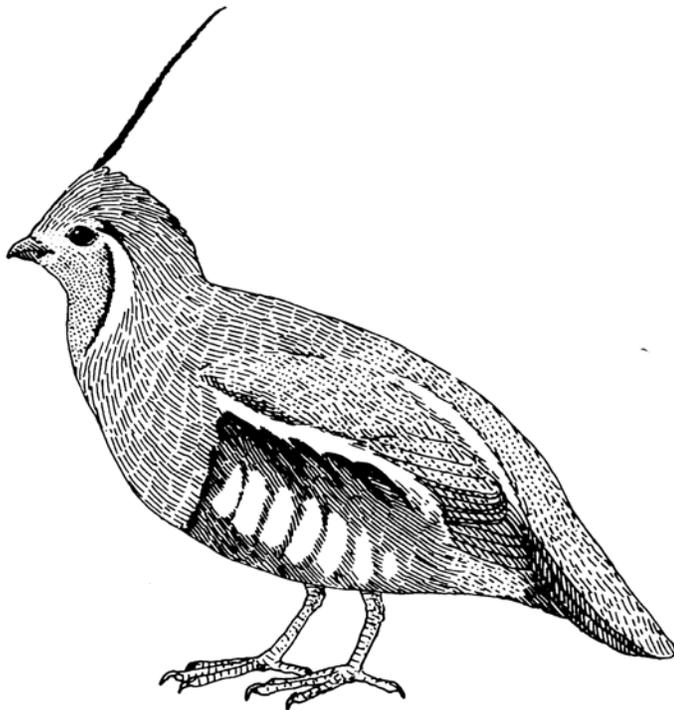**California Wildlife Habitat Relationships Program**
California Department of Fish and Game

HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO:
MOUNTAIN QUAIL

HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO:
MOUNTAIN QUAIL

by

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PREFACE

This document is part of the California Wildlife Habitat Relationships (CWHR) System operated and maintained by the California Department of Fish and Game (CDFG) in cooperation with the California Interagency Wildlife Task Group (CIWTG). This information will be useful for environmental assessments and wildlife habitat management.

The structure and style of this series is basically consistent with the "Habitat Suitability Index Models" or "Bluebook" series produced by the USDI, Fish and Wildlife Service (FWS) since 1981. Moreover, models previously published by the FWS form the basis of the current models for all species for which a "Bluebook" is available. As is the case for the "Bluebook" series, this CWHR series is not copyrighted because it is intended that the information should be as freely available as possible. In fact, it is expected that these products will evolve rapidly over the next decade.

This document consists of two major sections. The Habitat Use Information functions as an up-to-date review of our current understanding regarding the basic habitat requirements of the species. This section typically builds on prior publications, including the FWS "Bluebook" series. However, the Habitat Suitability Index (HSI) Model section is quite different from previously published models. All models in this CWHR series are designed as macros (AML computer programs) for use with ARC/INFO geographic information system (GIS) software running on a UNIX platform. As such, they represent a step up in model realism in that spatial issues can be dealt with explicitly. They are "Level II" models in contrast to the "Level I" (matrix) models initially available in the CWHR System. For example, issues such as habitat fragmentation and distance to habitat elements may be dealt with in spatially explicit "Level II" models. Unfortunately, a major constraint remains the unavailability of mapped habitat information most useful in defining a given species' habitat. For example, there are no readily available maps of snag density. Consequently, the models in this series are compromises between the need for more accurate models and the cost of mapping essential habitat characteristics. It is hoped that such constraints will diminish in time.

While "Level II" models incorporate spatial issues, they build on "Level I", nonspatial models maintained in the CWHR System. As the matrix models are field tested, and occasionally modified, these changes will be expressed in the spatial models as well. In other words, the continually evolving "Level I" models are an integral component of the GIS-based, spatial models. To use these "Level II" models one must have (1) UNIX-based ARC/INFO with GRID module, (2) digitized coverages of CWHR habitat types for the area under study and habitat element maps as required for a given species, (3) the AML presented in this document, and (4) a copy of the CWHR database. Digital copies of AMLs are available from the CWHR Coordinator at the CDFG.

Unlike many HSI models produced for the FWS, this series produces maps of habitat suitability with four classes of habitat quality: (1) None; (2) Low; (3) Medium; and (4) High. These maps must be considered hypotheses in need of testing rather than proven cause and effect relationships, and proper use of the CWHR System requires that field testing be done. The maps are only an initial "best guess" which professional wildlife biologists can use to optimize their field sampling. Reliance on the maps without field testing is risky even if the habitat information is accurate.

The CDFG and CIWTG strongly encourage feedback from users of this model and other CWHR components concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to wildlife management planning.

