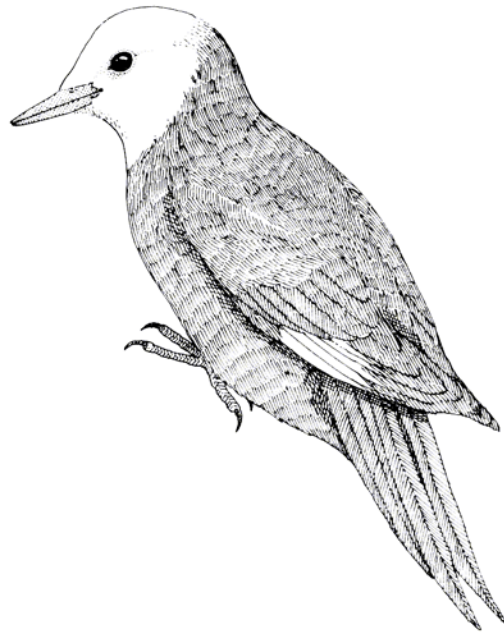**California Wildlife Habitat Relationships Program**
California Department of Fish and Game

HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO:
WHITE-HEADED WOODPECKER

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HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO:
WHITE-HEADED WOODPECKER

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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**WHITE-HEADED WOODPECKER (*Picoides albolarvatus)*

HABITAT USE INFORMATION

General

The white-headed woodpecker (*Picoides albolarvatus*) inhabits montane coniferous forests in western North America from southern British Columbia and Idaho to southern California (American Ornithologists' Union 1983). In California, they are common yearlong residents of coniferous forests up to the elevation of lodgepole pine (*Pinus contorta* var. *murrayana*) and red fir (*Abies magnifica*). They are found in appropriate habitats in the Cascade, Klamath, Sierra Nevada, Peninsular and Transverse Ranges and in the Warner Mountains (Zeiner et al. 1990). Occasionally they are found at lower elevations in the North Coast Range and in interior areas (McCaskie et al. 1988).

Food

White-headed woodpeckers forage in live, mature conifers having deeply creviced and scaly bark and on snags (Raphael and White 1984). In their study of cavity-nesting birds in the Sierra Nevada, Raphael and White (1984) found that white-headed woodpeckers foraged on live trees (71%), snags (28%), and on logs (2%). Jeffrey pine (*Pinus jeffreyi*) was used as a foraging substrate (49%), as was lodgepole pine (8%), red fir (20%), and white fir (*Abies concolor*) (24%). White-headed woodpeckers foraged on tree trunks (53%), live branches (16%), dead branches (6%), and foliage (26%). Raphael and White (1984) observed woodpeckers foraging by gleaning (85%), drilling in wood (12%), and by sapsucking (4%). In the central Sierra Nevada, white-headed woodpeckers utilized incense cedar (*Calocedrus decurrens*) to a greater extent during winter than during summer, and ponderosa pine (*Pinus ponderosa*) to a lesser degree during winter than during summer (Morrison et al. 1985). The annual diet of white-headed woodpeckers consists of pine and other conifer seeds (60%), ants (20%), and other insects (20%) (Bent 1939; Koch et al. 1970; Ligon 1973).

Water

White-headed woodpeckers have been observed drinking water (Van Rossem and Pierce 1915; Grinnell et al. 1930; Ligon 1973). Frequent drinking by this species, as compared to other members of the genus, may be correlated with the proportion of dry vegetable matter in their diet.

Cover

White-headed woodpecker cover requirements, which are satisfied by semi-open areas with large, mature trees providing 40 to 70% canopy closure, are similar to the food and reproductive requirements of the species (Bent 1939; Zeiner et al. 1990). In the Sierra Nevada, the presence of white-headed woodpeckers was dependent upon the availability

of large trees, especially snags, for foraging. Canopy closure and forest type appeared to have little effect upon their abundance (Beedy 1981). Although white-headed woodpeckers utilized both burned and unburned mixed coniferous stands on the eastside of the Sierra Nevada, they were five times as abundant on the burned plot as on the unburned plot (Bock and Lynch 1970).

