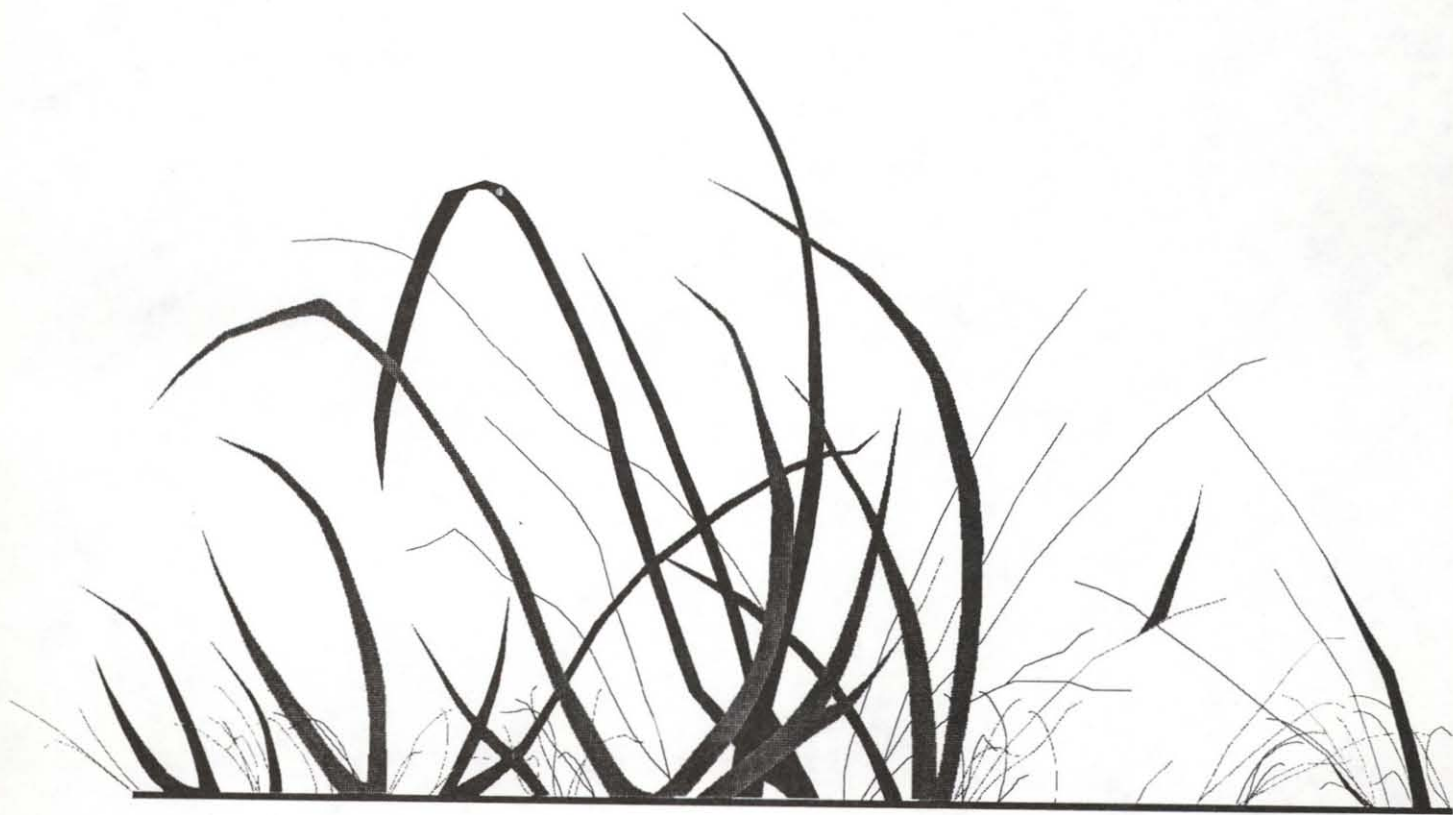
GETTING STARTED

Introduction

Welcome to the University of Idaho Home Range Analysis Programs. Program HOME RANGE calculates home range sizes using five different methods, and also tests some of the underlying assumptions for these methods.

Before you get started, you should be somewhat familiar with the basics of operating an IBM PC (or compatible) under PC-DOS (or MS-DOS). You'll need to know how to run programs, copy and delete files, and how to use other basic DOS commands. If you're not already familiar with these things, spend some time learning how your PC works and reviewing the DOS manual, or better still, ask someone who knows how. The disk that accompany this manual is formatted for standard 5 ¼ -inch (360K) or 3 ½ -inch (720K) disk drives and can be read only by IBM PC and compatibles. Before you do anything else, we want you to make a backup copy of the disk and then put the original away. You may want to put write-protect tab on the disk to prevent accidental erasure while making a backup or during installation.

Backing Up Your Disk

The first thing that you should do after getting this package is to **make a backup copy of all programs** present on the distribution disk. This can be accomplished by using the DOS COPY or DISKCOPY commands. Refer to the DOS manual for more examples on the usage of these commands. If you have two floppy drives, insert the distribution disk in drive A: and a blank formatted diskette in drive B:. At the A> prompt, type **COPY *.* B:** <Enter>. Or if you prefer, with your DOS disk in drive A: and a new disk in drive B: type **DISKCOPY A: B:** <Enter> and follow the instructions.

System Requirements

DOS   : PC/MS-DOS 2.10 or higher.

Hardware : IBM PC, PS/2, or 100% compatibles. The main HOME RANGE (HR.EXE) program and HRF64.COM require an 8087/80287/80387 math coprocessor. *(A version of program HOME RANGE which does not require the math coprocessor is available but it is much slower. This version is compiled using Microsoft FORTRAN 4.01 with the emulator library so that it will run both on machines that do or do not have the math coprocessor installed. If your machine has a math coprocessor installed, it will use it for floating-point calculations.)* HPLOT and HR3D (HREGA) require a compatible graphics card (CGA, EGA, VGA, Hercules). HPLOT plots to Hewlett-Packard (HP) plotters and compatibles, and drives HP 7470/7475 plotters. A hard disk is recommended if many runs are going to be made, if batch or macro files are used, or if very large runs are made (output file is 300K with 1000 locations, all options invoked).

Memory   : Operates with 256K of free RAM, 512K recommended.

What's on Your Disk

A summary of most of the files on your disk is given on a sheet entitled **Contents** of the **Distribution Disk** for your reference.

Installing HOME RANGE on Your Computer

The HOME RANGE package include all the files necessary for home range analysis. The utilities that you will need depends on the hardware and peripherals that are installed on your system. You may use either the installation utility, or follow the steps in *Setting Up On a Floppy or Hard Disk System* below to install HOME RANGE on your particular system. **It is recommended that you keep all the programs contained in this package on the same disk, or in the same directory on a hard disk.**

Using the Installation (INSTALL.EXE) Utility

You may use this utility to install the HOME RANGE program and its accompanying utilities on two-floppy or hard disk system. The purpose of INSTALL is to copy files from the distribution disk to another disk, and also help you to configure the home range driver. Before running the INSTALL program, make sure that you have two 5¼-inch or one 3½-inch diskette(s) already formatted, or if you have a hard disk, make sure that you have at least 700K of free space (if all files are to be copied). To run the INSTALL program, put distribution disk in drive A and type the following commands:

```
a:
install
```

If you want to configure the driver, see pages 5-6 for an explanation of the configuration (HRD.USR) file and some examples. Alternatively, you could make a copy of the example included on distribution disk and modify it to suit your set up.

Setting Up On a Floppy Disk System

First, you're going to create a bootable (system) disk. Get a blank disk and at the DOS prompt type

```
format b:/s
```

Your system will ask you to insert a DOS disk in drive A; just insert your regular system boot disk. If you have a two-drive system place a blank disk into drive B and press <Enter> when prompted. If you have a one drive system, place your blank disk into the drive whenever you are asked to insert a blank disk into drive B, and place your original boot disk into the drive whenever you are asked to insert a DOS disk into drive A.

When you are finished, your blank disk will be formatted and will contain a copy of the PC-DOS (or MS-DOS) operating system. Label it your HOME RANGE system disk and continue to the next step.

Put your HOME RANGE distribution disk into drive A. If you have a second drive, put your distribution disk into drive B. You can copy the files (see **Contents of Distribution Disk** for a listing of all files) one at a time from the distribution disk onto your system disk by typing

```
copy b:filename.ext a:
```

at the A> prompt where *filename.ext* is the name of the file you wish to copy. Repeat this step for all files on the distribution disk.

Setting Up On a Hard Disk

The first thing you want to do is to create a directory called **HR** (or whatever you choose) on your root directory. Assuming that your hard disk is designated as drive C, use the following commands:

```
c:
cd\
mkdir hr
```

Now place the distribution disk into drive A and type the command:

```
copy a:*.* c:\hr
```

Utilities

Some utility programs are included to help you in accessing the utilities and analyzing the results produced by program HOME RANGE. The first is the Home Range Driver (hereafter called the Driver or simply HRD). It is menu driven, and will let you run HOME RANGE, and the other utilities (2-D contour plotter, 3-D display of harmonic mean values, and Fourier method). See pages 5-8 on how to use and configure the driver.

Problems, Questions & Comments

If you have any problems or comments concerning programs in this package, we would greatly appreciate hearing about them in writing or by phone.

Problems   : Describe how it happened and include your system configuration (hardware——make, model, monitor, graphics card; dates of your program files; DOS version; peripheral devices, etc.). You may send a diskette with all input and output files if necessary.

Comments   : Anything you do or don't like about the program. Any ideas for improvements.

If you have any problems or comments concerning these software, please contact:

<div align="center">

Fred Leban, Oz Garton, Bruce Ackerman, or Mike Samuel [3]

PROGRAM HOME RANGE

Department of Fish & Wildlife

University of Idaho

Moscow, ID 83843

☎ (208) 885-6434 or 885-7239 ☎

</div>

Program Development

These programs were developed using the following hardware and software configurations:

1. IBM PC, 640K RAM, DOS 3.30, CGA, 20MB Hardcard, HP 7475A plotter.
2. IBM PC/XT, 640K RAM, DOS 3.30, EGA with monochrome & color display, 8087 math coprocessor, 20MB hard disk, internal 3½" drive, HP 7470A & 7475A plotters.
3. IBM PC/AT, 640K RAM, DOS 3.30, CGA, 80287 math coprocessor, HP 7475A plotter.
4. Epson Equity III +, 640K RAM, DOS 3.20, EGA/Hercules
5. IBM PS/2 60, 3MB RAM, DOS 3.30, VGA, 80287 math coprocessor.
6. IBM PS/2 70, 2MB RAM, DOS 4.00, VGA, 80387 math coprocessor.

Languages   : FORTRAN 77, Pascal and BASIC.
Compilers   : Microsoft FORTRAN 4.01, Turbo Pascal 3.0 & 4.0, and Microsoft QuickBASIC 4.0.
Library   : Mach 2 1.10 by MicroHelp, Inc., for QuickBASIC.
Linker   : Microsoft Overlay Linker 3.69.

---

[3] See page ix for current addresses and phone numbers for Bruce and Mike.

HOME RANGE DRIVER

Introduction

Driver program for Home Range package. All other programs can be accessed from this driver. Each program has its own hardware and software requirements.

Program	Functions
HR.EXE	Main HOME RANGE estimation program
HRF.COM	Home range estimation using Fourier transform method (32 by 32 grid)
HRF64.COM	Home range estimation using Fourier transform method (64 by 64 grid - requires math coprocessor)
HPLOT.EXE	Plotting program (screen, plotter, printer)
HR3D.COM	3-D plot of harmonic mean utilization distribution (CGA/EGA/VGA graphics board) (screen, printer)
HREGA.COM	3-D plot of harmonic mean utilization distribution (EGA/VGA)

Configuration File

You can configure this package so that it knows where to find the various programs by modifying the file called **HRD.USR**. The driver looks for this file on the same directory it was executed from. If present on the current directory, it reads this file, otherwise it will search for this file through all directories specified by the PATH statements. HRD looks for the associated programs in the default drive if the configuration file is not found.

There should be eight (8) lines in the HRD.USR file. The last two allow access to user-defined programs from within the HRD shell. The first forty (40) columns are reserved for the path statements and filenames for user-defined programs. The assignment of path statements is as follows:

Line   1 - Editor (your choice of line editors or word processors)
        2 - Main HOME RANGE program (HR)
        3 - HPLOT
        4 - HR3D
        5 - HREGA
        6 - Home Range using FFT
        7 - User-defined program 1 (cols. 1-40); description for menu (cols. 41-60)
        8 - User-defined program 2 (cols. 1-40); description for menu (cols. 41-60)

Example of HRD.USR File for Floppy System

```
Column numbers⁴
         1         2         3         4         5         6         7
1234567890123456789012345678901234567890123456789012345678901234567890123 45

A:\EDITOR.EXE                              ( User-defined editor drive/path/name )
A:\                                        ( Home Range drive/path )
A:\                                        ( HPLOT drive/path )
A:\                                        ( HR3D drive/path )
A:\                                        ( HREGA drive/path )
A:\                                        ( Home Range FFT drive/path )
A:\EPSON.COM                               Line Printer          ( User-defined 1 )
A:\MYPROG.COM                              Run MyProgram         ( User-defined 2 )
```

Example of HRD.USR File for Hard Disk System

```
C:\KEDIT\KEDIT.EXE                         ( KEDIT 4.00 drive/path/name )
C:\PROGRAMS\HOME\                          ( Home Range drive/path )
C:\PROGRAMS\HOME\                          ( HPLOT drive/path )
C:\PROGRAMS\HOME\                          ( HR3D /drive/path )
C:\PROGRAMS\HOME\                          ( HREGA (HR3D for EGA/VGA) drive/path )
C:\PROGRAMS\HOME\                          ( Home Range FFT drive/path )
C:\PROGRAMS\HOME\MYPROG.COM                Run MyProgram         ( User program 1 )
C:\TOOLS\BROWSE.COM                        File Viewer           ( User program 2 )
```

Running the Home Range Driver

Syntax: [d:][path]HRD [s]   where the optional command line parameter, *s*, will allow you to skip the logon screen and the disclaimer. If you are using this program for the first time, we request that you not skip these messages.

A. Floppy System

1. *One floppy disk drive*
   a. Insert diskette with HRD in drive A and type **HRD [s]** followed by <Enter>.
   b. After HRD has been loaded in memory, replace disk in drive A with your data disk.

2. *Two floppy disk drives*
   a. Insert disk with HRD in drive A and your data disk in drive B.
   b. Log onto the B drive and type **A:HRD [s]** <Enter>.

---

⁴Do not include the column numbers in your configuration file. They are shown to aid you in reading the example.

B. Hard Disk System

Copy HRD.COM to the (sub)directory where the HOME RANGE program is located or where the HOME RANGE package is located. HRD can also be run from another (sub)directory (assuming that you have set the proper path statements in your AUTOEXEC.BAT file and that the HRD.USR file is in the subdirectory). Type **HRD [s]** <Enter> to start.

Options From Main Menu

Making a Selection

Move the highlighted bar using the Up (↑) or Down (↓) Arrow keys or the <Space Bar> to the desired option, and press the <Enter> key. The last selection in any particular menu will get you back to the previous menu, or will return you to the operating system if you are in the main menu.

Menu Options

The driver menu appears as below:

```
╔════════════════════════════════════════════════════╗
║                                                      ║
║        HOME  RANGE  DRIVER    Version  1.02          ║
║  ┌────────────────────────────────────────────────┐ ║
║  │                                                  │ ║
║  │          Create or edit data                     │ ║
║  │          Run HOME RANGE                           │ ║
║  │          Run HPLOT                                │ ║
║  │          Run HR3D                                 │ ║
║  │          Manage files                             │ ║
║  │          Change directory                         │ ║
║  │          Run other programs                       │ ║
║  │          Shell to DOS                             │ ║
║  │          Exit to DOS                              │ ║
║  │                                                  │ ║
║  └────────────────────────────────────────────────┘ ║
║     Use ↑ ↓ keys or SPACE BAR to move highlighted    ║
║   bar to desired option, then hit ◀──┘ to select.    ║
╚════════════════════════════════════════════════════╝
```

1. *Create or edit data* - Accesses your choice of editor programs (line editor, word processor). Change the HRD.USR file to suit the editor that you use.

2. *Run HOME RANGE* - Runs the main HOME RANGE program.

3. *Run HPLOT* - Displays HOME RANGE output to the screen, plotter, or printer (see **HPLOT**, pages

53-58).

4. *Run HR3D* - Creates 3-D surface plot of harmonic mean utilization distribution to screen, or printer (see **Home Range 3D**, pages 59-62).

5. *Manage files* - Accesses file management utilities including directory listing, and copying, erasing, and renaming files.

6. *Change drive/directory* - Changes the current drive or directory. The current directory is displayed at the top of the screen. If you are changing drives, the drive letter must be followed by a colon (":"). To change (sub)directories on the same drive, enter the full path name. For example, you have a subdirectory named WILDLIFE\HOMRANGE on drive C: but you load HRD from C:\WILDLIFE\PROGRAMS. To go to C:\WILDLIFE\HOMRANGE, enter **WILDLIFE\HOMRANGE**.

    ☞ In some cases, it may be easier to change the directory using the **Shell to DOS** option (see #8 below).

7. *Run other programs* - Runs your choice of other programs included in this package or other external programs. There is room for two programs of the user's choice to be installed here. Example: Home Range using Fourier method (64 x 64 grid), etc. An example of the *Run Other Programs* menu might appear as below:

```
┌─────────────────────────────────────┐
│ ┌─────────────────────────────────┐ │
│ │       Run Other Programs        │ │
│ ├─────────────────────────────────┤ │
│ │                                 │ │
│ │   Run HR3D for EGA/VGA          │ │
│ │   Run Home Range (FFT)          │ │
│ │   ** NOT INSTALLED **           │ │
│ │   ** NOT INSTALLED **           │ │
│ │   Run a Program                 │ │
│ │   Exit                          │ │
│ │                                 │ │
│ └─────────────────────────────────┘ │
└─────────────────────────────────────┘
```

8. *Shell to DOS* - Executes DOS commands or runs any program. Type **EXIT** when finished to return to the driver. Unpredictable results may occur if you load and run memory resident programs. However, we have run SuperKey without any problems.

    Note: The command interpreter file (COMMAND.COM) must be on the default drive or on the drive specified by the **SET COMSPEC=** statement in your DOS environment. Refer to the DOS manual on how to set up the environment.

    Recommended uses of this DOS interface are full directory listing of files, copying or erasing files, changing directories, running other programs, running SuperKey, etc.

9. *Exit to DOS* - Terminates HRD and returns to the operating system.

HOME RANGE ESTIMATORS

Introduction

An animal's home range has been defined as the area used by an individual during its normal activities such as food gathering, mating, and caring for young (Burt 1943). This definition is not statistically rigorous, and over the years, many statistical and non-statistical definitions have been proposed. A variety of methods have been traditionally used including the minimum convex polygon (Hayne 1949) and bivariate normal home range (Jennrich and Turner 1969). Recent papers have identified several problems with these commonly-used techniques, primarily in failure to meet assumptions about underlying distributions (MacDonald et al. 1980, Schoener 1981, Anderson 1982, Worton 1987). Samuel and Garton (1985) developed a robust weighted bivariate normal estimator. Recent techniques have employed the concept of a nonparametric utilization distribution (UD) based on frequency of animal locations (Ford and Krumme 1979, Dixon and Chapman 1980, Anderson 1982, Worton 1987). Increasing emphasis has been placed on spatial patterns of use, including centers of activity, core areas, and dynamics of the home range (Dixon and Chapman 1980, Jaremovic and Croft 1987).

The HOME RANGE program was developed to provide home range estimates based on an extension of the harmonic mean utilization distribution (Dixon and Chapman 1980). In addition, the program computes the minimum convex polygon (including estimates based on a specified percentage of inner points), bivariate normal and weighted bivariate normal home ranges (Samuel and Garton 1985) for comparison. A separate program (HRF) calculates the home range estimate using the Fast Fourier Transform (Anderson 1982). Animal locations may be tested for bivariate normality using a Cramer-von Mises goodness-of-fit test. Potential outliers are identified using three different procedures. Three tests of serial correlation are made (Swihart and Slade 1985a,b, 1986).

The HOME RANGE program features seven basic options for calculating various aspects of home range use patterns. These features may be selected separately or in combinations. The options chosen will vary depending upon the quantity and quality of data acquired and user objectives. A brief discussion of each option and pertinent literature sources follows to aid in the selection process.

Convex Polygon

One of the first home range estimators was the minimum convex polygon (Hayne 1949). This is a simple and an intuitive method for calculating the area enclosed by a set of locations (Bekoff and Mech 1984). The peripheral locations of an animal are connected in such a way that the internal angles of the polygon thus generated do not exceed 180 degrees. But its usefulness diminishes when used to estimate the area which can or will be used by an animal (use of a utilization distribution). It is strongly biased at small sample sizes and may not be asymptotic (Jennrich and Turner 1969, Mares et al. 1980, Schoener 1981, Anderson 1982, Worton 1987). It is severely affected by outliers, and may include large areas never observed to be used by the animal (MacDonald et al. 1980). It provides no information on the area potentially used by an animal, only that which was used during the exact

9

periods of observation. It also provides no information as to how the area within the home range is used. The program reports the area and draws the boundary for this method.

Other variations, such as several different concave polygons have been suggested (Harvey and Barbour 1965, Jennrich and Turner 1969), but are difficult to define or program unambiguously, and are not used here. The algorithms proposed vary widely, and some are ambiguous depending on which boundary locations are chosen for the starting point (McDonald *et al.* 1980, Worton 1987).

Percent Convex Polygon

A new routine was recently added to calculate "percent" convex polygons (Michener 1979, Bowen 1982, Bekoff and Mech 1984). These are concentric minimum convex polygons whose boundaries encompass only a specified innermost percentage of all the observations. This method provides some information on area used within the home range. It can also be used to reduce the effect of outliers. The above authors differ slightly on how the current "center" should be determined, as outer observations are removed. This program takes the computation-intensive approach of removing the observation farthest from the arithmetic center, recalculating a new arithmetic center, then repeating until the required number of observations has been sequentially removed. Michener (1979) considered the 50% convex polygon to be a "core" area. Percent convex polygons are calculated for each contour specified in the CONTOUR command, in addition to the traditional 100% polygon previously discussed.