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ACKNOWLEDGMENTS

MOUNTAIN QUAIL (*Oreortyx pictus*)

HABITAT USE INFORMATION

General

Mountain quail (*Oreortyx pictus*) inhabit upland forest and woodland habitats in the western United States, northern Baja California, British Columbia, and Hawaii (American Ornithologists' Union 1983). In California they are common to uncommon residents of the South and North Coast Ranges, and the Cascade, Klamath, and Sierra Nevada mountain ranges (Zeiner et al. 1990). Habitats utilized by this species in California include pinyon-juniper (*Pinus-Juniperus*), oak woodland (*Quercus* spp.), chaparral, coastal forest, and montane forest associations (Miller 1951). Critical components of mountain quail habitat include tall, dense shrubs, and water (Guiterrez 1975, 1980; Brennan et al. 1987).

Food

Diets of adult mountain quail contain more than 96% vegetable matter (Guiterrez 1975), while the diets of young birds may contain up to 20% animal food (Lahnum 1944). In central California, mountain quail may exploit as many as 130 different food resources though only a few resources contribute the majority of the total volume of the diet (Guiterrez 1980). The type of food consumed and the amount that each type contributes to the diet varies both seasonally and geographically (Browning 1977; Guiterrez 1977). During winter and spring, mountain quail in California eat green leaves and buds. In summer, seeds comprise the bulk of the diet, and during the fall seeds, acorns, pine nuts, and fruits from a variety of shrubs are consumed (Grenfell et al. 1980). A generalized diet developed from 96 specimens taken in central California contained 37% seeds, 8% greens, 9% flowers, 5% fruits, 21% bulbs, 2% fungi, 4% animal matter, and 14% acorns (Guiterrez 1980).

In California, the most important shrub species for mountain quail were *Ceanothus* spp. manzanita (*Arctostaphylos* spp.), silk tassel (*Garrya* spp.), toyon (*Heteromeles arbutifolia*), poison oak *(Toxicodendron diversilobum*), squaw bush (*Rhus trilobata*), and laurel sumac (*Malosma laurina*) with preference varying by ecosystem (Grenfell et al. 1980). Six genera of plants including woodland star (*Lithophragma* spp.), oak (*Quercus* spp.), chickweed (*Stellaria* spp.), storksbill (*Erodium* spp.), and clover (*Trifolium* spp.) comprised over 60% of the total volume of foods consumed by mountain quail in central California (Guiterrez 1980). Mountain quail forage by digging for bulbs, jumping for seed heads, shelling acorns, climbing for seeds, plucking leaves and fruits, scratching for seed, and pecking at exposed foods (Guiterrez 1980). The type of foraging method used varies seasonally with pecking occurring all year. During the summer, mountain quail feed by digging, jumping, climbing, plucking, and scratching, while mountain mountian quail feed by shelling acorns, digging, and scratching in the fall. In winter and spring, they feed by plucking leaves, buds, and fruits (Guiterrez 1980).

Water

Mountain quail require daily drinking water during the hot weather, and young birds need water soon after hatching to survive (Grinnell and Swarth 1913; McLean 1930; Rahm 1938). Johnsgard (1973) noted that mountain quail nesting at high elevations were restricted to areas within 1.6 km (1 mile) of water, while those nesting at lower elevations placed their nests further from water and visited the watering site only after the young had hatched. The maximum distance of adult and immature mountain quail from water at Joshua Tree National Monument was 1.6 km (1 mile) and 0.8 km (0.5 mile), respectively (Miller and Stebbins 1964). Brennan et al. (1987) found mountain quail at distances from water averaging 94 m (310 ft) in the northern Coast and Sierra Nevada ranges, 166 m (548 ft) in the Klamath Mountains, and 199 m (657 ft) on the Modoc Plateau. An average distance of 131 m (432 ft) from water with a range of 0-500 m (0-1,650 ft) was obtained for the four regions combined. Mountain quail in central California were found at an average distance of 184 m (607 ft) from water (Guiterrez 1980). This distance increased to 202 m (667 ft) for foraging birds. Brennan (1991) studied mountain quail habitats in four western states, and he found birds in Idaho at average distances from water varying from 16-83 m (53-274 ft).

Cover

In California, mountain quail inhabit pinyon-juniper, oak woodland, chaparral, coastal forest, and montane forest associations (Miller 1951). In central California, 97% of Guiterrez's (1980) observations occurred in mixed evergreen forest and chaparral habitat types. Foraging quail were found at an average distance of 106 m (350 ft) from chaparral, while birds engaged in other activities were found an average distance of 100 m (330 ft) from chaparral. Ninety-five percent of observations of mountain quail in northern California occurred in mixed forest and brush cover types (Brennan et al. 1987).