Reproduction

White-headed woodpeckers breed from mid-April to late August, with peak activity occurring from mid-June through mid-July (Zeiner et al. 1990). Nests are located in open coniferous habitats and are often placed near or on the edges of roads, natural openings, and small clearings (Raphael and White 1984; Milne and Hejl 1989). As many as three nest cavities may be excavated per pair per year (Thomas 1979). Raphael and White (1984) found 18% of white-headed woodpecker nests in each of the following forest types: pine-sage (*Artemisia tridentata*), burned pine-fir, red fir , burned red fir, and burned red fir edge. Nine percent of nests were located on the edge of burned pine-fir stands. Nest sites included snags (82%), and stumps and logs (9% each). Red fir snags were favored as nest sites with 55% of nests located in them. Twenty-seven percent of white-headed woodpecker nests were found in Jeffrey pine snags, and 9 percent in both lodgepole pine and white fir snags. Snags which were at least 61 cm (24 in) in diameter at nest height and which had a hard shell with a soft interior, were preferred. Nests were found at heights varying from two to 15 m (6 to 50 ft) above ground (Raphael and White 1984).

In the central and southern Sierra Nevada, white-headed woodpecker nests were located in mixed coniferous forests (62%), in red fir (13%), in and along the edges of wet montane meadows (19%), in Jeffrey pine (4%), and in lodgepole pine (2%) (Milne and Hejl 1989). Forty-two percent of the nests in that study were in stands of mature and overmature trees having 40% canopy cover, 40% that were in stands with 40 to 69% canopy cover, and the remainder (18%) in and along the edges of wet meadows. Nests were located at an average height of three m (10 ft) above ground in trees with an average dbh of 80 cm (32 in) (Milne and Hejl 1989). Sixty percent of the nests were found in broken-topped snags and stumps, 11% in snags without broken tops, and 28% in leaning or fallen logs (Milne and Hejl 1989).

Interspersion and Composition

Density estimates of nesting white-headed woodpeckers in the Sierra Nevada vary from a low of 10 birds/40 ha (100 ac) in open-canopy, red fir forest to a high of 16 birds/40 ha (100 ac) in open-canopy, mixed conifer forest (Beedy 1981). The density of post-nesting birds varies from 13 birds/40 ha (100 ac) in open-canopy, mixed conifer forest to 18 birds/40 ha (100 ac) in closed-canopy red fir forest (Beedy 1981). Bock and Lynch (1970) found 0.5 pairs/40 ha (100 ac) in a burned, mixed coniferous stand on the eastside of the Sierra Nevada. Thomas (1979) speculated that the Blue Mountains of Oregon may support 12.4 pairs of white-headed woodpeckers per 100 ha (250 ac).

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area.

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

Season.

This model is designed to predict the suitability of habitat for white-headed woodpeckers throughout the year. The model works best at predicting habitat suitability 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 white-headed woodpeckers 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 white-headed woodpeckers was not found in the literature. This model assumes two home ranges is the minimum area required to support a white-headed woodpecker 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.

White-headed woodpeckers require free water, particularly during the breeding season. This model downgrades all grid cells one suitability level if they are further than 800 m 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) 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.

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	8,615	28,263
Day to Day Distance/ Home Range radius	359	1,178
Distance to water	800	1,600

Area variables:	Hectares	M^2	Acres	Ft^2
Home Range	40.47	404,700	100	4,356,000
Core Habitat	∃ 80.94	∃ 809,400	∃ 200	∃ 8,712,000

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 800 m 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 (∃ two home ranges) 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 ($\exists$ 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 white-headed woodpecker.

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pp.

APPENDIX 1: White-Headed Woodpecker Macro

```
/*      WHITE-HEADED WOODPECKER

/* wwomodel.aml - This macro creates an HSI coverage for the
/*         White-headed Woodpecker.

/* 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 WHR grid which indicates high quality habitat.

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

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

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

/*   SpecCode: The WHR code for the species

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


&setvar SpecCode = B305

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

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```
        &setvar Homerange     = 404700
        &setvar DayPay        = 359
        &setvar DispersePay   = 8615
        &setvar WaterDist     = 800
        &setvar AcreCalc      = 4047
   &end
&else
  &if %.Measure% = Feet &then
     &do
       &setvar Homerange     = 4356000
       &setvar DayPay        = 1178
       &setvar DispersePay   = 28263
       &setvar WaterDist     = 2625
       &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 (WHR grid name): the name of the grid containing all
/*   the WHR 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 WHR 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
```

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```
/*

&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.

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

docell
```

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```
   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.

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```
/*    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...
```

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```
/*    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
```

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```
/*    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
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
```