Bivariate Normal Ellipse

The bivariate normal (non-circular) estimator was developed by Jennrich and Turner (1969), and Koeppl *et al.* (1975). It can be derived directly as a confidence region around the mean of a two-dimensional bivariate normal distribution (e.g. Johnson and Wichern 1982:187-202). Madden and Marcus (1978), MacDonald *et al.* (1980), Schoener (1981), and Anderson (1982) critiqued the method. The model is parametric, and should only be used on data that are bivariate normally distributed. The shape of the estimated home range will of course be restricted to an ellipse, regardless of the true pattern of the animal's movements, and may include areas not used by the animal. Data from many animals have been found not to conform to the assumed bivariate normal distribution (Waldschmidt 1979, MacDonald *et al.* 1980). If the bivariate normal distribution is appropriate for the data, the method should be robust at small sample sizes, otherwise it will include too large an area. The large sample (asymptotic) standard errors are estimated for the 75% and 95% home range areas (Dunn and Brisbin 1982). To date, this is the only method which has a standard error. Adherence to a bivariate normal distribution (Smith 1983, Samuel and Garton 1985) can be tested in the program. The method is somewhat affected by outliers.

Weighted Bivariate Normal Ellipse

This technique is a variation of the bivariate normal (non-circular) home range (Samuel and Garton 1985). A bivariate normal distribution of animal locations is assumed, but locations that are far removed from the geometric center have a reduced influence on the home range ellipse. This reduced influence is indicated by weights less than 1.0 assigned to extreme locations. These weights should be used to identify data errors and outliers (see **Outliers**, page 14). The maximum likelihood weighting procedure follows Randles *et al.* (1978). Details of the procedure, and an example of the influence of outlying points on the size and orientation of the home range estimate, are given in Samuel and Garton (1985). This method should be more robust to deviations from a bivariate normal distribution. Again, fit to the underlying weighted bivariate normal distribution can be tested. This method should also be much less affected by outliers.

Bivariate Distribution Tests

Animal locations may be tested for bivariate normality or bivariate uniformity using a Cramer-von Mises goodness-of-fit test. Critical values for the bivariate normal and uniform tests are calculated using finite sample, empirical distribution-free (EDF) procedures (Stephens 1974). This procedure should be more powerful than the χ^2 test proposed by Smith (1983). The bivariate normal test is made by comparing the squared Mahalanobis distances to an expected exponential distribution. The weighted bivariate normal test is similar, but the squared Mahalanobis distances have an expected χ^2 distribution with 1.96 degrees of freedom (Campbell 1980). The critical values for the weighted bivariate test are interpolated from Koziol (1982:Table 1). The bivariate uniform test follows the methods of nearest neighbor analysis of spatial patterns reviewed by Diggle (1979). Nearest distances from random points to animal locations sweep areas that are expected to follow an exponential distribution when the points are uniformly distributed. This test closely parallels the bivariate normal test. Examples of both tests are presented in Samuel and Garton (1985).

Harmonic Mean

The harmonic mean home range estimator is a nonparametric method, based on the volume under a fitted three-dimensional utilization distribution. It may be bi- or multimodal. The distribution is based on harmonic mean values calculated at grid points systematically located throughout the animal's home range (Dixon and Chapman 1980). The underlying nonparametric utilization distribution is calculated using harmonic means, one of several areal distributions described in detail by Neft (1966). The contours of the utilization distribution may be chosen as specified harmonic values (Dixon and Chapman 1980), or as specified percentages of the animal's utilization distribution.

The concept of utilization distributions is discussed by Van Winkle (1975) and Anderson (1982). The determination of a utilization distribution requires estimating the probability of use at any location in the home range. The harmonic values at each grid point are used to calculate a utilization

distribution. All grid points with harmonic values that exceed the highest harmonic value for any animal location, are considered to be outside the home range. These grid points are excluded from the utilization distribution. The *potential* utilization (observations ÷ area) is estimated at each grid point by dividing the total number of animal locations by the squared harmonic value at each grid point. Potential utilization is summed over all grid points within the home range and scaled to 1.0 to create a utilization distribution. Percentages of the utilization distribution are determined from the ordered sum of grid points.

The harmonic mean estimate was criticized by Spencer and Barrett (1984) and Worton (1987, 1989), as being overly sensitive to the choice of scale parameters. Jaremovic and Croft (1987) described a different grid cell system. The advantages and applications of the harmonic mean estimator to determine activity centers were discussed by Dixon and Chapman (1980). There may be more than one activity center, and centers of activity need not be in the center of the distribution. These activity centers should be more robust to changing area use patterns than with other methods. Because it is nonparametric, the harmonic mean estimator should be more robust to deviations from any particular underlying distribution. Sample size required for a nonparametric method such as this is large, because the underlying distribution must be estimated from the data, rather than fitting an assumed parametric distribution. It should be less affected by outliers. Harmonic mean values for each observation can be used to identify outliers.

Fourier Transform

The Fourier transform method (Anderson 1982) is another nonparametric technique based on a utilization distribution. The home range size is calculated from the estimate of the UD as the smallest area encompassed by some percentage, say 95%, of the volume of the distribution. Anderson (1982) tested the method, and found it superior to the convex polygon and bivariate normal ellipse. This method has not been used extensively in studies of home range, even though Anderson (1982) contended that the UD contains more information than the home range size alone, and can visually illustrate spatial use (as does the harmonic mean). However, the Fourier method has been used in home range studies of the giant kangaroo rat (Braun 1985) and the eastern grey kangaroo (Jaremovic and Croft 1987). Although it is possible to obtain regions for which the estimated UD has negative values which render the UD meaningless, these areas can be ignored since biologists are usually interested in centers of activity (Worton 1987, 1989). Its properties are similar to those of the harmonic mean technique——robustness to underlying distribution and to outliers. As does the harmonic method, the Fourier method requires relatively large sample sizes (N > 100) to estimate the UD accurately, because the estimates are biased at small sample sizes due to the difficulty in estimating the tails of a distribution (Anderson 1982, Worton 1987). Anderson (1982) recommends that MAP(0.50) should be used for estimating home range sizes instead of the MAP(0.95). See pages 63-66 for a more complete description of the implementation of the Fourier transform method of home range analysis. Worton (1987, 1989) presented kernel estimation techniques which are related to the Fourier method, but may have additional favorable properties.

OTHER HOME RANGE CONCEPTS

Core Areas

The concept of core areas has received considerable use in the ecological literature. The idea has generally been used to denote central areas of consistent or intense use (Kaufmann 1962:170). The identification of core areas is an effort to describe the "internal anatomy" of home ranges (Adams and Davis 1967, Ewer 1968, Leuthold 1977). Core areas should be unaffected by outliers and less affected by sample size.

HOME RANGE identifies core areas by comparing the utilization distribution from harmonic mean calculations with a uniform use model (Samuel et al. 1985a). Core areas are defined here as the maximum area where the observed utilization distribution (based on harmonic values) exceeds a uniform utilization distribution. Others have defined core areas as inclusion of 50% of observations (Kaufmann 1962), 50% harmonic mean contours (Dixon and Chapman 1980), MAP(0.50) estimates (Anderson 1982, Braun 1985), or 50% convex polygons (Michener 1979, Bowen 1982). In the harmonic mean core area, the uniform distribution is used as the null model because it indicates a lack of any preference for areas within the home range. A Kolmogorov test (D+, p=0.05) was formerly used to determine if observed use was significantly greater than expected (Samuel et al. 1985a). This has been replaced by a χ^2 test (Samuel and Green 1988), made on the ordered cumulative distribution of observed data, compared to the uniform model. An illustration of the statistical test and further description of the methods are presented in Samuel et al. (1985a) and Samuel and Green (1988).

Center of Activity

Center of activity has often been used to describe the single most important point in the animal's home range. Previous methods have used estimators such the arithmetic mean of X and Y coordinates of locations, or the mode (center) of an assumed parametric distribution such as the bivariate normal (Van Winkle 1975, Dixon and Chapman 1980, Lair 1987). But these methods share the disadvantage that the defined center of activity may not actually be in the area most intensively used by the animal.

Dixon and Chapman (1980) suggested that the harmonic center of activity (minimum value of the nonparametric harmonic mean distribution) should be more reliable for determining the location of the most important use areas. This method should also be preferred when the center of activity shifts through time (Dixon and Chapman 1980). Lair (1987) tested estimators based on the arithmetic mean, median, and harmonic means of empirical data, and found the harmonic mean the most satisfactory.

Multiple centers of activity also may exist in an animal's home range. This is easily determined using the nonparametric estimators (just as utilization contours may have multiple segments). Don and Rennolls (1983) proposed a parametric model based on multiple, circular normal distributions surrounding known centers of activity.

Use of Weighting Factor

Each observation must be given a weight indicating the relative importance of that point. These weights are only used in the harmonic mean analysis. The HOME RANGE program assumes that weights are assigned so that they sum to the total number of independent animal locations used to estimate the harmonic home range. However, this is not absolutely required. The most common application will consider all points as equal in importance and therefore have weights of 1.0 for each observation. However, two independent observations at a single X, Y coordinate might use a weight of 2.0, etc., rather than entering the same locations twice. The automatic grid density calculation option (pages 15 & 17) should not be used when the sum of the weights does not equal the number of non-zero observations. For this case, grid density must be calculated manually.

Outlier locations may be excluded from the harmonic home range estimate, but still plotted, by using a zero weight. Subsets of the animal locations may also be analyzed by assigning zero weights to those points that are excluded from the analysis. An alternative application might use the weights to represent the relative amount of time spent at each location (Braun 1985, Samuel and Garton 1987). Such an approach might be appropriate when the amount of time spent at each location is recorded. Weighting factors might also be used to reduce serial correlation, if "non-independent" points can be identified. The weight of each point would then reflect the number of locations gathered within each "time to independence" (Swihart and Slade 1985b). Another application might be to weight each observation by the number of animals present, to obtain a composite home range, say for all the individuals in a wolf pack. These weights should usually be scaled so as to sum to the number of independent locations. Failure to observe this limitation may result in harmonic mean values that cannot be compared between individuals.

Outliers

Animals may occasionally wander from their normal activity areas (excursions, sallies, nomadic movements) producing extreme locations (outliers) that dramatically affect home range estimates. Extreme locations may result from brief long-distance excursions by the animal, or from mapping or coding errors in the data. By Burt's (1943) definition, occasional excursions outside the "normal" area of use should not be considered part of the home range. Outliers can also represent transitional locations between seasonal use areas, or one-time excursions to areas beyond the boundaries of the normal home range. If the biologist is interested in identifying that area used repeatedly by an animal in its daily activities, outlying points should be excluded from the analysis. Extreme locations may have a substantial influence on the home range determination. Outliers influence home range estimates using convex polygon and bivariate normal methods, and to a lesser extent, the harmonic mean and Fourier transform techniques. The inclusion of outlying points can result in large areas being included in the home range boundary, which may be outside the areas normally used by the individual. Contours based on the harmonic mean utilization distribution define areas that encompass a percentage of the total potential use. Outlying points have a dramatic effect on the higher percentage contours (e.g. 95%), but usually have a smaller influence on the selection of lower percentage contours (e.g. 50, 75%). Outliers tend to have less of an influence with large sample sizes than with small sample sizes, especially for the harmonic mean technique. Outliers also can affect the selection of core use areas.

The convex polygon method is strongly influenced by outliers.

The HOME RANGE program helps to identify outliers and data coding errors through three different procedures: (1) a binomial test of observation density, (2) a weighted bivariate normal technique, and (3) a list of points with large harmonic values. These methods are provided to identify any potential outliers, but they must be examined by hand and kept or deleted. These points must be removed from the input data set by the user to remove their influence on the home range estimates. However, points may be excluded from the harmonic mean analysis by assigning zero weights (see **Use of Weighting Factor**, page 14) or by removing these points from the input data file. Potential outlier locations are identified (but not excluded from analysis) by a binomial statistical confidence interval test. The test compares a relative measure of location density between progressively less extreme locations in the data. Significant changes in the relative density are used to identify potential outliers. Locations that have weights from the weighted bivariate normal analysis less than 0.6 should also be considered potential outliers. Finally, observations with harmonic mean values markedly higher than the rest should also be reviewed as potential outliers. We suggest all of these procedures be used to identify data errors, and to assist in the identification of observations that are outside the normal use area.

Harmonic Grid Density/Scale

Once the user decides which data to include in the analysis, the scale and grid density for harmonic mean home range estimates must be determined. Both the scale and grid density influence the home range estimates obtained from the harmonic mean method (Dixon and Chapman 1980, Spencer and Barrett 1984, Worton 1987, 1989). This is one part of the program which new users find most confusing.

The harmonic estimate is based on a utilization distribution, calculated on a rectangular grid of square cells. This grid is used to calculate the nonparametric harmonic mean distribution from the animal's location data. The number of cells in the grid is specified on the SELECT card (page 25), for the X and Y axes. The default value is 48 * 21, the maximum is 72 * 32. Size of each grid cell in real units (e.g. meters) is therefore dependent on the SCALE parameter and the number of cells.

The plot area is 24 * SCALE units wide (west-east) and 10.5 * SCALE units high (north-south), and this ratio is fixed. This arrangement is a convenient artifact from the previous mainframe version where the plot actually measured 24 * 10.5 inches, and the plot scale was actually determined by the SCALE parameter. However, this procedure was only able to plot on one kind of plotter, without doing extensive changes and compiling. Scale of the plot was controlled by the user, but it was sometimes difficult to achieve a plot of a convenient size. With the present program, several kinds of plotters and other display hardware can be accommodated, and each plot fits on a standard page. However, the plot scale can no longer be set by the user. *(We hope to provide this option in the future.)*

Each of the animal locations, and all of the harmonic contours must fit on the harmonic grid; otherwise the estimates will be invalid. This can be adjusted by the choice of the SCALE and the number of grid cells. The size of the plot area must be large enough to accommodate all of the data. Increasing the SCALE ensures a large enough area, but if too large, the resolution of the harmonic estimate is affected. This results because the animal's locations are cramped into a small part of the grid, and most of the grid is wasted. Essentially, the grid should just fit the data, and the number of grid cells should be appropriate so that the locations are spread throughout the grid. If the grid cells

are too large, too many animal locations fall within a few cells (see Anderson 1982:Fig. 1), and harmonic contours will incorrectly have similar estimates regardless of the percent of the distribution described. This extreme situation must be avoided to achieve reliable harmonic mean estimates. If the grid cells are too small, each animal location could ultimately fall within its own grid cell (see Anderson 1982:Fig. 1), and cause separate contours to be drawn around each location. The increase in grid density will also substantially increase computer time required for harmonic mean calculations. We have not chosen to add capacity for more grid cells for this reason.

Decreasing the SCALE (making the grid smaller in real units), or increasing the number of cells, both result in smaller grid cells. This increases the resolution of the plot, and can result in contours with more detail, especially if many of the locations are densely clustered. The data are spread more thinly on the grid. Increasing the SCALE (producing a larger grid) reduces the chance of locations or contours extending past the grid boundaries (causing the error message *"Observation not assigned to grid"*). If the error message *"Plot scale too small to determine total utilization volume"* occurs, the grid SCALE should then be increased. Similarly, decreasing the number of grid cells causes poor resolution, because the locations are not dispersed over enough grid cells making calculation of contours difficult.

As a rule of thumb, we suggest choosing the SCALE parameter so that it is approximately the larger of one-eighth of the range of Y coordinates, or one-twentieth of the range of the X coordinates. This procedure will usually result in a suitable dispersion of locations, without extending over the grid boundary. Rotation of the axes (described below) should be considered when the data are oriented predominantly in a north-south direction.

Next, the grid density should be selected to achieve an average of one observation per grid cell. This can be accomplished automatically by choosing -1,-1 for the number of grid cells on the SELECT card. An algorithm has been developed to select an optimal grid density (number of grid cells). The algorithm is provided at the end of this section. It can be calculated by hand, but this is not usually necessary except in unusual applications. Occasionally, if some locations are highly clustered, the error message *"Grid density exceeds maximum"* will be printed. This means that the number of cells chosen by the algorithm was higher than the allowable maximum (72 x 32). This may be resolved by decreasing the SCALE, to get a smaller harmonic grid (real units).

In order for harmonic estimates to be most comparable between animals, we suggest that the SCALE and grid cell parameters be the same for each animal. Run each animal separately with a reasonable choice of SCALE and the -1,-1 choice for automatic calculation of grid density. Then choose an average or typical value for SCALE and number of grid cells, based on the initial runs for each animal. Finally, re-run all of the animals using the average values selected. It may be necessary to separate two groups of animals with very different movement patterns, such as adults and juveniles, males and females, residents and floaters, etc. Usually this must be done when the two sets of home ranges differ greatly in size.

Rotation of Axes

If the distribution of locations is much longer in the north to south direction (Y axis), the data can be rotated. This allows a much better fit to the rectangular grid. The simplest approach is to insert a minus sign in front of each Y (north) coordinate. Then rearrange the FORTRAN format statement to read the Y coordinate before the X coordinate. For instance, instead of reading the east and north

coordinates as 1000.0□□200.0[5], using (F6.1,2X,F5.1), read 1000.0□-200.0 using (T8,F6.1,T1,F6.1). This will produce a plot with north on the left, instead of the top (see **FORTRAN Format Primer**, page 31).

Algorithm for Manual Calculation of Grid Density

The number of grid cells should be selected to achieve an average of one animal location per grid point. This can be calculated automatically using the -1,-1 option on the SELECT card. But it is occasionally useful to manually calculate the best number of grid cells.

This can be accomplished by using the following algorithm, based on the area covered by the locations, and the number of points on the perimeter of the convex polygon.

(a) Calculate the number of effective points (EP), using the total points (TP) and the number of points defining the perimeter (PP) of the convex polygon home range.

$$EP = (TP - PP) + 0.25 (PP) = TP - 0.75 (PP)$$

(b) Calculate the average area per grid point (AVG) from the minimum convex polygon (MCP) area and the number of effective points.

$$AVG = MCP \text{ area} / EP$$

(c) Calculate the grid width (GW) per point:

$$GW = SQRT(AVG)$$

(d) Number of grid points on the X axis is:

$$(SCALE \text{ units per inch} / GW) * 24$$

(e) Number of grid points on the Y axis is:

$$(SCALE \text{ units per inch} / GW) * 10.5$$

The results can be rounded to the next lower integer value, and input on the program selection card (see **Selection Card**, page 25). The HOME RANGE program automatically calculates grid density by this procedure when the number of grid points on the X or Y axis is specified as negative (see pages 25-27). This algorithm was developed as an *ad hoc* procedure for achieving repeatable harmonic mean estimates that also reflect the number of animal locations. No theoretical justifications can be offered, but applications appear to support its use.

---

[5]□ indicates a space (ASCII character 32).

Serial Correlation

Serial (or auto-) correlation occurs when locations are obtained which are too close together in time and space——they are not independent, that is, the animal has not had time to cross a statistically significant part of its home range. But all of the home range estimators discussed so far require, essentially, that locations be independent random samples of the animal's movements in its home range. Significant autocorrelation will likely make home range estimates too small (biased). This is because the "effective" sample size is actually smaller than the number of locations made.

Schoener (1981) proposed an index, t^2/r^2, to indicate the average time which must elapse for observations to be independent——the "time to independence." This index compares the mean distance moved in each time interval to the mean distance between all possible pairs of locations. Significant deviations from the expected value of 2.0 indicate that sequential locations are related to each other, rather than random samples. However, Lair (1987) suggested using a shorter "biological time to independence", since an animal can choose not to move in a time interval.

Swihart and Slade (1985b, 1987) modified the t^2/r^2 ratio, and developed two other indices to serial correlations, namely: ψ (psi, Swihart and Slade 1985a), and γ (gamma, Swihart and Slade 1986). These are statistical indices based on the correlation between the X coordinate for each location and the previous X coordinate (and similarly for Y, and cross-correlations of X with previous Y, and vice versa).

These three indices of serial correlation (ψ, γ, and t^2/r^2) are automatically calculated, and can be used to determine whether the sampling interval is adequate to ensure that data are not autocorrelated. Significant autocorrelation will likely make home range estimates inaccurate (too small) in comparison to a home range estimated only from independent data. Unfortunately, simple critical values for ψ and γ are not yet available, but as very rough guidelines, the values (Table 1, below) indicate significant ($P < 0.05$) autocorrelation. Swihart and Slade (1985b, 1987) described methods for determining significance of t^2/r^2 under certain conditions. Standard errors are provided by the program for t^2/r^2 under five sets of assumptions (Swihart and Slade 1985b, 1987). These can be tested against the expected value of 2.0 using a *t*-test.

Table 1. Rules-of-thumb for use of serial correlation tests. However, the user must apply these indices cautiously to determine the correct set of assumptions regarding the length of bursts (Swihart and Slade 1986, 1987).

Index	Expected value (if observations are independent)	Test significant if value
ψ (psi)	0.0	> 0.6
γ (gamma)	0.0	> 0.3
t^2/r^2	2.0	< 1.6 or > 2.4

When significant autocorrelation exists, it can be overcome by (1) randomly deleting locations until serial correlation is no longer significant, (2) by determining the "time to independence" (Swihart and

Slade 1985b), and removing locations too close together in time, or (3) using reduced weighting factors (< 1.0) for locations within each "time to independence" such that each set of weights sums to 1.0 (Samuel and Garton 1987). In some cases, for animals which use their home range slowly, such as moose (Garton *et al.* 1985), it may be impossible to obtain a large sample size of independent observations within a biological season (Swihart *et al.* 1988). Lair (1987) argued that in some cases, space use patterns would likely change before an adequate, statistically independent sample was attained.