Mountain quail require cover in some form during most of their activities (Guiterrez 1980). In northern California, the average distance to cover varied from 0.4 m (1.3 ft) in the Klamath Mountains to 1.2 m (4 ft) in the Sierra Nevada, and birds were never found more than 13 m (43 ft) from cover (Brennan et al. 1987). Mean distance from escape cover varied from 0.9 m (3 ft) in Idaho to 13.9 m (46 ft) in Nevada, with absolute distances varying from 0-5 m (0-17 ft) in Oregon and Idaho and from 0-35 m (0-116 ft) in Nevada (Brennan 1991). When foraging, mountain quail in central California were found at a mean distance of 1.5 m (5 ft) from cover and, when all activities were combined at a distance of 0.9 m (3 ft) (Guiterrez 1980).

In northern California, mountain quail were found in habitats characterized by shrub canopies that varied from 37% coverage in the Coast Range to 51% in the Sierra Nevada (Brennan et al. 1987). In central California, foraging quail were found in habitats with an average shrub cover of 18%, while birds engaged in other activities occupied areas with an average cover of 23% (Guiterrez 1980). Mean shrub cover varied from 30% in Nevada to 78% in Idaho, while 63% of the survey sites possessing shrub covers of 60% (Brennan 1991). Mean maximum shrub height varied from 1.4 m (4.6 ft) in Nevada to 5.9 m (19.5 ft) in Idaho (Brennan 1991). In northern

California, mean maximum shrub heights varied from 1.8 m (6.0 ft) in the Sierra Nevada to 3.3 m (11.0 ft) in the Coast Range (Brennan et al. 1987).

Slope may also be used in conjunction with plant cover to facilitate escape (Guiterrez 1975). Johnsgard (1973) noted that mountain quail may take advantage of hillsides with slopes $> 20^o$ by running upslope to escape predators. Mountain quail habitats in northern California were characterized by mean slopes varying from 5° on the Modoc Plateau to 25° in the Coast Range (Brennan et al. 1987). Habitats in central California had a mean slope of 28° (Guiterrez 1980).

Reproduction

Mountain quail breed from late March to late August, while most nesting activities occur in May through July depending on location. In the central Sierra Nevada, nesting occurs from mid-June to mid-July (Johnsgard 1973). Nests consist of slight depressions scratched out by the birds, and nests are lined with grasses, leaves, or pine needles. The nest is usually located at the base of a tree, adjacent to a log, or under a bush. Nesting cover varies greatly as to species but generally contains a dense mixture of large shrubs and trees (Johnsgard 1973).

Interspersion and Composition

In California, breeding pairs of mountain quail occupied home ranges varying from 2-20 ha (5-50 ac) (Johnsgard 1973), but in Idaho home ranges of a sedentary population averaged 260 ha (642 acres) (Ormiston 1966). Mountain quail densities in northern California varied from 8.9 birds/100 ha (250 ac) on the Modoc Plateau to 30.0 birds/100 ha (250 ac) in the Klamath Mountains (Brennan and Block 1986). Individuals may make vertical migrations as great as 32 km (19 mi). In montane locations, they usually breed at higher elevations but move downslope following the snowline during the winter (Zeiner et al. 1990).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area.

The California Wildlife Habitat Relationships System (CWHR) (Airola 1988; Mayer and Laudenslayer; 1988, Zeiner et al. 1990) contains habitat ratings for each habitat type predicted to be occupied by mountain quail in California.

Season.

This model is designed to predict the suitability of habitat for mountain quail throughout the year. Model predictions, however, may be more accurate for breeding habitat.

Cover types.

This model can be used anywhere in California for which an ARC/INFO map of CWHR habitat types exists. The CWHR System contains suitability ratings for reproduction, cover, and feeding for all habitats mountain quail are predicted to occupy. These ratings can be used in conjunction with the ARC/INFO habitat map to model wildlife habitat suitability.

Minimum habitat area.

Minimum habitat area is defined as the minimum amount of contiguous habitat required before a species will occupy an area. Specific information on minimum areas required for mountain quail was not found in the literature. This model assumes two home ranges is the minimum area required to support a mountain quail population during the breeding season.

Verification level.

The spatial model presented here has not been verified in the field. The CWHR suitability values used are based on a combination of literature searches and expert opinion. We strongly encourage field testing of both the CWHR database and this spatial model.

Model Description

Overview.

This model uses CWHR habitat type as the main factor determining suitability of an area for this species. In addition, distance to water is used to adjust the suitability of the area.
A CWHR habitat type map must be constructed in ARC/INFO GRID format as a basis for the model. The GRID module of ARC/INFO was used because of its superior functionality for spatial modeling. Only crude spatial modeling is possible in the vector portion of the ARC/INFO program, and much of the modeling done here would have been impossible without the abilities of the GRID module. In addition to more sophisticated modeling, the GRID module's execution speed is very rapid, allowing a complex model to run in less than 30 minutes.

The following sections document the logic and assumptions used to interpret habitat suitability.

Cover component.

A CWHR habitat map must be constructed. The mapped data (coverage) must be in ARC/INFO GRID format. A grid is a GIS coverage composed of a matrix of information. When the grid coverage is created, the size of the grid cell should be determined based on the resolution of the habitat data and the home range size of the species with the smallest home range in the study. You must be able to map the home range of the smallest species with reasonable accuracy. However, if the cell size becomes too small, data processing time can increase considerably. We recommend a grid cell size of 30 m (98 ft). Each grid cell can be assigned attributes. The initial map must have an attribute identifying the CWHR habitat type of each grid cell. A CWHR suitability value is assigned to each grid cell in the coverage based on its habitat type. Each CWHR habitat is rated as high, medium, low or of no value for each of three life requisites: reproduction, feeding, and cover. The geometric mean value of the three suitability values was used to determine the base value of each grid cell for this analysis.

Distance to water.

Mountain quail require free water, particularly during the breeding season. This model downgrades all grid cells one suitability level if they are further than 600 m (1,969 ft) from a lake or permanent stream.

Species distribution.

The study area must be manually compared to the range maps in the CWHR Species Notes (Zeiner et al. 1990) or more recent versions of the range maps available from CDFG to ensure that it is within the species' range. All grid cells outside the species' range have a suitability of zero.

Spatial analysis.

Ideally, a spatial model of distribution should operate on coverages containing habitat element information of primary importance to a species. For example, in the case of woodpeckers, the size and density of snags as well as the vegetation type would be of great importance. For many small rodents, the amount and size of dead and down woody material would be important. Unfortunately, the large cost involved in collecting microhabitat (habitat element) information and keeping it current makes it likely that geographic information system (GIS) coverages showing such information will be unavailable for extensive areas into the foreseeable future.

The model described here makes use of readily available information such as CWHR habitat type, elevation, slope, aspect, roads, rivers, streams and lakes. The goal of the model is to eliminate areas that are unlikely to be utilized by the species and lessen the value of marginally suitable areas. It does not attempt to address all the microhabitat issues discussed above, nor does it account for other environmental factors such as toxins, competitors, or predators. If and when such information becomes available, this model could be modified to make use of it.

Although mountain quail are known to prefer edge conditions, the resolution and accuracy of our data did not allow us to explicitly analyze the effect of edge. This issue is addressed indirectly in the CWHR database and by using the geometric mean rather than the arithmetic mean when extracting habitat suitability ratings from the CWHR database. Open areas containing a shrub understory are rated higher than more dense types that would lack a shrub understory.

In conclusion, field surveys will likely discover that the species is not as widespread or abundant as predictions by this model suggest. The model predicts potentially available habitat. There are a variety of reasons why the habitat may not be utilized.

Definitions.

Home Range: the area regularly used for all life activities by an individual during the season(s) for which this model is applicable.

Dispersal Distance: the distance an individual will disperse to establish a new home range. In this model it is used to determine if Potential Colony Habitat will be utilized.

Day to Day Distance: the distance an individual is willing to travel on a daily or semi-daily basis to utilize a distant resource (Potential Day to Day Habitat). The distance used in the model is the home range radius. This is determined by calculating the radius of a circle with an area of one home range.

Core Habitat: a contiguous area of habitat of medium or high quality that has an area greater than two home ranges in size. This habitat is in continuous use by the species. The species is successful enough in this habitat to produce offspring that may disperse from this area to the Colony Habitat and Other Habitat.

Potential Colony Habitat: a contiguous area of habitat of medium or high quality that has an area between one and two home ranges in size. It is not necessarily used continuously by the species. The distance from a core area will affect how often Potential Colony Habitat is utilized.

Colony Habitat: Potential Colony Habitat that is within the dispersal distance of the species. These areas receive their full original value unless they are further than three home range radii from a core area. These distant areas receive a value of low since there is a low probability that they will be utilized regularly.

Potential Day to Day Habitat: an area of high or medium quality habitat less than one home range, or habitat of low quality of any size. This piece of habitat alone is too small or of inadequate quality to be Core Habitat.

Day to Day Habitat: Potential Day to Day Habitat that is close enough to Core or Colony Habitat can be utilized by individuals moving out from those areas on a day to day basis. The grid cell must be within Day to Day Distance of Core or Colony Habitat.

Other Habitat: contiguous areas of low value habitat larger than two home ranges in size, including small areas of high and medium quality habitat that may be imbedded in them, are included as usable habitat by the species. Such areas may act as "sinks" because long-term reproduction may not match mortality.

The table below indicates the specific distances and areas assumed by this model.