In contrast to all other home range estimators which require serially uncorrelated data, one home range estimator has been developed which requires bursts of intentionally correlated data. The Multivariate Ornstein-Uhlenbeck (MOU) model (Dunn and Gipson 1977, Dunn and Brisbin 1982) assumes that the animal's home range is bivariate normal, and that the movements within any burst are also described by a bivariate normal distribution. This method has received little use. The method has been reviewed by MacDonald *et al.* (1980) and Worton (1987), who concluded that the assumptions about an animal's movement may be unrealistic.

Strategies for Temporal Sampling Patterns

Researchers should be aware of the time-sampling problems in collecting telemetry data. One particular concern is with the data collection procedure. Only those locations that meet the implied assumptions should be included in any analysis. The first assumption requires that locations be independent from each other (see **Serial Correlation**, page 18). This can affect calculation of home range contours and activity areas. This assumption is frequently violated when data are collected by repeated observations separated by relatively short time intervals (Swihart and Slade 1985b, Lair 1987, Worton 1987). This problem is especially critical when sampling efforts are not equally distributed through time. For example, suppose an animal was radio-located on two consecutive days. On the first day, the researcher spent the entire day with the animal recording locations every hour. By the end of the day, 10 relocations had been made. On the second day, the researcher only located the animal once in the morning and once in the evening; the rest of the day was spent locating other individuals. If all data were entered, 12 relocations would define the animal's home range for those two days. The data from the first day would outweigh that from the second day, when in fact the animal spent an equal amount of time (one day) in each area.

A second related assumption is that the probability of detecting an animal in any part of its home range is proportional to the amount of time the animal spends in that area. This especially affects calculation of activity areas. This assumption may be frequently violated when data are collected while radio-tracking from the ground in relatively inaccessible areas. Data collected from animals with large home ranges are also susceptible to violations of this assumption. When biologists are more likely to find or locate animals that are close to roads or trails, the estimate of potential use for these accessible areas will be biased (Garshelis 1983). This should not be a significant problem with data collected from an airplane, or where access is not limited. Similarly, researchers may be tempted to oversample areas where animals are easiest to locate (e.g. nest or den sites, open areas). One often wishes to locate an animal as many times as possible. But while large sample sizes are usually desirable, consideration must be given to avoiding also uneven or serially correlated data (see **Necessary Sample Sizes**, page 20). Locations which violate these assumptions cause spurious activity areas to be identified, which

reflect only data collection procedures and not the animal's true behavior. It is extremely important that the user attempting to describe activity areas also identify sources of bias and remove inappropriate data from the analysis. If they are not removed, results from the HOME RANGE program may be misleading.

Finally, observations should ideally be made randomly throughout the 24-hour cycle, or at least throughout an animal's activity period (Smith *et al.* 1981). Likewise, samples should be made throughout the season of interest. However, Smith *et al.* (1981) argued that an entire season's home range for coyotes can be ascertained from a few nights of continuous tracking. Such assumptions must be tested before relying on them. Home ranges can change within seasons (Dixon and Chapman 1980, Lair 1987). Such an assumption might hold only for a territorial central-place forager, like a coyote with a den (Swihart *et al.* 1988). Swihart *et al.* (1988) showed that the rate of home range use depends on body size and foraging mode.

Data which are collected in a non-random manner will not reflect the true home range of an animal.

Necessary Sample Sizes

Necessary sample sizes for some home range estimators have been studied, but results depend on the choice of home range estimators and the underlying distributions (Jennrich and Turner 1969, Mares *et al.* 1980, Schoener 1981, Smith *et al.* 1981, Anderson 1982, Bekoff and Mech 1984, Laundre and Keller 1984, Swihart and Slade 1985a, Jaremovic and Croft 1987). We refer the reader to these references.

Most work on necessary sample sizes has been done using the convex polygon for territorial species, where the home range has some fairly definite boundary. In these cases, whether studies are empirical (songbirds, Odum and Kuenzler 1955; coyotes, Smith *et al.* 1981, Laundre and Keller 1984; wolves, Fuller and Snow 1988) or computer simulations (Bekoff and Mech 1984; Swihart and Slade 1985a), the convex polygon estimator may require moderate sample sizes (20-50 locations per season). However, some authors find larger sample sizes (100-200) are necessary to avoid problems with accuracy and precision (Bekoff and Mech 1984, Laundre and Keller 1984, Swihart and Slade 1985a).

However, when compared with an infinite sampling distribution, which would better describe non-territorial species, the convex polygon has been found to be severely biased at even large sample sizes (Schoener 1981, Anderson 1982, Swihart and Slade 1985a).

Sample sizes for the ellipse estimator have been studied (Jennrich and Turner 1969, Schoener 1981, Anderson 1982, Jaremovic and Croft 1987). Sample size requirements are similar to those for the convex polygon (20-50), provided the data are from a unimodal, non-skewed distribution. Otherwise, estimates may be severely biased even at large sample sizes (Anderson 1982). Uniquely, sample sizes required to obtain a specific precision for the ellipse estimators may be calculated using the asymptotic standard error (Dunn and Brisbin 1982).

Under natural conditions, such as a multimodal, skewed distribution, simulations show that the harmonic mean and Fourier estimators appear most stable, and while requiring larger sample sizes (50-100 locations per season), they have better properties (Anderson 1982, Jaremovic and Croft 1987, Ackerman and Garton *unpublished data*). Not only do these contours subjectively conform to observed areas of use, but additional information is provided about use patterns within the home range.

USING THE HOME RANGE PROGRAM

The determination of a harmonic utilization distribution requires estimating the probability of use at any location in the home range. The harmonic values at each grid point may be used to calculate a utilization distribution. All grid points with harmonic values that exceed the maximum for any animal location are considered to be outside the home range. These are excluded from the utilization distribution. The potential utilization (observations ÷ area) is estimated at each grid point by dividing the total number of animal locations by the squared harmonic value at the grid point. Potential utilization is summed over all grid points within the home range and scaled to 1.0 to create a utilization distribution. Percentages of the utilization distribution are determined from the ordered sum of grid points.

The HOME RANGE program differs from the original algorithm of Dixon and Chapman (1980) for calculating harmonic mean estimates in several important ways:

(1) animal observations are relocated to a constant mean distance from the nearest grid point,
(2) this distance is the mean radius of the grid, and thus harmonic calculations depend on the grid size,
(3) a utilization distribution is produced from the harmonic mean measure at each of the grid points,
(4) utilization contours may be estimated as percentiles of this distribution,
(5) density of grid points for harmonic mean calculations may be varied, and
(6) significant core areas are identified and plotted.

Dixon and Chapman (1980) recommended that observations within one unit of distance to a grid point should be intentionally biased by adding one. This procedure has several disadvantages. First, the bias is not independent of scale. The addition of one unit may be appropriate for small harmonic values, but inappropriate for animals with large home ranges. Second, if observations are close to a grid point, the use of a small bias causes the bias factor to overwhelm the harmonic calculation. A more suitable bias should incorporate the scale of the home range being estimated. HOME RANGE relocates all observations to a mean distance from the nearest grid point. This distance is the radius that encompasses half the area of the grid. This procedure has the favorable property that the bias is automatically adjusted with grid size and scale variations.

Three sections of program input and output occur during a run: program control, data input, and output. Program control consists of six subsections that provide a title for the run, select program options, provide scale information to the program, report the method used for entering animal locations, choose the plot offset, and determine the values of contours to be plotted. Data input contains format specifications and animal locations, according to the method selected in program control. The output text file summarizes the options selected, lists animal locations for verification, provides data on harmonic values, and shows home range estimates for the methods selected. Three other output files may be produced for use in secondary analysis of home range calculations. One contains data for plotting the home range contours. The second file contains each location for plotting the animal's movements. The third output file contains the harmonic value calculated at each grid point, for creating a 3-dimensional plot of the utilization distribution. Each input and output phase is described in subsequent sections.

21

Program Limitations

A maximum of **1000** animal locations can be used in one run (previous microcomputer versions allowed only **300**). Twenty contours can be plotted in one run. Time to run with all options invoked (IBM PC/XT at 4.77 MHz):

Number of locations	25	50	100	200	300	1000
Time in minutes	1	2	3.5	8	12	70

Output Files

Four files can be created, named after the input file, but with different extensions. (1) File "*.OUT" contains text output describing the input data, home range methods requested, calculated home ranges, and results of distribution tests. (2) File "*.PLT" contains the coordinates of symbols and curves to generate plots. The format of this file is described on pages 53-54 and by example in Appendix A (see pages 77-79). The HPLOT utility is used to access this file and drive an HP plotter (HP 7470A 2-pen; HP 7475A 6-pen), or plot to the screen with an Color Graphics Adapter (CGA) or Enhanced Graphics Adapter (EGA) and graphics monitor. Hercules graphics cards are also supported. (3) The optional "*.MOV" file contains list of coordinates to map the animal's movements used for plotting with HPLOT. Its format is similar to that of the "*.PLT" file. (4) The optional "*.HAR" file contains a matrix of harmonic mean values for generating 3-D plots of the utilization distribution using HR3D or HREGA. Format of the "*.HAR" output file is described on page 59. It consists of the calculated harmonic mean values at each grid intersection. The grid harmonic values, may be squared and inverted (total observations ÷ harmonic mean squared) to determine the relative utilization volume associated with each grid intersection. If the harmonic mean value at a grid intersection is larger than the harmonic mean value at any observation, then the calculated value is set to zero.

All files are in ASCII format and can be printed using the DOS "PRINT" command, or edited using an editor or word processing program.

New Features

Percent-use convex polygons (Michener 1979, Bowen 1982) are generated for all contours specified by the CONTOUR control card (if convex polygon is chosen on SELECT control card). Polygons are "concentric", and each includes the specified innermost percentage of the locations. Output format is the same as for the original (100%) minimum convex polygon, which is always included. Convex polygons may now be plotted.

Three indices to serial correlation (Swihart and Slade 1985a,b, 1986) with standard errors for t^2/r^2 are now generated (see **Serial Correlation**, page 18).

The three lists of data points in the output have been improved by retaining observation ID and sequence number labels for each location. This makes it easier to identify problem data points.

The test for a significant harmonic mean core area now uses a χ^2 test rather than a D-max

goodness-of-fit test (Samuel and Green 1988).

The random number generator used in the test of a bivariate uniform distribution has been improved. The algorithm for the current random number generator (Wichmann and Hill 1982) is superior to that used previously (Schrage 1979). The seeds for the generator can either be read from the computer's clock or input from the keyboard. If the user chooses to supply the seeds, the user will be prompted for three seeds after the program calculates the bivariate home ranges. The seeds can be any integer number between 1 and 30000. These seeds are stored in the ouput file (*.OUT) for your information.

Plots from several animals (or same animal for several seasons, etc.) can now be combined by appending the "*.PLT" files together. See HPLOT utility documentation (page 53) for information on codes for different curves and symbols.

Batch processing - Allows you to run a group or list of input files (up to a maximum of 100) at once. A report (number of errors and warnings) for each run is written to a log file (*.LOG). Here's what you need to do: Create a list of files (ASCII or DOS text format) that you want to run in a batch (see the example **FILES.DIR** included on disk). Remember that each filename can be no longer than 12 characters. Also, do *not* include drive and path names with the filename. Each filename must be left justified (columns 1 to 12). You may also include identifying information (up to 50 characters) about a particular file. Remember that this information is optional *but* if you do include them, it should be placed starting at column 15 and can go all the way to column 64.

Changes and Clarifications in Input Control Cards

All character strings in the input data file can either be in upper or lower case.

A default set of home range methods and tests can be selected by replacing the SELECT card with one with DEFAULT in cols. 1-7, and omitting the METHOD, OFFSET, and CONTOUR control cards.

FORMAT: Observation ID information (identifying locations) must be read in as character format (e.g. A8) in the format statement.

Mainframe Features Not Present in the Microcomputer Version

Station and bearing-range data cannot presently be used ["EVAL 1", "EVAL 2" options - described previously in Samuel *et al.* 1985b]. Only X and Y coordinates can be entered ["ENTER" option]. (*May be reinstated in the future.*)

The rescaled grid intersection coordinates cannot be output to file 22.

Most aspects of plotting are now controlled by the various utility programs. This allows more flexible plotting to a variety of hardware without changing and recompiling the program. Mandatory user control of plot size is removed from the program. Plot size is now determined by program HPLOT or other graphics program chosen by the user. However, the SCALE parameter is still crucial in determining the correct size for the harmonic grid. It is not presently easy to generate plots of a given scale to match topographic maps or aerial photographs, etc. (see **Harmonic Grid Density/Scale**, page 15).

Running HOME RANGE

1. Create an input file in ASCII format (see **Program Control, Data Input,** and **Examples** sections). (See example *.DAT input files included). It is easiest to copy the command cards from one of the input files included, make the necessary changes, then append those cards onto your own data file. Make sure your editor does not add tab characters. Correct column alignment of values is critical.

2. Load program into memory and start it by entering **HR** at the DOS prompt or by choosing the option *Run HOME RANGE* from the driver.

3. Prompt - "*Do you want to input filenames from a list?*" "Y" or "N". This an option to have HR runs analyses on a group of files in *batch mode* [see **Batch processing,** page 23] (if Yes) or a single input data file at a time (if No).
   a. Prompt - "*What is name of file list?*" Enter filename that contains a list of files. (See **FILES.DIR** for an example of listing of filenames.)
   b. Prompt - "*What is name of input file?*" Enter your input filename. If no drive is specified, output will go to the default drive. If a drive is specified for the input file, you will be prompted for the drive for output.

4. Prompt - "*Do you want to output harmonic values from grid to file for later plotting?*" "Y" or "N". This is for optional plotting of the 3-D utilization distribution using HR3D/HREGA utilities.

5. Prompt - "*Do you want to output animal locations for plotting in consecutive order?*" "Y" or "N". This is for optional plotting of animal's movements, using HPLOT utility.

6. Prompt - "*Do you want the distance moved between consecutive observations computed?*" "Y" or "N"

7. Prompt - "*Do you want to enter seeds for the random number generator from the keyboard?*" "Y" or "N"

8. Program executes.

9. If the test of distributions is requested (col. 16 on SELECT card), the program will generate seeds for the random number generator from the computer's clock if you answer "N" to step 7, otherwise you will be prompted to input three seeds.

10. Prompt - "*Do you want to run home range again?*" "Y" or "N". If yes, the program will begin again, requesting a new input data filename. This is faster than reloading the program into memory.

11. Output may include four files: "*.OUT", "*.PLT", "*.MOV", and "*.HAR" (last two optional). If you are running HR in batch mode, a log file (*.LOG) is created that summarizes the run. Errors and warnings are reported in this file.

12. In case of difficulty, <Ctrl> <Break> will eventually stop the program.

PROGRAM CONTROL

Program control is comprised of six input sections (SELECT, SCALE, METHOD, OFFSET, CONTOUR, and FORMAT) that direct program execution and options. Cards must be ordered in the following sequence. Command cards can either be in upper- or lowercase letters.

Title Card

An alphanumeric string of 40 characters that will be displayed on print and plot output.

FORMAT (A5,5X,5A8)
Col 1 - 5.   TITLE
Col 11 - 50.   Alphanumeric string to be displayed on plot output.

Selection Card

The selection card indicates those home range estimators, options, and calculations to be performed.

FORMAT (A6,4X,7I1,2I5)
Col 1 - 6.   SELECT
Col 11.   '0'   To calculate harmonic mean estimates, and plot locations only, without contours
         '1'   To calculate harmonic mean estimate, and plot contours and locations
         '2'   To suppress harmonic mean calculation, but plot locations only, without contours
Col 12.   '1'   To plot weighted bivariate normal home range
Col 13.   '1'   To plot core areas
Col 14.   '1'   To identify outliers
Col 15.   '1'   To plot bivariate normal home range
Col 16.   '1'   To test for bivariate normality and other tests
Col 17.   '1'   To estimate minimum convex polygon
Col 18 - 22.   Number of grid points on X axis (default is 48)
Col 23 - 27.   Number of grid points on Y axis (default is 21)
             These *must* be right-justified with no decimal point.

NOTE: Standard program options may be specified by replacing the SELECT card with a 'DEFAULT' card (cols 1-7) and omitting all other control cards except TITLE, SCALE and FORMAT (see **Equivalent of Default Setup** below and **Example 2**, page 52). With the DEFAULT option, program HOME RANGE will provide standard harmonic mean home range analysis.

Equivalent of Default Setup

```
Column numbers⁶
            1           2          3          4
1234567890123456789012345678901234567890012345

SELECT      1011010    -1    -1     24     10
METHOD      ENTER
OFFSET                 0.0          0.0    CENTER
CONTOUR     002
0.95
0.75
```

Col 1 - 6.   'SELECT'

Col 11.   Animal locations are always plotted. When Col 11 = '0', nothing else is plotted. When Col 11 = '1', the harmonic contours specified by the contour cards are also plotted. Core areas will not be plotted if contours are not selected. When Col 11 = '2'; calculation of harmonic mean estimate is suppressed. Animal locations are plotted.

Col 12.   When Col 12 = '1', then the 75% and 95% weighted bivariate home ranges are calculated. It will also be calculated if Col 16 = '1' (requesting tests of distribution). Weighted points are identified.

Col 13.   When Col 13 = '1', the maximum area that meets the definition of a core area will be calculated and plotted. No plot of core areas will occur if the distribution is not significantly different (P > 0.10) from the uniform distribution. Core areas will not be estimated if the contour cards specify values greater than 1.0 for any selected contours (requesting plotting of specific harmonic mean contours, not percentiles).

Col 14.   When Col 14 = '1', animal observations that may be outliers are identified. Outliers are tested using a binomial model of the percentage of error polygons containing observations. Observations are tested in decreasing harmonic mean order. A one-tailed 95% confidence interval test is made to identify significant changes in the percent of error polygons with observations. Outlier points are not removed from harmonic mean calculations or any other calculations. Outliers will be identified only when all contours are percentiles of the utilization distribution (contour values equal 1.0 or less).

Col 15.   When Col 15 = '1', the 95% bivariate home range is calculated and plotted. It will also be calculated and plotted when Col 16 = '1' (requesting tests of distribution).

Col 16.   When Col 16 = '1', a test for bivariate normality is made on both the bivariate normal and weighted bivariate normal home ranges. A test for bivariate uniform distribution is also calculated. This option automatically requests calculation of both bivariate normal methods.

Col 17.   When Col 17 = '1', the minimum convex polygon area is estimated. Perimeter points are plotted.

---

⁶Note: The column numbers are added to aid in reading the example. Do not include them in your data file.

Col 18 - 22. The number of grid points on the X-axis is set to default of 48 if this value is zero or blank. If the value is negative, the number of grid points is determined automatically using the procedure on pages 14-17. Higher or lower grid densities may be chosen to facilitate location of the center of activity or to change the ability to distinguish between use areas. Higher grid densities will increase run time. Changes from the default of 48 must be accompanied by a corresponding ratio change in the Y-axis. If the X-axis is set at 72, Y must be set at 32, a 50% increase in both axes (see Col 23-27 below). Maximum number of grid points on the X-axis is 72. Values must be right justified with no decimal point.

Col 23 - 27. Same as Col 18-22, but for the Y-axis. Default is 21 grid points; maximum allowable is 32. Values must be right justified with no decimal point.

Scale Card

The scale card supplies information on the units of data measurement, the number of units per plot inch, and the error polygon size.

FORMAT (A5,5X,2A6,1X,F7.4,1X,F10.5)
Col 1 - 5.   SCALE
Col 11 - 22.   Units of measurement of X and Y coordinates (e.g. meters, kilometers)
Col 24 - 30.   Number of units per plot inch
Col 32 - 41.   Minimum distance between observations

Col 1 - 5.   'SCALE'
Col 11 - 22.   Units of measurement of X and Y coordinates (e.g., feet, meters, or kilometers). Home range areas reported in the program output are in these units squared (square feet, square meters, square kilometers, etc.).

Col 24 - 30.   Scale for harmonic grid, in number of measurement units. This parameter scales the length of the X and Y axes of the harmonic grid. The axes are 24 and 10.5 * SCALE, respectively. Data should be input so that the greatest range in the data occurs along the X-axis. Users should make the scale as large as possible, but still include all observations and contours on the plot. Grid size and scale are no longer identical to plot size and scale as they were on main frame (see **Harmonic Grid Density/Scale**, page 15).

Col 32 - 41.   Minimum distance between observations. This parameter is essentially the typical accuracy of the animal locations, in the same units. The value is used to estimate an average error polygon. Error polygons are treated as simple squares with this distance as a side. The distance value must be greater than 3.0 units, otherwise calculations for the harmonic means will be biased. Distances are in the same units as Col 11-22.

Method Card

The method card indicates how the animal locations were entered. One of three different methods must be selected.

FORMAT (A6,4X,A6)
Col 1 - 6.   METHOD
Col 11 - 16.   Method of data entry
       'ENTER'
       'EVAL 1'
       'EVAL 2'
       (*'EVAL 1 and 2' are not currently implemented, but may be reinstated in the future*)

Col 1 - 6.   'METHOD'
Col 11 - 16.   The method of data entry describes how the animal locations were recorded. The 'ENTER' method indicates that the X, Y coordinates of the animal have already been determined. The 'EVAL 1' method assumes that the X, Y coordinates of a station, the angle, and distance to each location are recorded. 'EVAL 2' assumes that two stations and angles are recorded for each animal location.

Each data entry method requires a different number of data elements as described below. Data elements must be input in the order specified. Observation identification code (ID) is not used in any program computations, and is for user convenience only. An ID element **MUST** be entered, but it may be a blank field. Users find it helpful to use this to record such information as date, time of day, or a sequence number. A weighting factor **MUST** also be entered for each observation. Typical weights will be 1.0 for locations used in the harmonic home range estimate and 0.0 for outliers to be ommitted from harmonic mean estimates. If X and Y coordinates have preceding digits which never change, as in many UTM coordinate applications, they can be omitted.