Distance variables:	Meters	Feet
Dispersal Distance	21,845	71,668
Day to Day Distance/ Home Range radius	910	2,986
Distance to water	600	1,969

Area variablesVariables:	Hectares	M2	Acres	Ft2
Home Range	260	2,602,221	643	28,009,080
Core Habitat	≥ 520	$\geq 4,204,442$	$\geq 1,286$	$\geq 56,018,160$

Application of the Model

A copy of the ARC/INFO AML can be found in Appendix 1. The steps carried out by the macro are as follows:

1.   Downgrade areas too far from water: the first step is to downgrade areas too far from water. If the grid cell is more than 600 m (1,969 ft) from water it loses one level of suitability

2.   Determine Core Habitat: this is done by first converting all medium quality habitat to high quality habitat and removing all low value habitat. Then contiguous areas of habitat are grouped into regions. The area of each of the regions is determined. Those large enough ($\geq$ two home ranges in size) are maintained in the Core Habitat coverage. If no Core Habitat is identified then the model will indicate no suitable habitat in the study area.

3.   Identify Potential Colony Habitat: using the coverage from Step 2, determine which regions are one to two home ranges in size. These are Potential Colonies.

4.   Identify Potential Day Use Habitat: using the coverage derived in Step 2, determine which areas qualify as Potential Day to Day Habitat.

5.   Calculate the Cost Grid: since it is presumed to be more difficult for animals to travel through unsuitable habitat than suitable habitat we use a cost grid to limit travel based on habitat suitability. The cost to travel is one for high or medium quality habitat. This means that to travel 1 m through this habitat costs 1 m of Dispersal Distance. The cost to travel through low quality habitat is two and unsuitable habitat costs four. This means that to travel 1 m through unsuitable habitat costs the species 4 m of Dispersal Distance.

6.   Calculate the Cost Distance Grid: a cost distance grid containing the minimum cost to travel from each grid cell to the closest Core Habitat is then calculated using the Cost Grid (Step 5) and the Core Habitat (Step 2).

7.   Identify Colony Habitat: based on the Cost Distance Grid (Step 6), only Potential Colony Habitat within the Dispersal Distance of the species to Core Habitat is retained. Colonies are close enough if any cell in the Colony is within the Dispersal Distance from Core Habitat. The suitability of any Colony located further than three home range radii from a Core Habitat is changed to low since it is unlikely it will be utilized regularly.

8.   Create the Core + Colony Grid: combine the Core Habitat (Step 2) and the Colony Habitat (Step 7) and calculate the cost to travel from any cell to Core or Colony Habitat. This is used to determine which Potential Day to Day Habitat could be utilized.

9.   Identify Day to Day Habitat: grid cells of Day to Day Habitat are only accessible to the species if they are within Day to Day Distance from the edge of the nearest Core or Colony Habitat. Add these areas to the Core + Colony Grid (Step 8).

10.   Add Other Habitat: large areas (≥ two home ranges in size) of low value habitat, possibly with small areas of high and medium habitat imbedded in them may be utilized, although marginally. Add these areas back into the Core + Colony + Day to Day Grid (Step 9), if any exist, to create the grid showing areas that will potentially be utilized by the species. Each grid cell contains a one if it is utilized and a zero if it is not.

11.   Restore Values: all areas that have been retained as having positive habitat value receive their original geometric mean value from the original geometric value grid (see Cover component section) with the exception of distant colonies. Distant colonies (colonies more than three home range radii distant) have their value reduced to low because of the low likelihood of utilization.

Problems with the Approach

Cost.

The cost to travel across low suitability and unsuitable habitat is not known. It is likely that it is quite different for different species. This model incorporates a reasonable guess for the cost of movement. A small bird will cross unsuitable habitat much more easily than a small mammal. To some extent differences in vagility between species is accounted for by different estimates of dispersal distances.

Dispersal distance.

The distance animals are willing to disperse from their nest or den site is not well understood. We have used distances from studies of the species or similar species when possible, otherwise first approximations are used. More research is urgently needed on wildlife dispersal.

Day to day distance.

The distance animals are willing to travel on a day to day basis to use distant food sources has not been quantified for most species. This issue is less of a concern than dispersal distance since the possible distances are much more limited, especially with small mammals, reptiles, and amphibians. Home range size is assumed to be correlated with this coefficient.

SOURCES OF OTHER MODELS

No other habitat models were found for the mountain quail.

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APPENDIX 1: Mountain Quail Macro

```
/*        MOUNTAIN QUAIL

/* mtqmodel.aml - This macro creates an HSI coverage for the
/*          Mountain Quail.

/* Version:  Arc/Info 6.1 (Unix), GRID-based model.

/* Authors:  Irene Timossi, Sarah Miller, Wilde Legard,
/*        and Reginald H. Barrett
/*        Department of Forestry & Resource Management
/*        University of California, Berkeley

/* Revision: 2/10/95

/* ------------------------------------------------------------------

/* convert .ID to uppercase for info manipulations

&setvar .ID [translate %.ID%]

/* Start Grid

grid

/*

&type (1)  Initializing Constants...

/*   Homerange: the size of the species' homerange.

/*   DayPay: The amount the species is willing to pay traveling on
/*   a day-to-day basis.  Used to determine the area utilized on a
/*   day-to-day basis.

/*   DispersePay: Distance traveled when dispersing.  The amount
/*   the animal is willing to pay when dispersing from a core area.

/*   Waterdist: Home range diameter added to nest distance to water.  Is
/*   the maximum distance from water that a species can be for reproduction.

/*   High:  The value in the CWHR grid which indicates high quality habitat.

/*   Medium:  The value in the CWHR grid which indicates medium quality habitat.

/*   Low:  The value in the CWHR grid which indicates low quality habitat.

/*   None:  The value in the CWHR grid which indicates habitat of no value.

/*   SpecCode: The CWHR code for the species

/*   AcreCalc:  The number needed to convert square units
/*          (feet or meters) to acres.


&setvar SpecCode = B141

&if %.Measure% = Meters &then
```

13

```
    &do
      &setvar Homerange     = 2602221
      &setvar DayPay        = 910
      &setvar DispersePay   = 21845
      &setvar WaterDist     = 600
      &setvar AcreCalc      = 4047
    &end
  &else
    &if %.Measure% = Feet &then
      &do
        &setvar Homerange     = 28009080
        &setvar DayPay        = 2986
        &setvar DispersePay   = 71668
        &setvar WaterDist     = 1969
        &setvar AcreCalc      = 43560
      &end
    &else
      &do
        &type Measurement type incorrect, check spelling.
        &type Only Meters and Feet are correct.
        &goto &BADEND
      &end

&setvar High       = 3
&setvar Medium     = 2
&setvar Low        = 1
&setvar None       = 0


/*   The following global variables are declared in the menu:

/*   .WHRgrid (CWHR grid name): the name of the grid containing all
/*   the CWHR information.

/*   .Bound (Boundary grid name): the grid containing only the
/*   boundary of the coverage. All cells inside the boundary
/*   have a value of 1. All cells outside the boundary must
/*   have a value < 1.

/*   .ID (Identifier): a 1 to 4 character code used to identify
/*   the files produced by this program. You may prefer
/*   to use an abbreviation of the species' common name
/*   (e.g. use `fis1` for fisher).

/*   .SizeOfCell (Cell size): the size (width) of the cells
/*   used in the coverage grids. All grids used in the
/*   analysis must have the same cell size.

/*   .Measure:  the units the coverage is measured in (feet or meters).


&type (2)  Creating working grid of geometric means...

/*   Create a Geometric Means grid (Geom) for the species by
/*   copying these values from the CWHR grid if they are close enough
/*   to water.

if (((%.Stream% <= %WaterDist%) or (%.Lake% <= %WaterDist%)) or (%.WHRgrid%.%SpecCode%_G == 0))
  Geom = %.WHRgrid%.%SpecCode%_G
else
```

```
  Geom = %.WHRgrid%.%SpecCode%_G - 1
endif

/*

&type (3)  Changing %Medium% value cells to %High% value for Merge grid...

/*    Create a grid (Merge) merging Medium and High
/*    value cells from the Geometric mean grid (Geom),
/*    while leaving the value of other cells (Low and None) unchanged.
/*    Merge by changing the value of all medium cells to High.

Merge = con(Geom == %Medium%,%High%,Geom)

/*

&type (4)  Converting Merge grid zones into a Region grid...

/*    Convert the zones of the merge grid (Merge) into
/*    unique regions (Region). These will be used later
/*    to create core, colony, and day-to-day areas.

Region = regiongroup(Merge,#,EIGHT)

/*

&type (5)  Calculating the area of Region grid zones...

/*    Calculate the area of the zones (ZoneArea) on the region
/*    grid (Region).

ZoneArea = zonalarea(Region)

/*

&type (6)  Creating a Core Area grid...

/*    Extract areas from the zonal area grid (ZoneArea)
/*    suitable for core areas (Core). Core areas are defined
/*    as the Medium+High zones in the merge grid (Merge)
/*    with an area of at least two home ranges (%Homerange%).
/*    Set their value = 1.

if (Merge == %High% and ZoneArea >= %Homerange% * 2)
  Core = 1
endif

&if not [exists Core -vat] &then
  &goto END

/*

&type (7)  Creating a Colony grid...

/*    Extract areas from the zonal area grid (zoneArea)
/*    possibly suitable for colonization (ColTemp).
/*    Colony areas are defined as Low or Medium+High zones
/*    in the Merge grid (Merge) with an area of between one
/*    and two home ranges (%Homerange%). Set their value = 1.
```

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```
/*    Then set all nodata values in the grid to zero (Colony).

docell
  if (Merge == %High%)
    if (ZoneArea > %Homerange% and ZoneArea < %Homerange% * 2)
      ColTemp = 1
    endif
  endif
end

Colony = con(isnull(ColTemp),0,ColTemp)

/*

&type (8)  Creating a Day-to-Day Use grid...