ENTER Option. This method is the most commonly used approach. This option assumes that the animal locations are entered as grid coordinates. Data elements are input as follows:
      1) X coordinate (east-west)
      2) Y coordinate (north-south)
      3) observation ID (should be read in character format)
      4) weight (usually equals 1.0)

EVAL1 Option. This option assumes that the X, Y coordinates of one fixed station, and the bearing and the distance to each animal location are recorded. Trigonometric functions are used to find the X, Y grid coordinates of animal locations. Data elements are input as follows:
      1) X coordinate
      2) Y coordinate

3) angle (in degrees) measured counter-clockwise from the positive X-axis (must have decimal point)
4) distance
5) observation ID (should be read in character format)

EVAL2 Option. This option assumes that two fixed stations are used in determining animal locations. Both stations triangulate on the animal location. Bearings from each location are recorded. Data are input in the following order:

1) X coordinate of first station
2) Y coordinate of first station
3) angle (in degrees) measured counter-clockwise from the positive X-axis (must have decimal point)
4) X coordinate of second station
5) Y coordinate of second station
6) angle (in degrees) measured counter-clockwise from positive X-axis (must have decimal point)
7) observation ID (should be read in character format)

Offset Card

The offset card provides an option to either center the animal locations in the plot or to offset the minimum animal location relative to the plot origin. This option is not used much with the current microcomputer setup.

FORMAT (A6,4X,F10.2,2X,F10.2,2X,A6)
Col 1 - 6.   OFFSET
Col 11 - 20. X offset in same units of data
Col 23 - 32. Y offset in same units of data
Col 35 - 40. 'CENTER' for automatic centering

Col 1 - 6.   'OFFSET'
Col 11 - 20. The number of units from the origin that the location with the minimum X coordinate will be offset.
Col 23 - 32. The number of units from the origin that the location with the minimum Y coordinate will be offset.
Col 35 - 40. If 'CENTER' is specified, the animal locations are automatically centered on the plot. X and Y axis offsets are ignored when centering is specified. The centering option requires an iterative procedure that increases computation time.

Contour Cards

The first contour card defines the number of utilization contours to be plotted. A subsequent card gives the value for each contour level. When all contour values are 1.0 or less, they are treated as percentiles of the utilization distribution. For example, a single value of 0.95 plots the harmonic mean contour that encloses 95% of the utilization volume. Any value greater than 1.0 causes the contours to be plotted as actual harmonic mean values. Thus, specific harmonic mean contours may be requested, i.e., 20, 40, and 60 (no outliers, core areas, or percent convex polygons are then calculated). A maximum of **20** contours are allowed.

Contour Card 1

FORMAT (A7,3X,I3)
Col 1 - 7.   CONTOUR
Col 11 - 13. Number of contour levels (**right justified with no decimal point**)

Col 1 - 7.   'CONTOUR'
Col 11 - 13. Number of contour levels to be plotted (**must be one or more**).

Subsequent Contour Cards

As many cards as indicated in Cols 11-13 of previous card.

FORMAT (F10.4)
Col 1 - 10.   Contour level (**must have decimal point**)
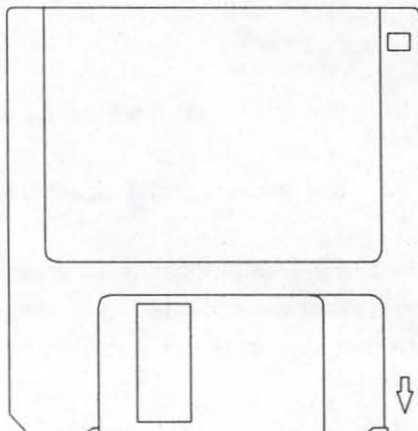
DATA INPUT

Animal location data cards immediately follow the last contour card. The first input card is a format of the observations that follow. A maximum of **1000** animal locations are allowed. The number of elements contained on each data card is determined by the program control METHOD card.

Format Card

This card specifies the format for reading all subsequent location data cards.

FORMAT (A6,4X,12A6)
Col 1 - 6. FORMAT
Col 11 - 78. Format of data to be entered

Col 1 - 6. 'FORMAT'
Col 11 - 78. Format for data input (see examples).

Data Cards

One card for each animal location, up to 1000.

FORMAT (Defined by format card)

FORTRAN Format Primer

F6.1 Real number, 6 columns, 1 to right of decimal (e.g. 1000.0 or -931.7). *(Presence of decimal point in any other position will override this.)* Negative sign must be included too.

A8 Alphanumeric string, 8 columns, e.g. ABCD1234

I3 Integer, 3 columns, no decimal, e.g. 237 or -12

T8 Tab over or go to column 8

4X Skip over 4 columns from the current position

For example, if you have data where East = 1000.0, North = 200.0, ID = F30, and Weight = 1.00, and arranged it in column format as:

```
East       North  ID Weight
1000.0     200.0 F30 1.00
```

If you read East first, then North, your format statement could be (F6.1,1X,F5.1,1X,A3,1X,F4.2). But if you want to read North first, then East, the format statement might be (T8,F5.0,T1,F5.1,T14,A3,1X,F4.2).

EXAMPLES

Two examples are shown to illustrate the options available in the HOME RANGE program. Each example is based on the home range estimate of a single animal (female boreal owl [*Aegolius funereus*] 55 in central Idaho) during the summer (Hayward *et al*. 1987). The data (contained in the file BOREAL.DAT) from example 1 should to used to check proper implementation of the HOME RANGE program, with all program options invoked. The program input and output files have been annotated with comments and explanations printed inside a double-line box. The animal movements and harmonic grid are saved to a file for later plotting (see Fig. 6, page 50 and Fig. 7, page 51 respectively). Figure 7 is created using the HR3D utility to show the harmonic mean utilization distribution in 3-dimensions. The example also illustrates the use of zero weights to eliminate outlier points from the harmonic home range estimate.

The second example shows the use of default program options.

Example 1

Program Input

```
This section displays the control cards for Example 1. The relocation data for boreal owl 55 follow
the format card. Data are recorded in UTM grid coordinates. The Y coordinate is recorded first,
followed by the X coordinate, and location ID and weight. The location ID represents the coded
type of location (R = roosting, N = nesting), Julian date and year of the observation. Note that
the data are coded as north then east coordinates, reversed in FORMAT statement.
```

```
TITLE       BOREAL 55 FEMALE SUMMER 84-86
SELECT      1111111    -1    -1
SCALE       METERS           1220.0   100.0
METHOD      ENTER
OFFSET      0.0              0.0           CENTER
CONTOUR     2
0.75
0.95
FORMAT      (6X,F5.0,T1,F5.0,16X,A6,2X,F3.0)
26650 39500      R138-4   1.0
26550 39600      R138-4   1.0
26450 39550      N140-4   1.0
26700 38800      R189-4   1.0
27500 40200      N190-6   1.0
27700 39900      R192-6   1.0
27600 39400      R193-6   1.0
27700 39500      R194-6   1.0
28700 38000      R195-6   1.0
28700 38000      R196-6   1.0
26100 38800      R198-6   1.0
```

27200	39000	R199-6	1.0
28200	39700	R200-6	1.0
29200	39300	R201-6	1.0
29200	38800	R202-6	1.0
29500	35900	R203-6	1.0
30200	34700	R205-6	1.0
29800	35400	R207-6	1.0
29800	35400	R208-6	1.0
29600	35100	R210-6	1.0
29600	35200	R215-6	1.0
29700	35200	R217-6	1.0
29600	35000	R220-6	1.0
29700	35200	R222-6	1.0
29600	35100	R224-6	1.0
29400	35300	R227-6	1.0
29000	35600	R229-6	1.0
28900	35800	R230-6	1.0
29600	36500	R250-6	1.0
29500	37000	R252-6	1.0
29600	35200	R256-6	1.0
29600	35400	R260-6	1.0
27100	34500	R267-6	0.0
24700	39100	R270-6	1.0
24700	39000	R271-6	1.0
24500	39300	R275-6	1.0
25000	39500	R276-6	1.0
25400	39700	R277-6	1.0
24700	39700	R278-6	1.0
25700	39600	R280-6	1.0
25600	39900	R281-6	1.0
25400	39700	R283-6	1.0
25400	39500	R285-6	1.0
24900	39600	R289-6	1.0
26600	38200	R292-6	1.0

This point was intentionally given zero weight
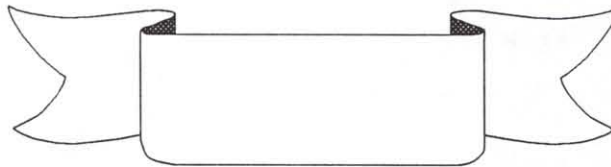
Program Output - Example 1

```
 -------------------------------------------------------------
|                                                             |
|                     PROGRAM HOME RANGE                      |
|                                                             |
|            Copyright (c) 1987, 1988, 1989, 1990.            |
|            Bruce B. Ackerman and Michael D. Samuel          |
|                                                             |
|                         March 1990                          |
|                                                             |
|        *** DIMENSIONED TO READ 1000 OBSERVATIONS ***        |
|          --- maximum grid size set at 72 by 32 ---          |
|                                                             |
 -------------------------------------------------------------
```

Name of input file is: BOREAL.DAT
File containing HOME RANGE output   text is: BOREAL.OUT
File containing HOME RANGE plotting data is: BOREAL.PLT
File containing HOME RANGE harmonic grid is: BOREAL.HAR
File containing animal locations to plot is: BOREAL.MOV

This portion of the output echoes/confirms the input control cards used in this example. Output is edited in some parts to save space.

TITLE IS BOREAL 55 FLOSSIE FEMALE SUMMER 84-86

ENTER OPTIONS FOR CONTOURS, WEIGHTED BIVARIATE NORMAL HOME RANGE, CORE AREA,
    OUTLIER OBSERVATIONS, BIVARIATE NORMAL HOME RANGE, BIVARIATE NORMAL TEST,
    AND MINIMUM CONVEX POLYGON AREA

ANSWER WAS 1 1 1 1 1 1 1

    CONTOURS WILL BE PLOTTED

    WEIGHTED BIVARIATE NORMAL HOME RANGE WILL BE PLOTTED

    CORE AREAS WILL BE PLOTTED

    OUTLIERS WILL BE IDENTIFIED

    BIVARIATE NORMAL HOME RANGE WILL BE PLOTTED

    LOCATIONS WILL BE TESTED FOR BIVARIATE NORMALITY

    MINIMUM CONVEX POLYGON WILL BE ESTIMATED

NUMBER OF GRID POINTS ON X AND Y AXIS ARE   -1   -1

PLOT SIZE IS X = 24.00 Y = 10.00

ENTER UNITS, PLOT INCH SCALE, AND MINIMUM DISTANCE BETWEEN OBSERVATIONS

        1220.00 METERS = 1 INCH ON PLOTTER OR

          1 METERS = 0.0008 INCHES ON PLOTTER

    MINIMUM MEASURED DISTANCE BETWEEN OBSERVATIONS =   100.0000 METERS

ENTER METHOD (ENTER, EVAL 1, EVAL 2)

METHOD IS ENTER

ENTER OFFSET AND CENTERING OPTION

X OFFSET IS 0.00 Y OFFSET IS 0.00 WITH AUTOMATIC CENTERING

ENTER NUMBER OF CONTOURS

CONTOUR LEVELS ARE TREATED AS PERCENTILES OF THE ANIMAL UTILIZATION DISTRIBUTION

THERE ARE 2 CONTOURS WHICH ARE
        0.95
        0.75

X AND Y COORDINATES AND IDS ARE READ IN WITH THE FOLLOWING
FORMAT   (6X,F5.0,T1,F5.0,16X,A6,2X,F3.0)

The X, Y coordinates, ID, and weight, for each relocation are listed in the order of input.
Observation #33 was intentionally given a zero (0.0) weight to indicate that it is a known outlier.

THE DATA VALUES ARE

OBS	X COORD	Y COORD	ID	WEIGHTS
1	39500.00	26650.00	R138-4	1.0000
2	39600.00	26550.00	R138-4	1.0000
3	39550.00	26450.00	N140-4	1.0000
4	38800.00	26700.00	R189-4	1.0000
5	40200.00	27500.00	N190-6	1.0000
.	....	....	......	......
.	....	....	......	......
.	....	....	......	......
31	35200.00	29600.00	R256-6	1.0000
32	35400.00	29600.00	R260-6	1.0000

33	34500.00	27100.00	R267-6	0.0000	¤	Zero weight
34	39100.00	24700.00	R270-6	1.0000		
35	39000.00	24700.00	R271-6	1.0000		
.	....	....	......	......		
.	....	....	......	......		
.	....	....	......	......		
41	39900.00	25600.00	R281-6	1.0000		
42	39700.00	25400.00	R283-6	1.0000		
43	39500.00	25400.00	R285-6	1.0000		
44	39600.00	24900.00	R289-6	1.0000		
45	38200.00	26600.00	R292-6	1.0000		

The minimum and maximum values for each axis are calculated. The harmonic grid density is automatically calculated. The location of the arithmetic center of activity is shown.

```
XMIN =     34500.00    YMIN =     24500.00
XMAX =     40200.00    YMAX =     30200.00

PLOT GRID DENSITY AUTOMATICALLY CALCULATED

NO. OF GRID POINTS ON THE X AXIS = 48
NO. OF GRID POINTS ON THE Y AXIS = 21
```

ARITHMETIC CENTER OF OBSERVATIONS

```
X =     37741.1111
Y =     27701.1111
```

Information on independence of consecutive locations is given. This includes mean distance moved between consecutive location, three indices of serial correlation, with standard deviation of t^2/r^2, and eccentricity of the data. Each of these tests suggests strong serial correlation in the data (see Fig. 6, page 50).

```
MEAN DISTANCE BETWEEN CONSECUTIVE LOCATIONS              =    849.6401 METERS
MEAN DISTANCE FROM ARITHMETIC CENTER TO EACH LOCATION =   2604.1367 METERS


SERIAL CORRELATIONS AND CROSS-CORRELATIONS

 P(X,X-1)=  0.8692  P(Y,Y-1)=  0.9002  P(X,Y-1)= -0.8289 P(Y,X-1)= -0.6164

THREE INDICES OF AUTOCORRELATION:

 T2     = 1731079.6250    R2     = 7500088.5000

 T2/R2  = 0.2308 (SWIHART AND SLADE. 1985. ECOLOGY 66(4):1176-1184.)
 PSI    = 3.2148 (SWIHART AND SLADE. 1985. J. WILDL. MANAGE. 49(4):1019-1025.)
```

```
GAMMA   = 0.8847 (SWIHART AND SLADE. 1986. ECOLOGY 67(1):255-258.)
LAMBDA1 = 6639215.6346     LAMBDA2 = 860796.4030
ECCENTRICITY =   2.7772
```

STANDARD DEVIATIONS OF T2/R2 UNDER DIFFERENT ASSUMPTIONS:

A. CONSECUTIVE OBSERVATIONS (SWIHART AND SLADE. 1985. ECOLOGY 66(4):1176-1184.)

```
    SDCU =       0.2567  (UNIFORM DISTRIBUTION - EQ. 5)
    SDCN =       0.2544  (NORMAL DISTRIBUTION  - EQ. 6)
```

B. NONCONSECUTIVE OBSERVATIONS (SWIHART AND SLADE. 1985. ECOLOGY
                              66(4):1176-1184.)

```
    SDNU =       0.2610  (UNIFORM DISTRIBUTION - EQ. 7)
    SDNN =       0.2598  (NORMAL DISTRIBUTION  - EQ. 8)
```

C. TRAPPING GRID (SWIHART AND SLADE. 1987. AM. MIDL. NAT. 117(1):204-207.)

```
    SDTG =       0.2586  (TRAPPING GRID)
```

THE GEOMETRIC CENTER IN UNCENTERED PLOT IS 6, 6

THE NEW XMIN VALUE IS 22910.0000
THE NEW YMIN VALUE IS 21450.0000

THE MINIMUM H VALUE IS 872.07 AT 21,14

The coordinates of observations and calculated harmonic mean values are listed a second time in the same sequence as the previous section.

GRID POINT HARMONIC MEAN BY OBSERVATIONS

OBS	X-COORD	Y-COORD	H-MEAN	ID	OLD ORDER	
1	39500.00	26650.00	1416.958	R138-4	1	
2	39600.00	26550.00	1302.547	R138-4	2	
3	39550.00	26450.00	1302.547	N140-4	3	
4	38800.00	26700.00	1467.876	R189-4	4	
5	40200.00	27500.00	1540.420	N190-6	5	
.	....	....	....	......	.	
.	....	....	....	......	.	
.	....	....	....	......	.	
31	35200.00	29600.00	872.073	R256-6	31	
32	35400.00	29600.00	872.073	R260-6	32	
33	34500.00	27100.00	0.000	R267-6	33	**ZERO WEIGHT**
34	39100.00	24700.00	1443.092	R270-6	34	
35	39000.00	24700.00	1830.600	R271-6	35	
.	....	....	....	......	.	

.	. . . .	. . . .	. . . .	. . . . . .	.
.	. . . .	. . . .	. . . .	. . . . . .	.
41	39900.00	25600.00	1441.372	R281-6	41
42	39700.00	25400.00	1366.032	R283-6	42
43	39500.00	25400.00	1171.260	R285-6	43
44	39600.00	24900.00	1171.260	R289-6	44
45	38200.00	26600.00	1854.787	R292-6	45

Observations are displayed a third time, sorted in ascending order by harmonic mean value. Harmonic values represent average distance between points. Lower harmonic values are close to the center of activity. Large harmonic values should be reviewed for extreme locations. Subsequent reference to observations is based on the new order of this sorted list. No outliers were found in this data set (not including observation #33 which was intentionally assigned zero weight).

SORTED HARMONIC MEANS

OBS	X-COORD	Y-COORD	H-MEAN	ID	OLD ORDER	
1	34500.00	27100.00	0.000	R267-6	33	⊗ Zero weight
2	35100.00	29600.00	872.073	R210-6	20	
3	35200.00	29600.00	872.073	R215-6	21	
4	35000.00	29600.00	872.073	R220-6	23	
5	35100.00	29600.00	872.073	R224-6	25	
.	. . . .	. . . .	. . . .	. . . . . .	. .	
.	. . . .	. . . .	. . . .	. . . . . .	. .	
.	. . . .	. . . .	. . . .	. . . . . .	. .	
41	38200.00	26600.00	1854.787	R292-6	45	
42	37000.00	29500.00	1856.047	R252-6	30	
43	39700.00	24700.00	1865.632	R278-6	39	
44	38800.00	29200.00	2107.791	R202-6	15	
45	39300.00	29200.00	2243.609	R201-6	14	⊗

NO OUTLIER POINTS DETECTED

Maximum harmonic value used as cut-off for calculating 3-D plot. Greater values set to zero.

Note: A bivariate test comparing the density of observations was used to identify potential outliers. This may be used to review points that could be extreme locations or data errors. However such points should not be arbitrarily removed. In this example, no locations failed the test.

Two contour levels were input to the program (95% and 75%). Harmonic mean for each level and total enclosed area at each level are calculated and output for plotting. A significant core area was found and was output for plotting. The core area is designated here as percent level 0.54 (the last contour level, i.e. 3, in this case). The estimated percent of area and use volume are estimated for the core area.

Area of 95% harmonic contour is 17.0 km².
Area of 75% harmonic contour is 9.1 km², in 3 segments.
Core area is 5.1 km², in 2 segments, representing 35% of the total area and 54% of the utilization volume. Three contours are output for later plotting.

```
ESTIMATED PERCENTILE CONTOUR LEVELS
   1   2182.033      0.950
   2   1846.372      0.750

      1584.473        ESTIMATED CORE AREA WITH 34.69 PERCENT OF AREA
                      AND 54.22 PERCENT OF UTILIZATION VOLUME

CONTOUR LEVEL =  1      H MEAN =     2182.0331     PERCENT LEVEL  0.95
    ENCLOSED AREA =  17014845.92 SQUARE METERS

    TOTAL AREA WITHIN CONTOUR =  17014845.92 SQUARE METERS

CONTOUR LEVEL =  2      H MEAN =     1846.3716     PERCENT LEVEL  0.75
    ENCLOSED AREA =   3067172.13 SQUARE METERS
    ENCLOSED AREA =     70373.77 SQUARE METERS
    ENCLOSED AREA =   6011928.82 SQUARE METERS

    TOTAL AREA WITHIN CONTOUR =   9149474.72 SQUARE METERS

CONTOUR LEVEL =  3      H MEAN =     1584.4731     PERCENT LEVEL  0.54
    ENCLOSED AREA =   1824989.92 SQUARE METERS
    ENCLOSED AREA =   3306454.04 SQUARE METERS

    TOTAL AREA WITHIN CONTOUR =   5131443.96 SQUARE METERS
```

NOTE: THE REMAINING COMPUTATIONS CONSIDER ALL LOCATIONS TO BE
      INDEPENDENT AND TO HAVE EQUAL IMPORTANCE. WEIGHTS ASSIGNED FOR
      HARMONIC MEAN CALCULATION DO NOT APPLY TO SUBSEQUENT ESTIMATES.

The 75% and 95% weighted bivariate home ranges are estimated, with standard errors. The 95% area is 40.0 km²; the 75% area is 18.4 km². The SQRT DET S may be used to produce other percent estimates (see Jennrich and Turner 1969). Points with weights < 1.0 are listed for review as possible outliers. The observations are tested for weighted bivariate normality. The observations were found to be different from a weighted bivariate normal distribution (W² = 0.939 was greater than the test statistic of 0.328, P < 0.01). Therefore, the data are not appropriate for the weighted bivariate normal method. Additional critical values are provided for other alpha levels. The 95% weighted ellipse is output for later plotting.

```
WEIGHTED BIVARIATE NORMAL HOME RANGE AREA

        75%       =   18421905.07
        95%       =   40027006.97
        SQRT DET S =   2155836.18
        XMEAN     =     37757.43
        YMEAN     =     27695.85
        SXX/SYY   =         1.1064
        SXY       =  -2955627.53

            LIST OF WEIGHTED POINTS

  ORDER   X-COORD    Y-COORD    WEIGHT      ID   OLD ORDER
  ---------------------------------------------------------
     1    34500.00   27100.00   0.60248   R267-6      33 ⋇
    27    39300.00   24500.00   0.98932   R275-6      36
    33    40200.00   27500.00   0.99974   N190-6       5
    40    39700.00   28200.00   0.95292   R200-6      13
    44    38800.00   29200.00   0.91117   R202-6      15
    45    39300.00   29200.00   0.76707   R201-6      14
  ---------------------------------------------------------
```

Known outlier has lowest weight

```
        ASYMPTOTIC SE FOR 95% AREA =   6166033.00
        ASYMPTOTIC SE FOR 75% AREA =   2837835.75

WEIGHTED BIVARIATE NORMAL HOME RANGE HAS BEEN PLOTTED

WEIGHTED BIVARIATE NORMALITY TEST FOR GOODNESS OF FIT
TEST USES CRAMER-VON MISES STATISTIC

W SQUARED = 0.939

CRITICAL VALUES:

        ALPHA = .01      0.328
        ALPHA = .025     0.284
        ALPHA = .05      0.224
        ALPHA = .10      0.173
        ALPHA = .15      0.151
```

The 75% and 95% home range areas for the bivariate normal method are estimated, with standard errors. The 95% home range area is 46.0 km²; the 75% is 21.2 km². The observations are tested for bivariate normality. The Cramer-von Mises statistic exceeds the critical value ($W^2 = 0.805$ was greater than $W^2 = 0.336$, $P < 0.01$). Therefore, the data are not appropriate for the bivariate normal method. Additional critical values are provided for other alpha levels. The 95% ellipse is output for later plotting.

```
BIVARIATE NORMAL HOME RANGE AREA

        75%        =    21287553.74
        95%        =    46033374.34
        SQRT DET S =     2446223.36
        XMEAN      =       37741.11
        YMEAN      =       27701.11
        SXX/SYY    =           1.1477
        SXY        =    -2944640.83

        ASYMPTOTIC SE FOR 95% AREA =    7020024.00
        ASYMPTOTIC SE FOR 75% AREA =    3246321.50

BIVARIATE NORMAL HOME RANGE HAS BEEN PLOTTED

        BIVARIATE NORMALITY TEST FOR GOODNESS OF FIT
        TEST USES CRAMER-VON MISES STATISTIC

        W SQUARED = 0.805

        CRITICAL VALUES:

        ALPHA = .01        0.336
        ALPHA = .025       0.272
        ALPHA = .05        0.223
        ALPHA = .10        0.176
        ALPHA = .15        0.148
```

A test for bivariate uniform distribution is performed on the data. A bivariate uniform distribution is rejected by the Cramer-von Mises statistic because $W^2 = 0.2622$ was greater than 0.223 [0.025 < p < 0.05] ($P < 0.05$). Therefore, the data are not appropriate for the minimum convex polygon method.

```
        THREE SEEDS FOR THE RANDOM NUMBER GENERATOR ARE:
            SEED #1 = 17120, SEED #2 = 13126, SEED #3 = 11400

        VALUE RETURNED BY THE RANDOM NUMBER FUNCTION IS 0.1221

            BIVARIATE UNIFORM TEST FOR GOODNESS OF FIT
            TEST USES CRAMER-VON MISES STATISTIC
```

```
            W SQUARED =      0.2622

            CRITICAL VALUES:

            ALPHA = .01      0.336
            ALPHA = .025     0.272
            ALPHA = .05      0.223
            ALPHA = .10      0.176
            ALPHA = .15      0.148
```

The minimum convex polygon (MCP) home range is calculated using all of the observations (100% polygon). The observation number and coordinates for each point on the MCP perimeter are identified. The home range is 21.2 km². The 100% convex polygon is output for later plotting.

100% CONVEX POLYGON HOME RANGE

THERE ARE 8 POINTS DEFINING THE PERIMETER OF THIS HOME RANGE.

NO	INDEX	X	Y	ID	OLD ORDER
1	36	34700.00	30200.00	R205-6	17
2	45	39300.00	29200.00	R201-6	14
3	33	40200.00	27500.00	N190-6	5
4	25	39900.00	25600.00	R281-6	41
5	43	39700.00	24700.00	R278-6	39
6	27	39300.00	24500.00	R275-6	36
7	1	34500.00	27100.00	R267-6	33
8	36	34700.00	30200.00	R205-6	17

```
NOTE: 1. POINTS ARE LISTED CLOCKWISE.
      2. THIS POLYGON ENCLOSES 45 POINTS, I.E., NO OUTLIERS WERE EXCLUDED.
      3. FIRST AND LAST POINTS ARE THE SAME TO CLOSE THE POLYGON.


THE AREA OF THIS 100% CONVEX POLYGON HOME RANGE IS:
      ENCLOSED AREA =  21190000.00 SQUARE METERS

      TOTAL AREA WITHIN CONTOUR =  21190000.00 SQUARE METERS

NOMINAL CONTOUR LEVEL IS: 100%  ACTUAL PERCENT OF POINTS INCLUDED IS: 100.0%
```

The percent convex polygon home range is calculated from the inner 95% of the observations. The observation number and coordinates for each point on the MCP perimeter are identified. The home range is 19.7 km². The 95% convex polygon is output for later plotting.

95% CONVEX POLYGON HOME RANGE

THERE ARE 11 POINTS DEFINING THE PERIMETER OF THIS HOME RANGE.

NO	INDEX	X	Y	ID	OLD ORDER
1	10	35400.00	29800.00	R208-6	19
2	42	39300.00	29200.00	R252-6	30
3	32	40200.00	27500.00	R198-6	11
4	25	39900.00	25600.00	R281-6	41
5	15	39600.00	24900.00	R289-6	44
6	26	39100.00	24700.00	R270-6	34
7	37	39000.00	24700.00	R195-6	9
8	1	34500.00	27100.00	R267-6	33
9	4	35000.00	29600.00	R220-6	23
10	12	35200.00	29700.00	R222-6	24
11	10	35400.00	29800.00	R208-6	19

NOTE: 1. POINTS ARE LISTED CLOCKWISE.
2. THIS POLYGON ENCLOSES 42 POINTS, I.E., NO OUTLIERS WERE EXCLUDED.
3. FIRST AND LAST POINTS ARE THE SAME TO CLOSE THE POLYGON.

THE AREA OF THIS 95% CONVEX POLYGON HOME RANGE IS:
ENCLOSED AREA = 19660000.00 SQUARE METERS

TOTAL AREA WITHIN CONTOUR = 19660000.00 SQUARE METERS

NOMINAL CONTOUR LEVEL IS: 95% ACTUAL PERCENT OF POINTS INCLUDED IS: 93.3%

The percent convex polygon home range is calculated from the inner 75% of the observations. The observation number and coordinates for each point on the MCP perimeter are identified. The home range is 19.1 km^2. The 75% convex polygon is output for later plotting.

75% CONVEX POLYGON HOME RANGE

THERE ARE 9 POINTS DEFINING THE PERIMETER OF THIS HOME RANGE.

NO	INDEX	X	Y	ID	OLD ORDER
1	4	35400.00	29800.00	R220-6	23
2	33	39300.00	29200.00	N190-6	5
3	23	40200.00	27500.00	R193-6	7
4	16	39900.00	25600.00	R203-6	16
5	5	39500.00	25000.00	R224-6	25
6	17	39100.00	24700.00	R138-4	2
7	28	39000.00	24700.00	R189-4	4
8	1	34500.00	27100.00	R267-6	33
9	4	35400.00	29800.00	R220-6	23

NOTE: 1. POINTS ARE LISTED CLOCKWISE.
      2. THIS POLYGON ENCLOSES 33 POINTS, I.E., NO OUTLIERS WERE EXCLUDED.
      3. FIRST AND LAST POINTS ARE THE SAME TO CLOSE THE POLYGON.

THE AREA OF THIS 75% CONVEX POLYGON HOME RANGE IS:
     ENCLOSED AREA = 19125000.00 SQUARE METERS

     TOTAL AREA WITHIN CONTOUR = 19125000.00 SQUARE METERS

NOMINAL CONTOUR LEVEL IS: 75%   ACTUAL PERCENT OF POINTS INCLUDED IS: 73.3%

--------------------------end of home range output------------------------

---

Figures in the following pages were created using *LaserPlotter* except for figure 7 which was produced by dumping the 3D plot to an HP LaserJet printer. (Figures 5 and 6 could also be generated by sending the plot and animal movement files to a plotter). *LaserPlotter* is a program that will make use of any of the Hewlett-Packard laser printers (LaserJet, LaserJet series II, LaserJet Plus, LaserJet 500+, and LaserJet 2000) as a plotter with any graphics programs that supports the HP 7470A, 7475A or ColorPro plotter, via a file or LPT1. They were generated in the following manner:

(1) The HPLOT utility was used to generate a Hewlett-Packard Graphics Language (HP-GL) file from the plot file (BOREAL.PLT) created by HOME RANGE. The Plot option was chosen, but instead of sending it directly to a plotter, the output was sent to a file. This step was repeated for the animal movements file (see Fig. 6, page 50).

(2) Four copies of the resulting HP-GL file were made. Each one was edited to emphasize only those features to be plotted.

(3) The resulting HP-GL files (the original copy created in step 1 and 4 edited versions created in step (2) were brought into the LaserPlotter program and printed on the HP LaserJet printer.

☞ The plots have been reduced about 15 percent.

LaserPlotter retails for $79.95 (Release 2.3, 1988) and is available from Insight Development Corporation, Moraga, CA or Hewlett-Packard Company, San Diego, CA. Other similar packages could be used.

Figure 1. Locations of boreal owl 55

Figure 2. 95 and 75% harmonic mean contours, and core areas
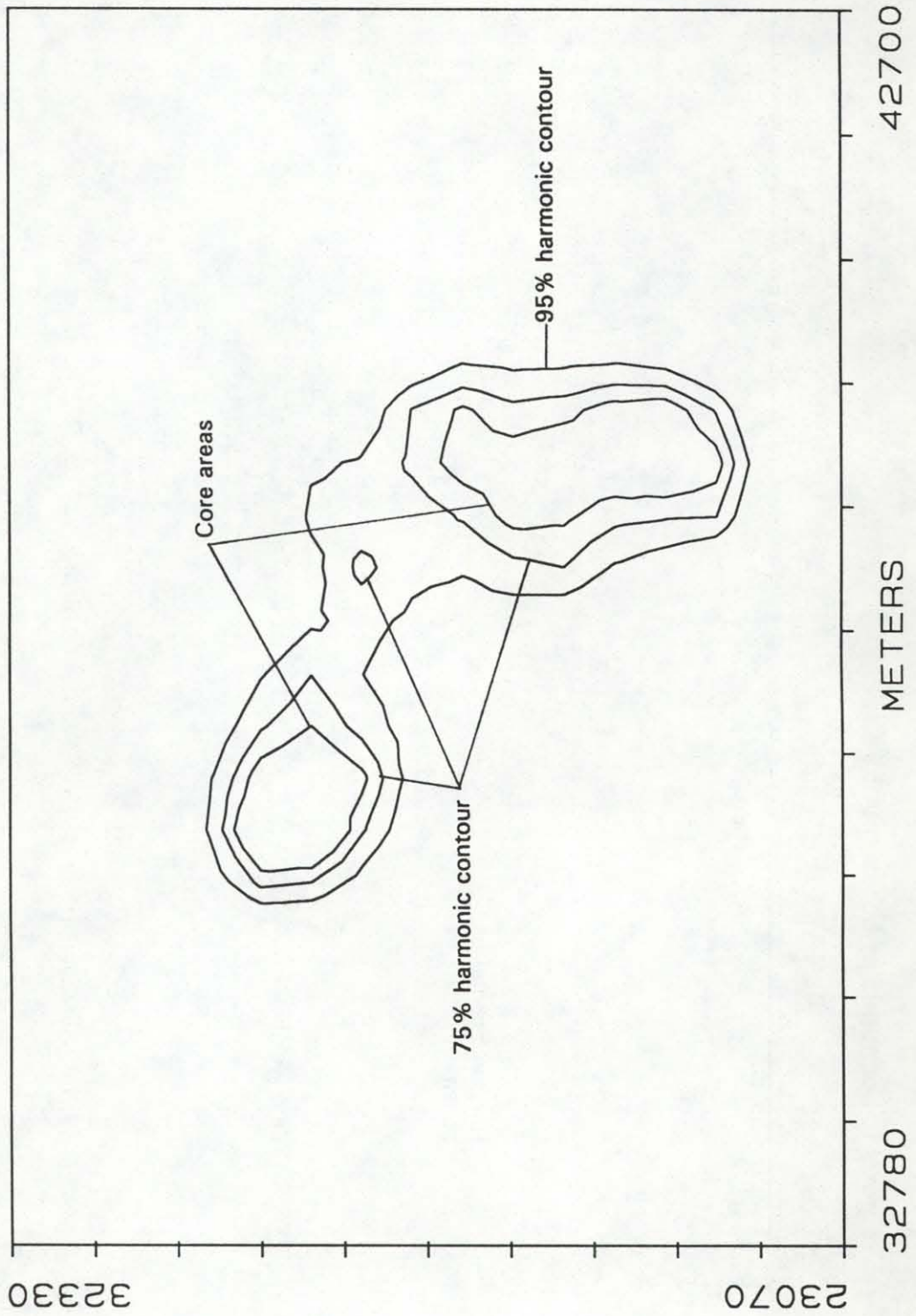
Figure 3. 95% bivariate normal and weighted bivariate normal ellipses

Bivariate normal home range

Weighted bivariate normal home range

METERS

Figure 4. 100, 95 and 75% convex polygons

100% convex polygon

95% convex polygon

75% convex polygon

METERS

Figure 5. Figures 1-4 overlayed together

BOREAL 55 FLOSSIE FEMALE SUMMER 84-86

Figure 6. Animal movements between consecutive locations (*Note different scale*)

BOREAL 55 FLOSSIE FEMALE SUMMER 84-86
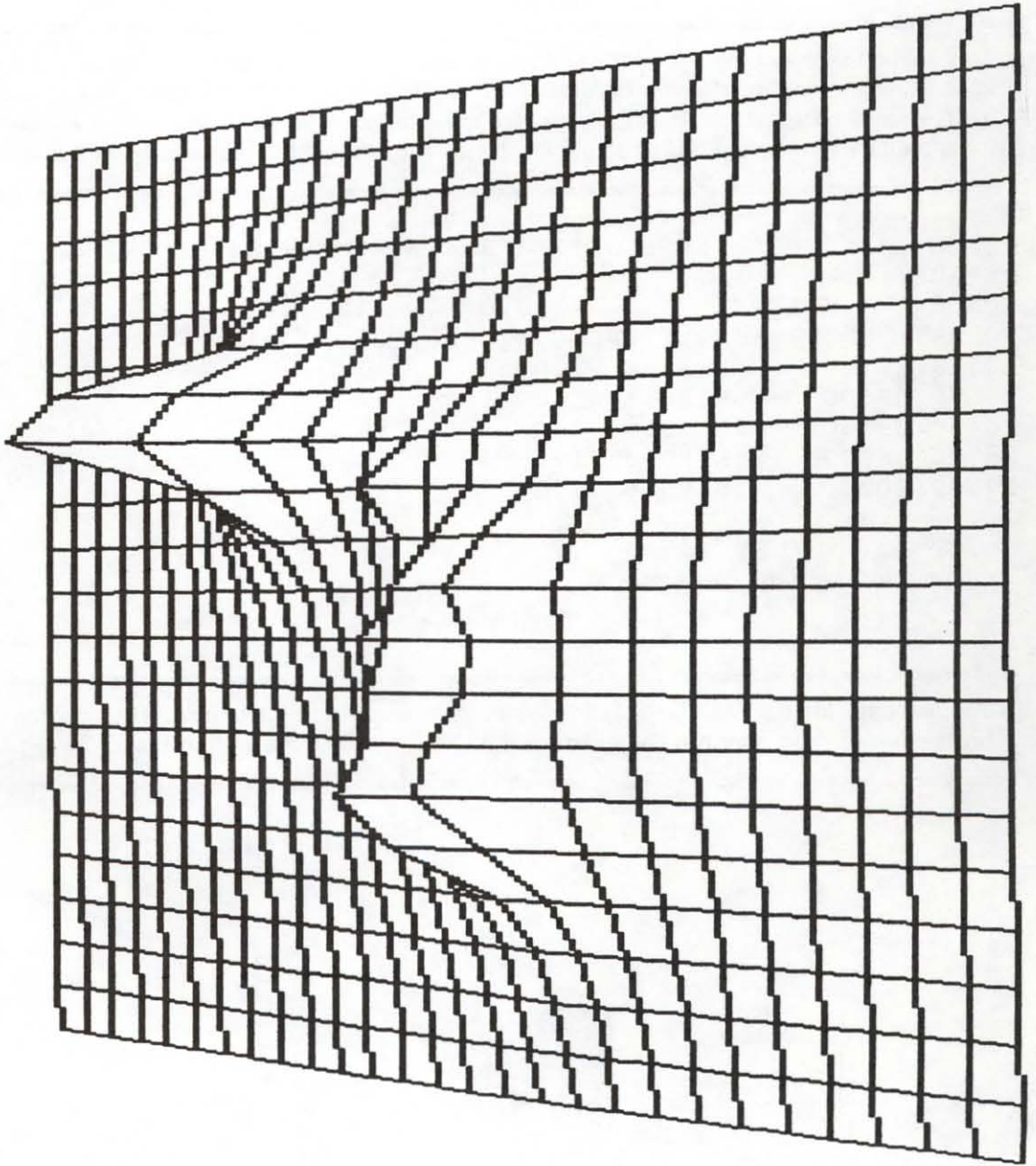
Figure 7. Harmonic mean utilization distribution