/*    Create a grid based on the values in the zonal
/*    area grid (ZoneArea) and merge grid (Merge)
/*    suitable for day-to-day use (DayToDay). Day-to-day use
/*    areas are defined as Low if the area is less than two
/*    homeranges in size or Medium+High zones in the
/*    merge grid (Merge) with an area of less than one home
/*    range (%Homerange%). Set their value = 1.

if ((Merge > %Low% and ZoneArea <= %Homerange%) or ~
    (Merge == %Low% and ZoneArea < %Homerange% * 2))
  DayToDay = 1
else
  DayToDay = 0
endif

/*

&type (9)  Creating a Cost Grid based on habitat value...

/*     Using the merge grid (Merge), create a cost grid (Cost)
/*     based on the habitat-value. Cost represents the relative
/*     resistance a species has to moving across different quality
/*     habitat:   Habitat-value   Cost
/*            None        4
/*            Low         2
/*            Medium+High     1

if (Merge == %None%)
  Cost = 4
else if (Merge == %Low%)
  Cost = 2
else if (merge == %High%)
  Cost = 1
endif

/*
&type (10) Calculating cost to travel from Core Areas...

/*    Calculate the cost to travel the distance (CostDist)
/*    from the nearest core area source (Core) using the cost
/*    grid (Cost).
/*
```

```
CostDist = CostDistance(Core,Cost)

/*

&type (11) Calculating which Colony areas are Cost Effective...

/*    If Colony Areas exist...
/*    Find the areas in the Colony grid (Colony) that could
/*    be colonized from the core areas:

/*    Assign costs to all cells in the Colony areas (Colony)
/*    from the Cost grid (CostDist). Zero surrounding NODATA areas.

/*    Make each colony a separate zone (ZoneReg) using
/*    the regiongroup command.

/*    Use zonalmin to find the minimum cost to arrive at each
/*    colony (ZoneMin).

/*    Set all NODATA cells to zero in ZoneMin to produce
/*    ColZer1.

/*    To find out which of the potential colonies can be utilized,
/*    determine which have a cost that is equal to or less than
/*    DispersePay. If the cost to get to a colony is less than
/*    or equal to DispersePay, keep it in grid Col.

/*    Fill the null value areas in Col with zeros to create ColZer2


&if not [exists ColTemp -vat] &then
  &goto SkipColony

ColDist = con(Colony > 0,CostDist,0)
ZoneReg = regiongroup(Colony,#,EIGHT)
ZoneMin = zonalmin(ZoneReg,ColDist)
ColZer1 = con(isnull(ZoneMin),0,ZoneMin)

if (ColZer1 <= %DispersePay% and ColZer1 > 0)
  Col = Colony
else
  Col = Core
endif

ColZer2 = con(isnull(Col),0,Col)

/*

&type (12)  Creating Core + Colony grid...

/*    If colonies exist....
/*    Create a grid (ColCore) that combines the core
/*    (Core) and colony (Colony) grids.
/*    This grid will be used to analyze day-to-day use.


if (Colony == 1)
  ColCore = 1
```

```
else
  ColCore = Core
endif

&label SkipColony


&type (13)  Calculate cost to travel from Core and Colony Areas...

/*    If colonies exist...
/*    Calculate the cost to travel the distance (CostDis2)
/*    from the nearest core or colony area source (ColCore).
/*    Otherwise just copy the CostDist grid to use for Day-to-Day
/*    analysis.

&if not [exists ColTemp -vat] &then
  CostDis2 = CostDist
&else CostDis2 = CostDistance(ColCore,Cost)

/*

&type (14) Calculating which Day-to-Day areas are Cost Effective...

/*    This step adds the utilized Day-to-Day cells to the
/*    Core + Colony Area grid (ColZer2) to produce the
/*    Day1 grid.

/*    Use the Core + Colony Cost grid (CostDis2)to find out
/*    what can actually be used day-to-day (any cell with
/*    a cost of DayPay or less).

/*    Retain any cell in the Day-to-Day grid (DayToDay) with
/*    a cost less than or equal to DayPay and greater than zero.

/*    If the Distance-Cost grid (CostDis2) = 0,
/*    it is part of the Core or Colony Area and
/*    should gets its value from Core + Colony Area
/*    grid (ColZer2).

&if [exists ColTemp -vat] &then
  &do
   if (CostDis2 <= %DayPay% and CostDis2 > 0)
     Day1 = DayToDay
   else
     Day1 = ColZer2
   endif
  &end
&else
  &do
   if (CostDis2 <= %DayPay% and CostDis2 > 0)
     Day1 = DayToDay
   else
     Day1 = Core
   endif
  &end

/*

&type (15)  Finding Other Areas That May Be Utilized....
```

```
/*    This step picks up any large low value areas and any small
/*    medium or high value polygons that are imbeded
/*    in them.