Example 2

Program Input

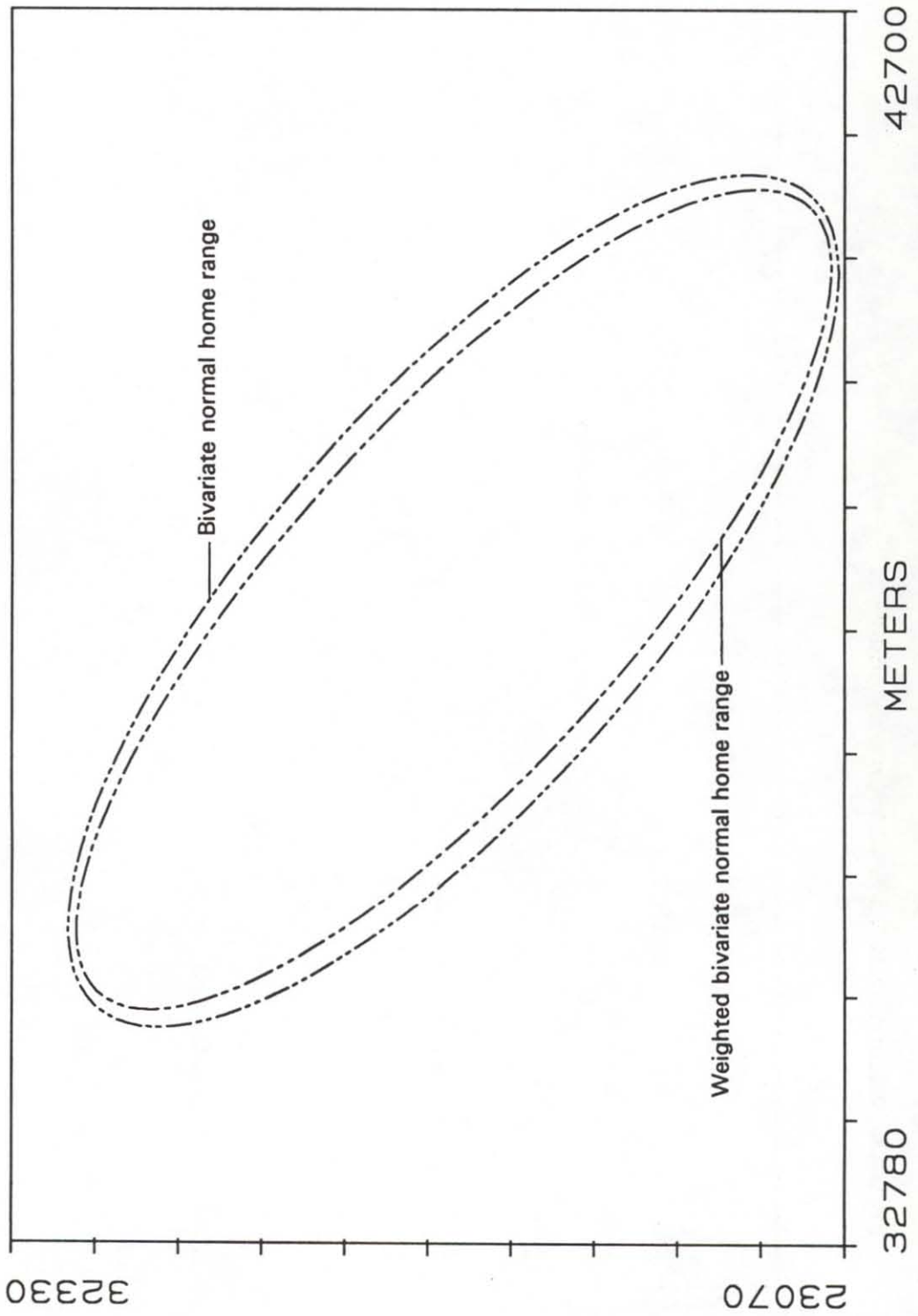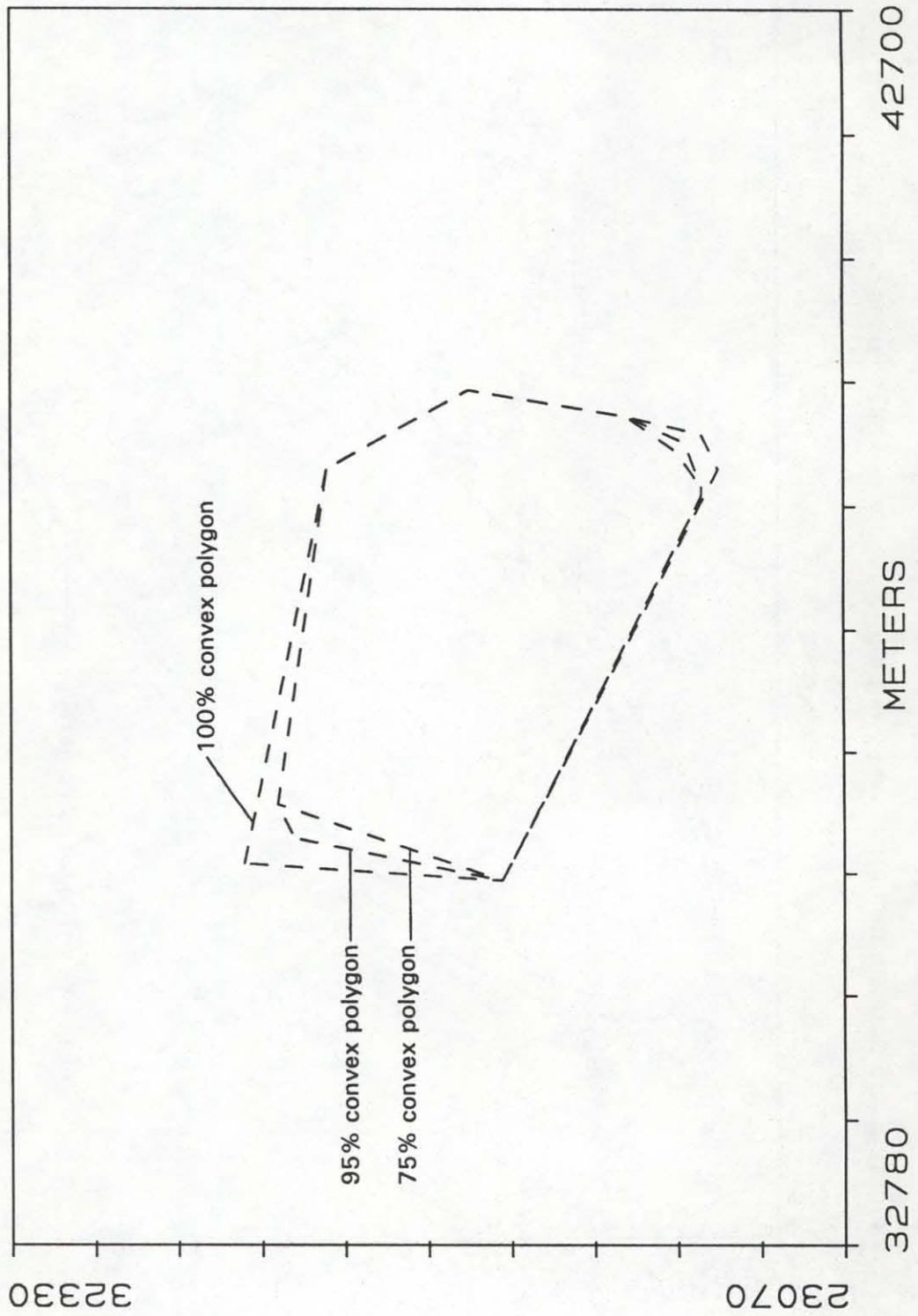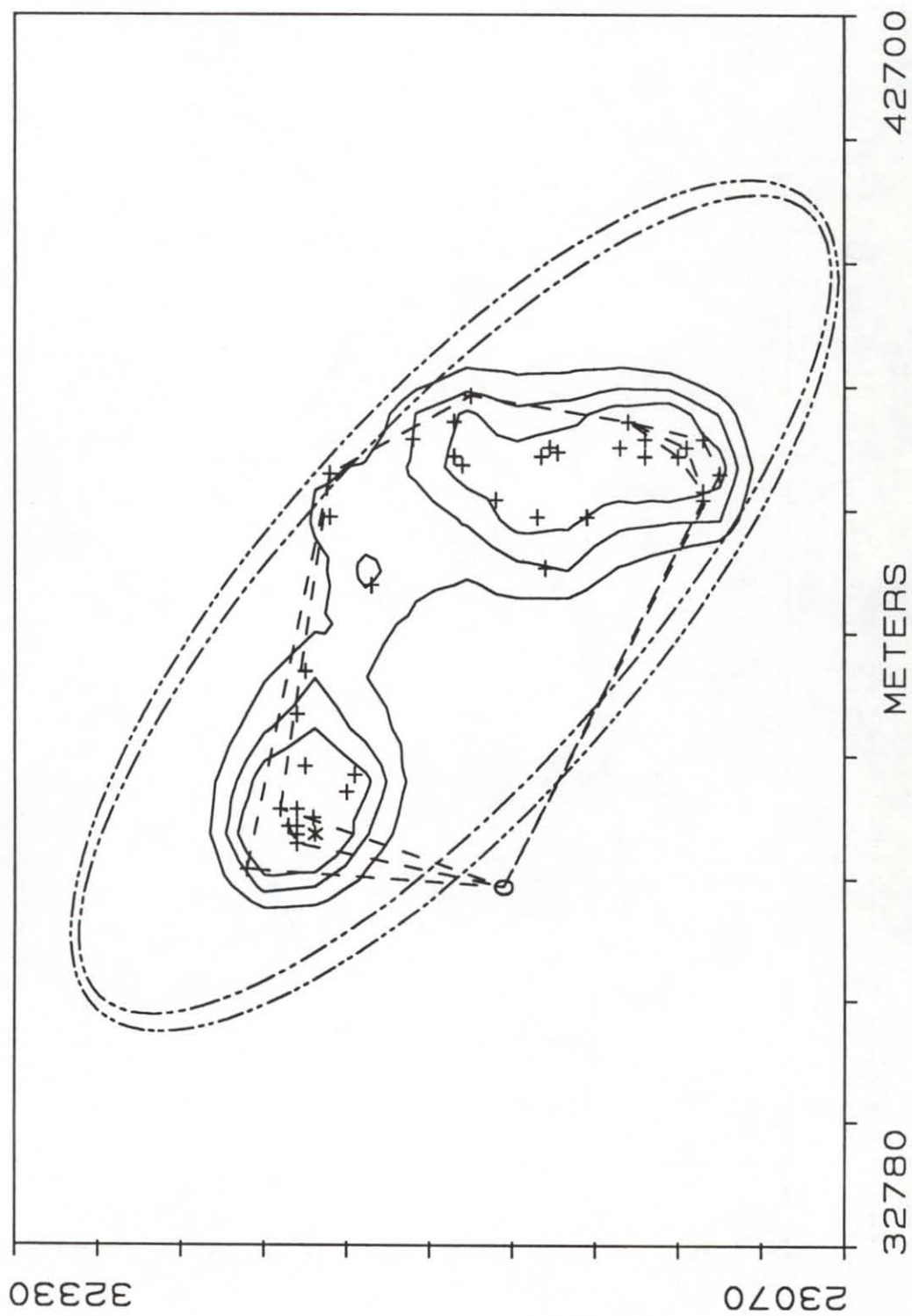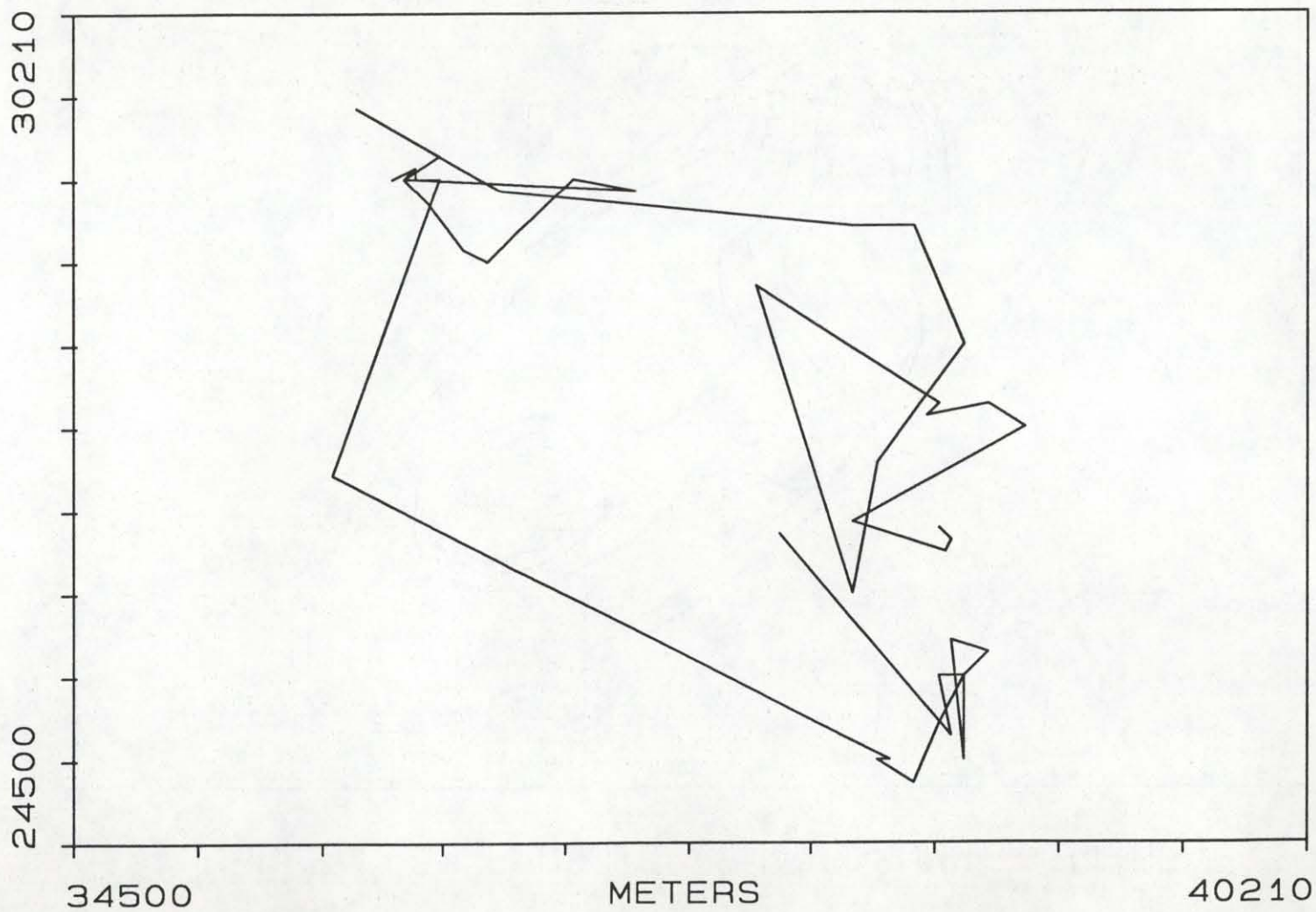This section displays the use of the Default option (see page 26 for details on use of the DEFAULT option). The relocation data for boreal owl 55 would follow the format card. The data are recorded in UTM grid coordinates. The Y coordinate is recorded first, followed by the X coordinate, and location ID and weight. This example illustrates the use of the equivalent DEFAULT options.

```
TITLE        BOREAL 55 FLOSSIE FEMALE SUMMER 84-86
DEFAULT
SCALE        METERS          1220.0          100.0
FORMAT       (T7,F5.0,T1,F5.0,T17,A6,T25,F3.0)
26650 39500        R138-4   1.0
26550 39600        R138-4   1.0
26450 39550        N140-4   1.0
26700 38800        R189-4   1.0
27500 40200        N190-6   1.0
...   ...          ...      ...
...   ...          ...      ...
```
(the rest of the data cards follow)

See the data file (DEFAULT.DAT) for the options used in this example. The program output has been omitted. You may run the example data file and view the output file.

HOME RANGE 2-DIMENSIONAL PLOTTING UTILITY

Introduction

HPLOT works in conjunction with the microcomputer version of the program HOME RANGE. Its sole purpose is to plot data output by HOME RANGE either to the screen or to the plotter. However, it could be used to plot other similar line data.

System Requirements

Hardware : IBM PC, PS/2, or 100% compatibles.

Plotter : Hewlett-Packard (HP) plotters model 7470A or 7475A.

Monitor and Graphics Adapter : (Optional) IBM Color (CGA), Enhanced (EGA) Graphics or Video Graphics Array (VGA) Adapter with a graphics monitor or Enhanced Color Display (ECD), and Hercules graphics card for displaying graphs.

Source : Microsoft QuickBASIC 4.0

Format of Input Data File

The input data file is typically created by program HOME RANGE and does not need to be altered by the user.

Limits : Location data can have 7 digits left of the decimal point.

: Currently dimensioned for up to 2,000 plotter positions (ellipses take 100, harmonic contours 80-150 each).

: ASCII text file (no tab characters)

Data : 1st line - TITLE (up to 47 characters), used to label plot. If a comma is present in the title, the entire title should be enclosed with double (") quotes, otherwise a **Data file format error** message will occur.

: 2nd line - UNIT of measurement (meters, feet, etc.), used to label axes.

: Subsequent lines with 5 columns of variables with a space between (or comma):

1st column - Selection code for line types and symbols

    1 = Harmonic mean - solid line

    2 = Weighted ellipse - broken line

    3 = Bivariate normal ellipse - broken line

    4 = Minimum convex polygon - dashed line

    5 = Symbols

2nd column - Contour percentage (0-100, core area [*its own value*])

3rd column - For contours: 1 = begin new line, 0 = continue existing line.

   0 ->   blank (not generally used)

  42 -> * (harmonic center of activity)

  43 -> + (animal location)

  48 -> O (animal location which was assigned zero weight)

4th column - X coordinates

5th column - Y coordinates

Values may be changed by the user to manipulate the symbols and line types used in the plot.

Advanced Applications

Files from several animals (or several seasons for the same animal, etc.) can be appended together using an editor or word processor, so that they can be plotted on the same figure. The first two command lines (title and units) may appear only once in the combined data file. All data for symbols must appear after all data for contours. A study area map or landmarks could be similarly coded and entered using digitized information.

The coded information in the first 3 columns can be used to import contour data into a Geographic Information System (GIS). This is easiest if only the one specific contour to be imported is requested from the HOME RANGE program. Once imported, the GIS can do many useful things such as change scale, overlay maps, tabulate the areas of vegetation types, stand ages, or land ownership, within a contour, or home range boundary.

Program Defaults

1. Both axes are plotted on the same scale (possible bug?).
2. Size of the plotted area is approximately 5¾ x 8½ inches on letter size paper.
3. Default input filename extension is *.PLT (does not need to be typed when input file name is requested). Any other extension must be typed out.
4. Baud rate is set at 9600. Make sure that the DIP switches are set correctly before sending any output to the plotter.

The DIP switches should be set as follows:

```
                              Binary Bit
   DIP Switches               Position

   S1 S2  Y US A3 B4 B3 B2 B1                HP 7475
          ■       ■     ■     ■      1
   ■  ■   ■       ■     ■     ■      0
          D M A4
            E
            T


   S1 S2  Y US B4 B3 B2 B1                   HP 7470
          ■  ■  ■        ■          1
   ■  ■                  ■     ■    0
          D A4
```

Running HPLOT

Syntax: [d:][path]HPLOT [s]   where the optional command line parameter, *s*, will allow you to skip the logon screen and the disclaimer. **If you are using this program for the first time, we request that you not skip these messages.**

Note: If you have a Hercules graphics adapter for your graphic output, you **MUST** run the Hercules driver (QBHERC.COM) by typing **QBHERC** before running HPLOT or in a batch file. Otherwise, an **"Illegal function call"** error message will occur when it tries to plot to the screen. The Hercules driver is a memory resident program (about 8K of RAM) and needs to be loaded only once per session.

A. Floppy System

1. *One floppy disk drive*
   a. Insert diskette with HPLOT in drive A and type **HPLOT [s]** followed by <Enter>.
   b. After HPLOT has been loaded in memory, replace disk in drive A with your data disk.

2. *Two floppy disk drives*
   a. Insert disk with HPLOT in drive A and your data disk in drive B.
   b. Change to the B drive and type **A:HPLOT [s]** <Enter>.

B. Hard Disk System

Copy HPLOT.EXE to the (sub)directory where the HOME RANGE program is located or where the "*.PLT" files are located. HPLOT can also be run from another (sub)directory (assuming that you have set the proper path statements in your AUTOEXEC.BAT file). Type **HPLOT [s]** <Enter> to start.

Menu Commands

A command can be executed either by typing the first character of the option or by moving the highlighted bar to the desired option using the Left (←) or Right (→) Arrow keys and then hitting <Enter>. A brief description of an option is given below the list of options. Move the highlighted bar using the arrow keys.

Initial Menu

Option Result

Setup   If you are going to use a plotter, this option will configure the plotter model and serial interface.

Menu   Display the main menu (see **Main Menu**, pages 56-57)

Info   Display some information about the program

Quit   Return to DOS

Main Menu

The HPLOT main menu appears as below:

```
C:\HR                                                                MENU
```
```
Graph Plot Files ChDir Shell Quit
Graph data on screen
```

Option Result

Graph   Display figure on the monitor, or dump to a printer. The figure types available are Low, High, ColorEGA, MonoEGA, EmulHGC depending on the desired resolution of the displayed figure and your system configuration.

  Low and High are for systems with (1) CGA, (2) EGA with ECD, and (3) Video Graphics

Array (VGA) for the new IBM PS/2 machines. **ColorEGA** requires EGA with ECD. In Low resolution, Y-values are printed in plotter units and X-values are printed in actual units. Four colors (depending on the palette setting) are possible in this mode. In High resolution mode, both X-and Y-values are given in actual units. Only two colors are possible but plot resolution will be better. You will be asked whether you want to change the foreground color. If you answer yes, HPLOT will prompt you to input a color number. Hit the <Space Bar> when you've finished viewing the plot.

MonoEGA requires EGA with a monochrome display. **EmulHGC** requires Hercules Graphics Card (HGC) or 100% compatibles with a monochrome monitor.

☞ The routine which checked for the correct display type has been removed to make allowances for other modes. Make sure that you press the correct key when making a choice! Should you press the wrong key, an **"Illegal function call"** error will occur. (If you chose low or high resolution graph, HPLOT still checks whether a color monitor is present).

You can dump screen graphics to a dot matrix printer by hitting the <Shift> and <PrtSc> keys simultaneously, provided you have executed the DOS graphics dump utility (GRAPHICS.COM) before running HPLOT.

You can dump screen graphics to a HP LaserJet printer if the LASER.BAT utility has been run previously.

Plot   Plot data on flat bed plotter. The plot will be as large as possible on the paper. This will be the best choice on most data files when plotter output is desired.

"Display data used in plotting? [y|n]"[7] shows choices made to determine size and scale of plot. We used it mainly for debugging purposes (see **Program Defaults**, page 54). It is useful if errors are suspected in axis labeling.

Files   Display file names on the current drive or directory. Up to 90 file names can be displayed using this option.

ChDir   Change the current drive/directory. If you want to change directories, the new directory name must be preceded by a backslash ("\"). The drive letter is optional. Five logical disk drives (A through E) can be accessed.

Shell   Shell to DOS. Return to the operating system temporarily. This option requires that the command processor (COMMAND.COM), or whatever is specified in your **SET COMSPEC =** statement in your DOS environment be on the default/specified drive. While in shell, you can execute DOS internal commands or run any external programs. However, we DO NOT recommend that you run any memory resident programs while in the shell——it could have unpredictable results! Type **EXIT** to return to HPLOT.

Quit   Return to the operating system or Home Range Driver. You will be asked to verify this option with a **Yes** or **No** answer.

---

[7]Some versions of HPLOT do not display this message.

Known Bugs

1. An extra tick mark is sometimes plotted on the y-axis.
2. Some other programs may not work with the plotter, after you have run HPLOT. Turning the plotter off and back on should correct this problem.
3. Rarely, some data files will not plot, or only plot partially. Once in a while, a successful screen graph will not be plotted properly. Try again, perhaps after rebooting.
4. If you first choose Low resolution graph for the Graph option, and then later choose High resolution, you will get a blank screen while graphing in High resolution. Choose High resolution graph first.

Tips

1. If you have problems distinguishing the various line types on a high resolution screen display, try plotting it in low resolution. Lines will be displayed in various colors.
2. If you select the Graph option, choose High resolution first before the others so that you won't get a blank screen. Should you select Low before High resolution, press the <Space Bar> to get back to the menu then choose High resolution again, but this time change the foreground color. The foreground color should never be black.
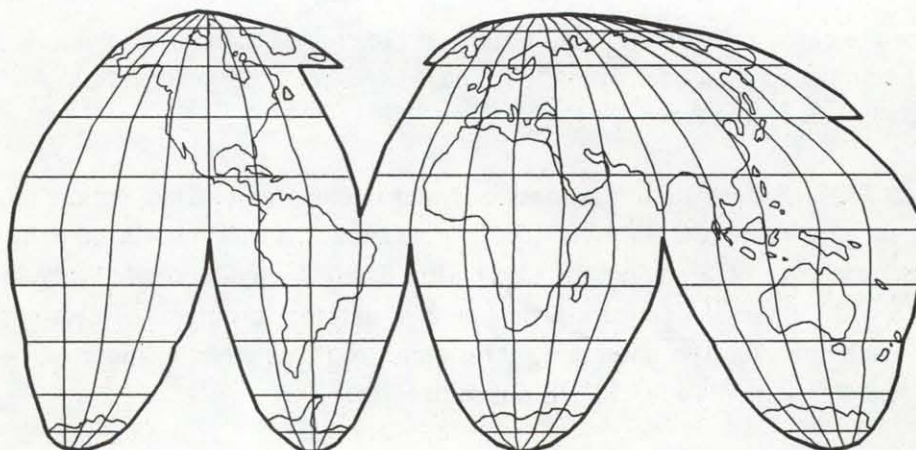
HOME RANGE 3-DIMENSIONAL PLOTTING UTILITY

Introduction

HR3D works in conjunction with the microcomputer version of the program HOME RANGE. Its sole purpose is to display the three-dimensional utilization distribution from the grid harmonic mean estimator output by HOME RANGE. However, other data in the same format may also be displayed using this utility. The display may be saved to a disk file. Once saved, a plot can be rapidly redisplayed. HREGA.COM is the version for Enhanced Graphics Adapters.

System Requirements

Hardware : IBM PC, PS/2, or 100% compatibles.
Display : Color (CGA), Enhanced (EGA) Graphics or Video Graphics Array (VGA) Adapter and a graphics monitor. Might work with Hercules Graphics Card (HGC) if you have a color emulation program.

Hardcopy : Dump to dot matrix or laser printer.
Credits : This program is based on Chandler and Faulkner's (1985) program for plotting a function.
Source : Turbo Pascal 3.0

Format of Input Data File

The input data file is typically created by program HOME RANGE, however, a similar grid of surface data created by another means could also be plotted.

Limits : Currently dimensioned for up to 1,800 points (grid size can be 60 x 30, with long direction on X-axis)
File : ASCII text file (no tab characters)
Data : Three (3) columns of X, Y, and Z variables. Program reads in free format, so column position is not critical, but there must be a space (or comma) between the columns. Data are sorted by X, then Y value. X and Y are integer values of the grid coordinates.

     1st - X-value on grid (integer, range 1-60, no decimal point)
     2nd - Y-value on grid (integer, range 1-30, no decimal point)
     3rd - Z-value harmonic mean value on grid (real, decimal required)

Running Home Range 3D

Syntax: [d:][path]HR3D [s]   where the optional command line parameter, *s*, will allow you to skip
                                  the logon screen and the disclaimer. **If you are using this program for
                                  the first time, we request that you not skip these messages.**

A. Floppy System

1. *One floppy disk drive*
   a. Insert diskette with HR3D in drive A and type **HR3D [s]** followed by <Enter>.
   b. After HR3D has been loaded in memory, replace disk in drive A with your data disk.

2. *Two floppy disk drives*
   a. Insert disk with HR3D in drive A and your data disk in drive B.
   b. Change to the B drive and type **A:HR3D [s]** <Enter>.

B. Hard Disk System

   Copy HR3D.COM to the (sub)directory where the HOME RANGE program is located or where the
"*.HAR" files are located. HR3D can also be run from another (sub)directory (assuming that you have
set the proper path statements in your AUTOEXEC.BAT file). Type **HR3D [s]** <Enter> to start.

Program Defaults

1. Low or medium resolution graph.
2. Graph will not be saved to disk.
3. The eye position from which the surface is viewed is:
   X-eye = 120, Y-eye = 10 and Z-eye = 10. That is, the surface is viewed from the outer end of
   the X axis. *Note:* X- and Y-eye should be greater than zero!
4. Color Monitor: graph foreground = blue, background = black, palette = 0
5. Full extent of grid is used.
6. Default extensions for input and graph filenames are ".HAR" and ".PIX" respectively, and need not
   be typed.

Options From Main Menu

Making a Selection

Move the highlighted bar to the desired option using the Up (↑) or Down (↓) Arrow keys or the <Space Bar> and press the <Enter> key to make the selection. The last selection on any menu will return you to the previous menu, or to the operating system if you are on the main menu. The main menu appears as below:

```
          HomeRange3D   Version 1.00

                Change defaults
                Generate 3D plot
                Display 3D plot
                Change directory
                Exit to DOS

       Use ↑ ↓ keys or SPACE BAR to move highlighted
       bar to desired option, then hit ◄──┘ to select.
```
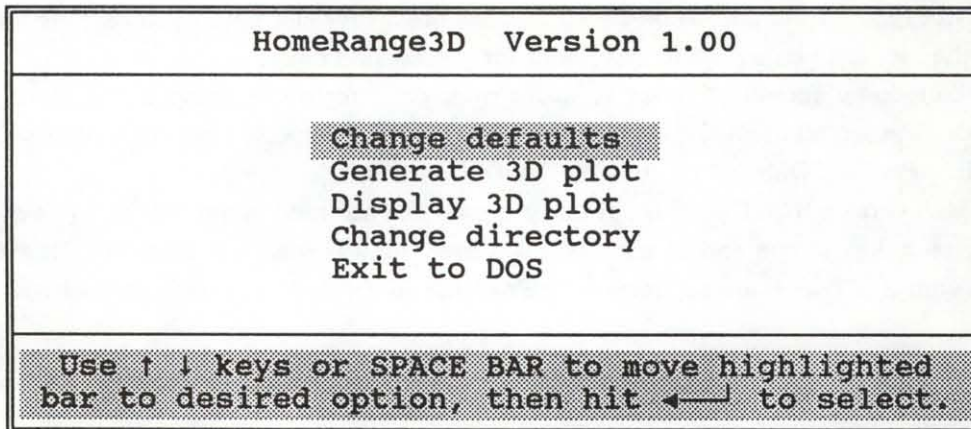
1. *Change defaults* - Current settings are displayed on the right of the screen. This option lets you change the default options listed previously under **Program Defaults**, page 60. The position from which the plot is viewed is governed by the X-, Y- and Z-eye coordinates. The X- and Y-eye coordinates should be non-negative, but the Z-eye position could be negative, (represents looking at the plot from the bottom up).

   If your plot contains large flat, uninteresting areas of grid at the sides, (caused by too large SCALE parameter in HOME RANGE) you can trim off excess grid in the X direction. This also fills the plot space better. This is controlled by the left (back) and right (front) X-points. Proper choice of these values tells the program to ignore grid intersections further away than these values. We suggest that you plot the entire grid (default) first before trimming off any area (although no permanent change has been made to the file). Some trial and error may be necessary to make the grid cells in both the X and Y direction appear equally spaced.

   Other parameters that can be changed include graph resolution, foreground and background colors, and the palette. Colors and palette obviously only matter with a color monitor. The palette only affects low resolution plots. Ranges for the various parameters are:

Graph resolution (low/high)	(1 - 2)
Graph foreground color	(1 - 15)
Graph background color	(0 - 15)
Palette color	(0 - 3)

If you choose to save a graph to disk, you will be prompted for a filename. The program checks whether the file already exists, and whether there is enough free space. Each CGA plot occupies 16K of disk space (EGA about 27K ≈ 28,000 bytes).

2. *Generate 3D plot* - This is the main module in this package. You'll be requested for an input filename. You may enter "*.HAR" to display all files with the extension "HAR" (harmonic mean values output by HOME RANGE). Or just press < Enter> to list all files with the extension "HAR" (default) on the current directory. Move the cursor to the correct file, and press < Enter>. The program reads your data file, plots it to the screen, and saves the figure to disk (if requested in advance). A beep signals the end of an operation such as plotting or saving the file to disk. If you did not request the plot to be saved to disk, press any key when you're done viewing the plot. If the plot is to be saved to disk, wait for the second beep.

You can dump screen graphics to a dot matrix printer by pressing the < Shift> and the < PrtSc> keys simultaneously, provided you have previously executed the DOS graphics dump utility (GRAPHICS.COM) before running HR3D.

The EGA version (HREGA.COM) of this program has a screen dump routine of its own. Press the < Enter> key at the end of each plot if a hard copy is required. Only EPSON FX, JX, MX printers with GrafTrax+ are supported. **THEY MUST BE OPERATING IN EPSON MODE, NOT IBM MODE.**

3. *Display 3D plot* - If you have plots that have already been saved on disk, you can view them with this option. You'll be requested for an input graph file name. You may enter "*.PIX" for all files with the extension "PIX" (created under option 2). Or just press < Enter> to list all "PIX" files (default) on the current directory. Move the cursor to the correct file and press < Enter>. The program displays the plot almost instantly.

4. *Change directory* - This option allows you to change the current drive or directory. If you change drives, the drive letter must be followed by a colon (":"). However, changing (sub)directories on the same drive is accomplished by entering the full path name. For example, if you have a subdirectory named WILDLIFE\HOMRANGE on drive C: but you load HR3D from C:\WILDLIFE\PROGRAMS. To change to C:\WILDLIFE\HOMRANGE, enter **WILDLIFE\HOMRANGE**.

6. *Exit to DOS* - Return to the operating system or Home Range Driver.

FOURIER TRANSFORM HOME RANGE ESTIMATE

Introduction

This program calculates the utilization distribution, and the home range size (or more precisely, the MAP(0.50) and MAP(0.95) indexes) from a sequence of animal locations (Anderson 1982). The calculations employ the Fast Fourier Transform (FFT) method of numerical analysis. It is a modification of the Pascal program originally written by Dr. D. John Anderson, Department of Zoology NJ-15, University of Washington, Seattle, WA 98195.

System Requirements

Hardware : IBM PC, PS/2, or 100% compatibles.
Source   : Turbo Pascal 3.0

Format of Input Data File

The X- and Y-coordinates are read from an input file. The program expects one coordinate pair per line, each consisting of an X-coordinate, a space or comma, and a Y-coordinate (see "*.FFT" files for an example). Command lines from HOME RANGE input files must not be present. Any other data to the left of the X and Y values will cause errors (data may be present to the right).

Program Parameters

There are a number of variables which may be changed to adjust accuracy, memory requirements, and execution time. The grid size is fixed for a particular version of the program. For the regular version (HRF.COM), it is fixed at 32 by 32. If you would like to double the grid size (64 by 64), use the HRF64 version. (HRF64 requires the math coprocessor. Computation time is doubled or tripled depending on your system configuration. HRF64 checks for the presence of a math coprocessor.)

Specifying Boundaries of the "World"

Animals move in a rectangular "world" which is bounded by variables LowXWorld, HighXWorld, and LowYWorld, HighYWorld. There are two methods of specifying the boundaries: The first is to specify the constant AutoBoundary = TRUE, in which case the program scans the data to determine the highest X and Y data value.

The advantage of this method is that one need not know the size of the world before the program is run. The disadvantage is that the size of the world is somewhat dependent upon the sample size (a data set with many observations will tend to have a greater range than one with few observations). This leads to a small sample size bias when calculating home range size from very few observations.

In the second method, the user specifies the boundary of the world (set AutoBoundary = FALSE). The advantage of this method, when comparing many home range estimates, is that the world can be the same size for all home range calculations, eliminating a potential source of bias. All simulations in Anderson (1982) were done with AutoBoundary = FALSE. However, this has the disadvantage that the size of the world in which the animals move must be known before the program is run. Also if the locations are confined to a very small portion of the world, because the boundaries were chosen too large, an inaccurate MAP estimate may result. A warning message will be printed if all the animal locations fall within a rectangle which is less than 20% of the area of the world.

There should be no observations near the edge of the world. This is because the FFT assumes that LowX wraps around and connects with HighX and LowY wraps around and connects to HighY. If there is a region around the outside of the world where there are no observations, no discontinuities will result at the point of wrap around.

Good results have been obtained with FractionBigger = 0.2. This is a confusing and often ignored problem. Fortunately, there should never be a need to use another value of FractionBigger.

Specifying the Number of Cells in the World

The world in which animals move is divided into cells. There are WorldX + 1 by WorldY + 1 cells in the world. Animal locations are recorded to a location no finer than one cell. The larger WorldX and WorldY are, the more storage is required, and the longer the execution time, but the more precise the MAP estimate. Estimates of area are no more precise than the area of one cell. Because an FFT is used, WorldX + 1 and WorldY + 1 are restricted to a power of two (i.e. 2, 4, 8, 16, 32, 64, 128, 256, ...). The present choices are 32 and 64. Extensive tests have been carried out and both have given satisfactory results.

Running Fourier Home Range Estimator

Syntax: [d:][path]HRF [s]   where the optional command line parameter, *s*, will allow you to skip the logon screen and the disclaimer. If you are using this program for the first time, we request that you not skip these messages.

A. Floppy System

1. *One floppy disk drive*
   a. Insert diskette with HRF in drive A and type **HRF [s]** followed by <Enter>.
   b. After HRF has been loaded in memory, replace disk in drive A with your data disk.

2. *Two floppy disk drives*
   a. Insert disk with HRF in drive A and your data disk in drive B.
   b. Log onto the B drive and type **A:HRF [s]** <Enter>.

B. Hard Disk System

Copy HRF.COM to the (sub)directory where the HOME RANGE program is located or where the "*.FFT" files are located. HRF can also be run from another (sub)directory (assuming that you have set the proper path statements in your AUTOEXEC.BAT file). Type **HRF [s]** <Enter> to start.

Options From Main Menu

Making a Selection

Move the highlighted bar to the desired option using the Up (↑) or Down (↓) Arrow keys or the <Space Bar>, and press <Enter> to make the selection. The main menu appears as below:

```
╔══════════════════════════════════════════════════════╗
║                                                        ║
║        Home Range - Fast Fourier Transform             ║
║  ────────────────────────────────────────────────     ║
║                                                        ║
║              AutoBoundary          T                   ║
║              Read data file                            ║
║              Change directory                          ║
║              Default settings                          ║
║              Exit to DOS                               ║
║                                                        ║
║  ────────────────────────────────────────────────     ║
║     Use ↑ ↓ keys or SPACE BAR to move highlighted      ║
║   bar to desired option, then hit ◄──┘ to select.      ║
╚══════════════════════════════════════════════════════╝
```

1. *AutoBoundary* - AutoBoundary is set to True by default, (designated by the letter **T** to the right of the option, False otherwise) meaning that the maximum and minimum values are calculated from the data. If the boundaries are known, you may change this option. You will be prompted for the lower and upper boundaries for the X and Y location. Enter the lower and upper boundary, separated by at least one space, on one line.

2. *Read data file* - Specify input file to read, and optional new name for the resulting output file. When asked for the file specification for the input file, you may enter "*.FFT" for all files with the extension "FFT". Or press <Enter> to list all files on the current directory. Move the cursor to the selected file. You'll be prompted for an output file name. You may press <Enter>, or type in the full file name. If <Enter>, the program will use the first part of the input file name and attach the extension ".OUT" to it. Should an output file of the same name already exist, the program will ask whether to overwrite it or not.

   Next, the program will read in the data file, display the steps that it is doing, print some information and program output to the screen, and beep when done.

3. *Change directory* - This option allows you to change the current drive or directory. If you change drives, the drive letter must be followed by a colon (":"). However, changing (sub)directories on the same drive is accomplished by entering the full path name. For example, if you have a subdirectory named WILDLIFE\HOMRANGE on drive C: but you load HRF from C:\WILDLIFE\PROGRAMS. To change to C:\WILDLIFE\HOMRANGE, enter **WILDLIFE\HOMRANGE**.

4. *Default settings* - Briefly describes what the default settings are.

5. *Exit to DOS* - Return to the operating system or Home Range Driver.

Program Output

At present, only the MAP(0.50) and MAP(0.95) estimates are printed. If you would like different MAP estimates to be output, we'll consider customizing the program for you. Also included in the output are the UD, the range of X and Y values, and any error messages.

Modifications

1. Adapted for Turbo Pascal version 3.0. Few changes in code were made except for renaming several variables, deletion of non-standard procedures, and redimensioning arrays.
2. Added cursor, input, logo, window, file handling, directory, and timer routines.
3. User prompted for input and output filenames and confirmation for overwriting an existing file.
4. User prompted for changes in program defaults. If defaults are accepted, the program calculates minimum and maximum values for X and Y coordinates. Otherwise, user is prompted for those values, so they must be known in advance.
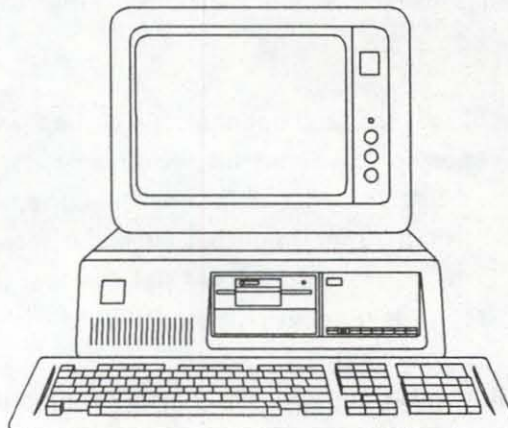
ERROR MESSAGES & TROUBLE SHOOTING GUIDE

Home Range Driver

The most common error messages are **"File not found"**, caused by name or path of a program spelled wrong, or program not found in the specified path, and **"Not enough memory"** means that you are loading a program that is too big to fit into available memory. Occasionally you may get a run-time error message of the form **"Run-time Error ##, PC = ####"** where the **"#"** will represent some numbers and letters (in hexadecimal). If you ever get this error, please record these numbers, and also how it happened.

I changed HRD.USR to show the paths in my directory, but it doesn't work.

☞ Each line must be blank out to column 40, after the appropriate path statement. Comments follow beginning in column 41.

☞ Verify that the path statements are correct for your computer.

HRD won't bring up my word processor, even though I listed it as the editor in HRD.USR on line 1.

☞ You may not have enough RAM to bring a full-size word processor (such as Microsoft Word, WordPerfect, etc.) when the Home Range Driver is resident.

HOME RANGE

Common FORTRAN Run-time Errors[8]

Error # Interpretation

1024 - Square root or log of zero, or other invalid number. Most commonly, this means that the data was never really read in, because of an error in the command lines.

2015 - Can't find input file specified (name spelled wrong or wrong disk named?).

2039 - Real number input values of wrong type. Numbers entered in wrong columns, two decimal points in same field? Letters erroneously in field? Letter 'O' instead of zero (0).

2415 - Integer input values of wrong type. Decimal point erroneously present?

3033 - Not enough room on disk to write output file.

4001 - Can't access 8087/80287/80387 math coprocessor (not present or not correctly implemented).

All of these errors are usually fatal. For other FORTRAN error codes, see the file HR.ERR.

---

[8] Applicable only if you are using the version that requires a math coprocessor. The version that does not require a math coprocessor has different error numbers and interpretations.

Common Run-time Errors/Messages

run-time error H100 - program control card(s) incorrectly specified, last card = ___

☞ An error has occurred in reading a command card. Double check the card mentioned, and also the previous card (sometimes the information is garbled).

error H120 or H160 - not enough distinct data points

☞ The program read zero or only one distinct data point(s). Either all points are identical, or none were actually read in at all. Check output to see if observations were echoed correctly.

error H121 or H161 - polygon never closed back to starting point

☞ Error in convex polygon calculation. Calculated perimeter of polygon failed to close within the small allowable tolerance. This is likely a symptom of a bigger problem. Look for other symptoms to treat. Occasionally it doesn't mean anything serious.

error H122 - grid density exceeds the maximum, change SCALE. Density set to maximum by default.

☞ Calculation of optimal grid density was requested, but the calculated optimal size was larger than the maximum allowable value (72 by 32). This indicates that there are many observations concentrated in a small area. It can be improved by reducing SCALE parameter, or possibly by eliminating outliers.

error H130 - plot scale too small to determine total utilization volume. Estimate based on harmonic value = ___ at grid ___,___

☞ The range of observations is larger than the harmonic grid (some hung over edge of grid). Harmonic estimates will not be correct. The dimensions of the grid can be (X = 24 * SCALE, Y = 10.5 * SCALE). Check for outliers and data errors. If none, increase the SCALE parameter.

warning H131 - no core area computed (10 or fewer points)

☞ No attempt is made to find a core area if ≤ 10 observations are used.

warning H132 - no significant core area present

☞ Core areas are only identified if their use is significantly greater then expected.

error H140 - value too small for contour level ____

☞ Symptom of a bigger problem. The harmonic mean estimator is unable to find or complete a contour. Often the program subsequently dies. Make sure all commands and data were read in correctly, then reexamine SCALE/grid size/minimum distance complex of parameters.

warning H150 - eigenvector solution not converging

☞ An error has occurred in calculating the eccentricity of the estimated ellipse home ranges. May cause ellipse to not report any area. Otherwise ignore it. This error affects only the eccentricity value.

Some observations were "Not assigned to grid"

☞ Those observations were off the harmonic grid. Possible causes are: SCALE parameter too small, or an outlier or data error was far from the other points.

Home range area reported as "★★★★★★★★★★★★"

☞ The number was too large, more than 10 digits left of the decimal point. Change the scale of your problem by dividing by 10, 100, 1000, etc. (e.g. change areas in m^2 to ha or km^2).

Values reported as "??????????"

☞ The program tried to read in something that was not a number. Sometimes if columns are out of line in the format statement, a letter, a decimal point, or a negative sign alone is mistakenly read in.

Data Input

I copied the example data file, changing only a few things, and now it doesn't work.

☞ Likely some values were entered out of their acceptable column ranges. Double check the command parameters echoed in the *.OUT output file. A value is likely too far left or right (often just 1 column), a decimal point in the wrong place, an integer not right justified in its field, letter instead of number (especially O ('Oh') instead of 0 (zero)), or tab characters.

☞ All real values must have decimal points.

☞ All integer values must not have decimal points, but must be right justified (examples: number of contours, number of grid points on X and Y axes).

The home range estimates seem way out of line, and an extra observation appeared in the data output.

☞ A blank line at the end of the data file may have been mistakenly inserted. It is interpreted as the point (0,0). This extreme outlier can have major impacts on results when included in the area estimates. It can also force other points off the harmonic grid, causing the message "location off grid".

The program only reads every other line of data.

☞ Usually weights (1.0) were not included in the input data file, so HOME RANGE mistakenly read the next X-coordinate as the weight and skipped to the next line.
☞ Sometimes through a format statement error, only 3 values were read on each line. Double check the data echoed in the *.OUT output file.

Output

I ran the same data set several times, and everything was the same except the result of the test for uniform distribution.

☞ This test compares the distribution of observations to a new randomly generated set of points, so changing the random number seeds will result in a different answer. Use the same seeds if an identical output is required.

HPLOT

File not found

☞ File does not exist in the current or specified directory.

Device I/O error

☞ Error during I/O operation. Check the condition of your disk by using the DOS CHKDSK command.

Bad file name

☞ File name given does not follow DOS convention. Do NOT specify any path name when requested for an input file. There's not enough room to accommodate it.