/*    First find any areas that are not currently in the included
/*    set (Day1Z) but are in the original geometric mean coverage (geom)
/*    set Other to 1 where Day1Z = 0.

/*    if Other is all nodata, create the All coverage from
/*    the Day1Z coverage.

/*    Split all Other areas into separate regions (OthReg)

/*    Calculate the area of the regions (OthArea).

/*    Keep any region in OthArea with an area > 2 homeranges (Util).

/*    Change any null values in Util to zeros (OthZero).

/*    Add these areas to the Day1 coverage to create All

Day1Z = con(isnull(Day1),0,Day1)

if ((Day1Z < 1) and (Geom > 0))
  Other = 1
endif

&if not [exists Other -vat] &then
  All = Day1Z
&else
  &do
    OthReg = regiongroup(Other,#,EIGHT)

    OthArea  = zonalarea(OthReg)

    if (OthArea >= %Homerange% * 2)
      Util = 1
    else
      Util = 0
    endif

    OthZero = con(isnull(Util),0,Util)

    if (OthZero == 1)
      All = OthZero
    else
      All = Day1Z
    endif
  &end
/*

&type (16) Creating a Value grid...

/*    For any cell in All that has a value of 1, store the suitability
/*    value from the Geometric mean grid (Geom) to the Value grid.

/*    Other cells inside the boundary (%.Bound%) get a value of 0.
```

```
/*

if (All == 1)
  Value = Geom
else if (%.Bound% == 1)
  Value = 0
endif

/*

&type (17)  Creating an HSI grid...

/*    if Colonies exist....
/*    For any cell that was part of a colony that is further than
/*    3 times the HR radius (DayPay) away from a core area, set the suitability
/*    to Low.  Distant colonies lose value because of their small size.
/*    This step produces grid Collow.

/*    Set all NODATA values in Collow to zero in ColZer3.

/*    Find any day-to-day use areas (DayToDay) that are being
/*    utilized (ColZer3).  If they are further than four homeranges
/*    from a core area (CostDist), they are utilized from a distant
/*    colony and their value will be decreased to Low in Day2.


/*    Then change nulls to zero in ValZero

/*    Keep all data within the boundary; call this final grid HSI.

&if [exists ColTemp -vat] &then
  &do
    if (ColZer1 >= %DayPay% * 3)
      Collow = %Low%
    else
      Collow = Value
    endif

    ColZer3 = con(isnull(Collow),0,Collow)

    if ((CostDist > %DayPay% * 4) and (ColZer3 > 0) and ~
       (DayToDay == 1))
      Day2 = 1
    else
      Day2 = ColZer3
    endif
  &end
&else
    Day2 = Value
valzero = con(isnull(Day2),0,Day2)

if (%.Bound% == 1)
  %.ID%hsi = valzero
endif

/*

&type (18)  Quiting from GRID and adding the acres field.....
```

```
/*      Quit from GRID (Q), then run additem to add an acre item to
/*      the HSI grid vat file (%ID%HSI.vat). Reindex on value when done.

Q
additem %.ID%hsi.vat %.ID%hsi.vat acres 10 10 i
indexitem %.ID%hsi.vat value

/*

&type (19)  Calculating acres.....

/*      Use INFO to calculate the acreage field: Multiply the number
/*      of cells by the cell size squared and divide by the number of
/*      square meters per acre (4047). Reindex on value when done.

&data arc info
arc
select %.ID%hsi.VAT
CALC ACRES = ( COUNT * %.SizeOfCell% * %.SizeOfCell% ) / %AcreCalc%
Q STOP

&END

indexitem %.ID%hsi.vat value

/*

&type  (20) Killing all intermediate coverages before ending macro...

/* &goto OKEND

grid

kill Geom
kill Merge
kill Region
kill ZoneArea
kill Core
kill ColTemp
kill Colony
kill DayToDay
kill Cost
kill CostDist
kill ColDist
kill ZoneReg
kill ZoneMin
kill ColZer1
kill Col
kill ColZer2
kill ColCore
kill CostDis2
kill Day1
kill Day1Z
kill Other
kill OthReg
kill OthArea
kill Util
kill OthZero
kill All
```

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```
kill Value
kill Collow
kill ColZer3
kill Day2
kill valzero

q

&goto OKEND

&label END
&type **
&type **
&type NO CORE AREAS EXIST, EXITING MACRO
&type **
&type **

kill Core
kill Region
kill ZoneArea
kill Merge
kill Geom

quit

&label OKEND
&label BADEND

&type -------------- All done! ----------------

&return
```