Path not found

☞ Specified path does not exist.

Disk not ready

☞ The disk drive door is open, or there's no disk in the drive.

Disk media error

☞ Something may be wrong with your diskette. Check the condition of your disk by using the DOS CHKDSK command.

I gave the name of a non-existent file, now I can't exit the file selection menu.

☞ Sorry, you'll need to reboot. Be careful out there!

Data file format error

☞ Your data file does not conform to the format that HPLOT requires. A probable cause for this error is that your data file contains tab characters inserted by some text processing programs, or title contains a comma without double quotes (") at both ends.

The program does not read any further than the title in the *.PLT file before bombing.

☞ If the title has a comma in it, the entire title must be enclosed with double quotes (").

The program displayed my figure on the screen, now how do I get out?

☞ Press <Space Bar>.

The program says it is sending my figure to the plotter, but nothing happens.

☞ Are the DIP switches on plotter set correctly?
☞ Did you execute the set-up function to correctly configure HPLOT for your plotter and serial interface?

The plotter makes a few marks, but quits.

☞ Rarely, a plot cannot be completed by HPLOT. This remains a mystery and is often remedied by trying again, or by rebooting. The source of the problem may be with other RAM-resident software. Try other files to verify that they will plot.

The program produces a plot, but distorts the image or goes out of bounds.

☞ Your computer may not be quite 100% IBM compatible, or your plotter may be incompatible with Hewlett-Packard Graphics Language.

The data doesn't fill the plot.

☞ Sometimes, especially with 6-7 digit UTM coordinates, the first 2-3 digits of each coordinate are not significant (they never change). This causes problems for HPLOT in scaling the figure. The easiest solution is to change the format statement to skip over the superfluous left-most digits, or delete those columns from the file.

How do I get a plot scaled exactly to overlay my base maps?

☞ At present, due to the number of graphics output devices, we are unable to provide this capability. Other reasonable options are interfacing with GIS software, or copying on variable-size copying machine.

HR3D

The *.PIX files included on the distribution diskettes do not run on my hardware or are distorted.

☞ The pre-saved display files (*.PIX) are very sensitive to details of graphics architecture and don't always run. HR3D will probably run on your machine, and be able to save new files for later re-play, even though the enclosed *.PIX files do not run.

REFERENCES

Abrash, M. 1987a. Inside the EGA. Programmer's Journal. 5(1):36-46.

_____. 1987b. EGA data control. Programmer's Journal. 5(3):30-36.

Adams, L., and S. D. Davis. 1967. The internal anatomy of home range. Journal of Mammalogy. 48(4):529-536.

Anderson, D. J. 1982. The home range: a new nonparametric estimation technique. Ecology 63(1):103-112.

Bekoff, M., and L. D. Mech. 1984. Simulation analyses of space use: home range estimates, variability, and sample size. Behavior Research Methods, Instruments and Computers. 16(1):32-37.

Borland. 1985. Turbo Pascal Version 3.0 Reference Manual. Borland International, Scotts Valley, CA. 376pp.

_____. 1987. Turbo Pascal Owner's Handbook Version 4.0. Borland International, Scotts Valley, CA. 640pp.

Bowen, W. D. 1982. Home range and spatial organization of coyotes in Jasper National Park, Alberta. Journal of Wildlife Management. 46(1):201-216.

Braun, S. E. 1985. Home range and activity patterns of the giant kangaroo rat, _Dipodomys ingens_. Journal of Mammalogy. 66(1):1-12.

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. Journal of Mammalogy. 24(3):346-352.

Campbell, N. A. 1980. Robust procedures in multivariate analysis I: Robust covariance estimation. Applied Statistics. 29(3):231-237.

Chandler, R., and G. Faulkner. 1985. The painter's algorithm. PC Tech Journal. 3(11):181-187.

Covington, M. 1985. The power of Turbo Pascal. PC Tech Journal. 3(2):112-123.

Diggle, P. J. 1979. Statistical methods for spatial point patterns in ecology. Pages 95-150 _in_ R. M. Cormack and J. K. Ord, editors. Spatial and Temporal Analysis in Ecology. International Co-operative Publishing House, Fairland, MD.

Dixon, K. R., and J. A. Chapman. 1980. Harmonic mean measure of animal activity areas. Ecology 61(5):1040-1044.

Don, B. A., and K. Rennolls. 1983. A home range model incorporating biological attraction points. Journal of Animal Ecology. 52(1):69-81.

Dunn, J. E., and I. L. Brisbin, Jr. 1982. Characterizations of the multivariate Ornstein-Uhlenbeck diffusion process in the context of home range analysis. Technical Report 16, Statistics Laboratory, University of Arkansas, Fayetteville, AR. 72pp.

_____, and P. S. Gipson. 1977. Analysis of radio telemetry data in studies of home range. Biometrics 33(1):85-101.

Ewer, R. F. 1968. Ethology of Mammals. Legos Press, London, England. 418pp.

Ford, R. G., and D. W. Krumme. 1979. The analysis of space use patterns. Journal of Theoretical Biology. 76(2):125-155.

Fuller, T. K., and W. J. Snow. 1988. Estimating winter wolf densities using radiotelemetry data. Wildlife Society Bulletin. 16(4):367-370.

Garshelis, D. L. 1983. The role of sampling intensity in the selection of a home range model. Pages 270-275 *in* D. G. Pincock, editor. Proceedings of the Fourth International Conference on Wildlife Biotelemetry, Applied Microelectronics Institute, Halifax, Nova Scotia, Canada.

Garton, E. O., M. D. Samuel, and J. M. Peek. 1985. Analysis of moose home ranges. Alces 21:77-89.

Harestad, A. S. 1981. Computer analysis of home range data. British Columbia Fish and Wildlife Branch, Bulletin B-11. 25pp.

Harvey, M. J., and R. W. Barbour. 1965. Home range of *Microtus ochrogaster* as determined by a modified minimum area method. Journal of Mammalogy. 46(3):398-402.

Hayne, D. W. 1949. Calculation of size of home range. Journal of Mammalogy. 30(1):1-18.

Hayward, G. D., P. H. Hayward, and E. O. Garton. 1987. Movements and home range use by boreal owls in Central Idaho. Pages 175-184 *in* R. W. Nero, C. R. Knapton, R. J. Hamre, editors. Biology and Conservation of Northern Forest Owls: symposium proceedings. General Technical Report RM-142, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Hewlett-Packard. 1982a. Interfacing and Programming Manual. Part No. 07474-90001. Hewlett-Packard Company, San Diego, CA.

_____. 1982b. Interconnection Guide. Part No. 07474-90003. Hewlett-Packard Company, San Diego, CA.

_____. 1983. Operator's Manual. Part No. 07474-90002. Hewlett-Packard Company, San Diego, CA.

_____. 1984. Interfacing and Programming Manual. Part No. 07475-90001. Hewlett-Packard Company, San Diego, CA.

_____. 1985. Operation and Interconnection Manual. Part No. 07475-90002. Hewlett-Packard Company, San Diego, CA.

IBM. 1984. BASIC 3.0 Manual. 3rd Edition. IBM Corporation, Boca Raton, FL. 478pp.

Jaremovic, R. V., and D. B. Croft. 1987. Comparisons of techniques to determine eastern grey kangaroo home range. Journal of Wildlife Management. 51(4):921-930.

Jennrich, R. I., and F. B. Turner. 1969. Measurement of non-circular home range. Journal of Theoretical Biology. 22(2):227-237.

Johnson, R. A., and D. W. Wichern. 1982. Applied Multivariate Analysis. Prentice-Hall, Englewood Cliffs, NJ. 594pp.

Kaufmann, J. H. 1962. Ecology and social behavior of the coati, *Nasua narica* on Barro Colorado Island, Panama. University of California, Publications in Zoology. 60:95-222.

Koeppl, J. W., N. A. Slade, and R. S. Hoffman. 1975. A bivariate home range model with possible application to ethological data analysis. Journal of Mammalogy. 56(1):81-90.

_____, _____, K. S. Harris, and R. S. Hoffman. 1977. A three-dimensional home range model. Journal of Mammalogy. 58(2):213-220.

Koziol, J. A. 1982. A class of invariant procedures for assessing multivariate normality. Biometrika 69(2):423-427.

Kumar, A. 1986. Using DOS to call programs from Turbo Pascal. Programmer's Journal. 4(1):31-38.

Lair, H. 1987. Estimating the location of the focal center in red squirrel home ranges. Ecology 68(4):1092-1101.

Laundre, J. W., and B. L. Keller. 1984. Home-range size of coyotes: a critical review. Journal of Wildlife Management. 48(1):127-139.

Lether, F. G. 1986. Curves made simple. PC Tech Journal. 4(1):159-170.

Leuthold, W. 1977. African Ungulates: a comparative review of their ethology and behavioral ecology. Springer-Verlag, New York, NY. 307pp.

Lindstedt, S. L., B. J. Miller, and S. W. Buskirk. 1986. Home range, time, and body size in mammals. Ecology 67(2):413-418.

Lubkin, B. 1986. A critical error handler for Turbo Pascal. Programmer's Journal. 4(3):27-31.

MacDonald, D. W., F. G. Ball, and N. G. Hough. 1980. The evaluation of home range size and configuration using radio tracking data. Pages 405-424 *in* C. J. Amlaner and D. W. MacDonald, editors. A Handbook on Biotelemetry and Radio Tracking. Pergamon Press, Oxford, UK.

Madden, R., and L. F. Marcus. 1978. Use of the *F* distribution in calculating bivariate normal home ranges. Journal of Mammalogy. 59(4):870-871.

Mansfield, V. 1985. Scientific graphics with the EGA. PC Tech Journal. 3(9):163-170.

Mares, M. A., M. R. Willig, and N. A. Bitar. 1980. Home range size in eastern chipmunks, *Tamias striatus*, as a function of number of captures: statistical biases of inadequate sampling. Journal of Mammalogy. 61(4):661-669.

Metzgar, L. H. 1972. The measurement of home range shape. Journal of Wildlife Management. 36(2):643-645.

Michener, G. R. 1979. Spatial relationships and social organization of adult Richardson's ground squirrels. Canadian Journal of Zoology. 57(1):125-139.

MicroHelp. 1986. Mach 2 1.10 Manual. MicroHelp, Marietta, GA. 200pp.

Microsoft. 1987a. Microsoft QuickBASIC 4.0: Learning and using Microsoft QuickBASIC. Part No. 00618. Microsoft Corporation, Redmond, WA. 386pp.

_____. 1987b. Programming in BASIC: Selected Topics. Part No. 00619. Microsoft Corporation, Redmond, WA. 322pp.

_____. 1987c. Microsoft QuickBASIC 4.0: BASIC Language Reference. Part No. 00620. Microsoft Corporation, Redmond, WA. 533pp.

_____. 1987d. Microsoft FORTRAN Optimizing Compiler 4.0 User's Guide. Part No. 00035. Microsoft Corporation, Redmond, WA. 507pp.

_____. 1987e. Microsoft FORTRAN Optimizing Compiler 4.0 Language Reference. Part No. 00036. Microsoft Corporation, Redmond, WA. 374pp.

Neft, D. S. 1966. Statistical Analysis for Areal Distributions. Monograph Series Number 2, Regional Science Research Institute, Philadelphia, PA. 172pp.

O'Brien, S. K., and W. K. Cheung. 1986. Assembler source code for DOS function calls. Programmer's Journal. 4(6):39.

Odum, E. P., and E. J. Kuenzler. 1955. Measurement of territory and home range size in birds. Auk 72(2):128-137.

Randles, R. H., J. D. Brofitt, J. S. Ramberg, and R. V. Hogg. 1978. Generalized linear and quadratic discriminant functions using robust estimates. Journal of the American Statistical Association. 73(363):564-568.

Romesburg, H. C. 1981. Wildlife science: gaining reliable knowledge. Journal of Wildlife Management. 45(2):293-313.

Samuel, M. D., and E. O. Garton. 1985. Home range: a weighted normal estimate and tests of underlying assumptions. Journal of Wildlife Management. 49(2):513-519.

_____, and _____. 1987. Incorporating activity time in harmonic home range analysis. Journal of Wildlife Management. 51(1):254-257.

_____, and R. E. Green. 1988. A revised test procedure for identifying core areas within the home range. Journal of Animal Ecology. 57(3):1067-1068.

_____, D. J. Pierce, and E. O. Garton. 1985a. Identifying areas of concentrated use within the home range. Journal of Animal Ecology. 54(3):711-719.

_____, _____, and _____, L. J. Nelson, and K. R. Dixon. 1985b. User's Manual for Program HOME RANGE. Revised Edition. Technical Report 15, Forestry, Wildlife and Range Experiment Station, University of Idaho, Moscow, ID. 70pp.

Schoener, T. W. 1981. An empirically based estimate of home range. Theoretical Population Biology. 20(3):281-325.

Schrage, L. 1979. A more portable FORTRAN random number generator. ACM Transactions on Mathematical Software. 5(2):132-138.

Smith, G. J., J. R. Cary, and O. J. Rongstad. 1981. Sampling strategies for radio-tracking coyotes. Wildlife Society Bulletin. 9(2):88-93.

Smith, W. P. 1983. A bivariate normal test for elliptical home-range models: biological implications and recommendations. Journal of Wildlife Management. 47(3):613-619.

Spencer, W. D., and R. H. Barrett. 1984. An evaluation of the harmonic mean measure for defining carnivore activity areas. Acta Zoologica Fennica. 171:255-259.

Stephens, M. A. 1974. EDF statistics for goodness of fit and some comparisons. Journal of the American Statistical Association. 69(347):730-737.

Swihart, R. K., and N. A. Slade. 1985a. Influence of sampling interval on estimates of home-range size. Journal of Wildlife Management. 49(4):1019-1025.

_____, and _____. 1985b. Testing for independence of observations in animal movements. Ecology 66(4):1176-1184.

_____, and _____. 1986. The importance of statistical power when testing for independence in animal movements. Ecology 67(1):255-258.

_____, and _____. 1987. A test of independence of movements as shown by live trapping. American Midland Naturalist. 117(1):204-207.

_____, _____, and B. J. Bergstrom. 1988. Relating body size to the rate of home range use in mammals. Ecology 69(2):393-399.

Van Winkle, W. 1975. Comparison of several probabilistic home-range models. Journal of Wildlife Management. 39(1):118-123.

Waldschmidt, S. R. 1979. The effect of statistically based models on home range size estimate in *Uta stansburiana*. American Midland Naturalist. 101(1):236-240.

Wichmann, B. A., and I. D. Hill. 1982. An efficient and portable pseudo-random number generator. Algorithm AS 183. Applied Statistics. 31(2):188-190.

Worton, B. J. 1987. A review of models of home range for animal movements. Ecological Modelling. 38(3/4):277-298.

_____. 1989. Kernel methods for estimating the utilization distribution in home range studies. Ecology 70(1):164-168.

APPENDIX

Listing[9] of plot file (BOREAL.PLT). Comments are given on the right and printed inside a box.

```
BOREAL 55 FLOSSIE FEMALE SUMMER 84-86  ▪   ┌─────────────────────────────┐
                                           │ Title and unit              │
METERS                                     └─────────────────────────────┘
1  95  1   34500.0000   28969.4766   ▪
1  95  0   34344.6250   29224.6270       ┌─────────────────────────────┐
1  95  0   34282.5664   29380.0000       │ 95% harmonic contour        │
1  95  0   34273.8164   29606.1836       └─────────────────────────────┘
1  95  0   34259.6367   29749.6367
.  ..  .   .........    .........
.  ..  .   .........    .........
.  ..  .   .........    .........
1  95  0   34914.7422   28574.7441
1  95  0   34685.9727   28770.0000
1  95  0   34580.0117   28850.0098
1  95  0   34500.0000   28969.4766       ┌───────────────────────────────────┐
1  75  1   34500.0000   29373.7910   ▪   │ 75% harmonic contour, segment 1   │
1  75  0   34497.6484   29377.6504       └───────────────────────────────────┘
1  75  0   34496.7109   29380.0000
1  75  0   34496.5781   29383.4219
1  75  0   34442.3242   29932.3223
.  ..  .   .........    .........
.  ..  .   .........    .........
.  ..  .   .........    .........
1  75  0   35110.0000   28734.1621
1  75  0   35088.3164   28748.3184
1  75  0   35062.9141   28770.0000
1  75  0   34742.1797   29012.1797
1  75  0   34500.0000   29373.7910
1  75  1   38160.0000   28590.4707   ▪   ┌───────────────────────────────────┐
1  75  0   38056.0820   28666.0820       │ 75% harmonic contour, segment 2   │
1  75  0   37969.3633   28770.0000       └───────────────────────────────────┘
1  75  0   38072.4102   28857.5879
1  75  0   38160.0000   28876.5469
1  75  0   38256.9492   28866.9492
1  75  0   38349.9961   28770.0000
1  75  0   38288.5469   28641.4551
1  75  0   38160.0000   28590.4707
1  75  1   38770.0000   24489.9121   ▪   ┌───────────────────────────────────┐
1  75  0   38764.1016   24494.0996       │ 75% harmonic contour, segment 3   │
1  75  0   38759.2305   24500.0000       └───────────────────────────────────┘
1  75  0   38756.9531   24513.0469
1  75  0   38739.0781   25079.0801
.  ..  .   .........    .........
```

─────────────────────────

[9]The listing has been truncated in most parts.

.	..	.	....	....		
1	75	0	39546.6719	24333.3281		
1	75	0	39380.0000	24283.0176		
1	75	0	39208.1250	24328.1230		
1	75	0	38784.6602	24485.3398		
1	75	0	38770.0000	24489.9121		
1	*54*	*1*	35110.0000	28913.9141	⛏	Harmonic core area, segment 1
1	54	0	34852.6406	29122.6387		
1	54	0	34661.5977	29380.0000		
1	54	0	34664.0664	29544.0645		
1	54	0	34626.3203	29863.6777		
.	..	.	....	....		
.	..	.	....	....		
.	..	.	....	....		
1	54	0	35720.0000	28711.9570		
1	54	0	35674.6992	28724.6992		
1	54	0	35557.3320	28770.0000		
1	54	0	35254.0039	28914.0039		
1	54	0	35110.0000	28913.9141		
1	*54*	*1*	38770.0000	26155.2422	⛏	Harmonic core area, segment 2
1	54	0	38709.5781	26269.5781		
1	54	0	38655.7422	26330.0000		
1	54	0	38660.3555	26439.6445		
1	54	0	38613.7539	26783.7539		
.	..	.	....	....		
.	..	.	....	....		
.	..	.	....	....		
1	54	0	38997.1719	25337.1699		
1	54	0	38974.6523	25515.3496		
1	54	0	38993.4766	25720.0000		
1	54	0	38945.5898	25895.5898		
1	54	0	38770.0000	26155.2422		
2	*95*	*1*	42317.9141	23411.9531	⛏	95% bivariate normal ellipse
2	95	0	42396.4570	23513.5996		
2	95	0	42456.6875	23631.7500		
2	95	0	42498.3750	23765.9395		
2	95	0	42521.3516	23915.6387		
.	..	.	....	....		
.	..	.	....	....		
.	..	.	....	....		
2	95	0	41827.9297	23177.4414		
2	95	0	41975.8984	23209.7285		
2	95	0	42107.2227	23259.7187		
2	95	0	42221.3789	23327.2168		
2	95	0	42317.9180	23411.9570		
3	*95*	*1*	42448.8516	23396.3184	⛏	95% weighted bivariate normal ellipse
3	95	0	42536.8906	23511.2520		
3	95	0	42606.0000	23642.7207		
3	95	0	42655.9141	23790.2051		
3	95	0	42686.4297	23953.1250		
.	..	.	....	....		

.	. .	.	. . . .	. . . .
.	. .	.	. . . .	. . . .
3	95	0	41915.4727	23110.0000
3	95	0	42075.0195	23154.9336
3	95	0	42217.4609	23217.8086
3	95	0	42342.2383	23298.3789
3	95	0	42448.8555	23396.3223
4	100	1	34700.0000	30200.0000
4	100	0	39300.0000	29200.0000
4	100	0	40200.0000	27500.0000
4	100	0	39900.0000	25600.0000
4	100	0	39700.0000	24700.0000
4	100	0	39300.0000	24500.0000
4	100	0	34500.0000	27100.0000
4	100	0	34700.0000	30200.0000
4	95	1	35400.0000	29800.0000
4	95	0	39300.0000	29200.0000
4	95	0	40200.0000	27500.0000
4	95	0	39900.0000	25600.0000
4	95	0	39600.0000	24900.0000
4	95	0	39100.0000	24700.0000
4	95	0	39000.0000	24700.0000
4	95	0	34500.0000	27100.0000
4	95	0	35000.0000	29600.0000
4	95	0	35200.0000	29700.0000
4	95	0	35400.0000	29800.0000
4	75	1	35400.0000	29800.0000
4	75	0	39300.0000	29200.0000
4	75	0	40200.0000	27500.0000
4	75	0	39900.0000	25600.0000
4	75	0	39500.0000	25000.0000
4	75	0	39100.0000	24700.0000
4	75	0	39000.0000	24700.0000
4	75	0	34500.0000	27100.0000
4	75	0	35400.0000	29800.0000
5	1	42	35110.0000	29380.0000
5	3	48	34500.0000	27100.0000
5	2	43	35100.0000	29600.0000
5	2	43	35200.0000	29600.0000
5	2	43	35000.0000	29600.0000
5	2	43	35100.0000	29600.0000
.	.	. .	. . . .	. . . .
.	.	. .	. . . .	. . . .
.	.	. .	. . . .	. . . .
5	2	43	38200.0000	26600.0000
5	2	43	37000.0000	29500.0000
5	2	43	39700.0000	24700.0000
5	2	43	38800.0000	29200.0000
5	2	43	39300.0000	29200.0000

100% minimum convex polygon

95% minimum convex polygon

75% minimum convex polygon

Harmonic center of activity (5 1 42)
Zero weight/outlier (5 3 48)
Observations (5 2 43)

INDEX