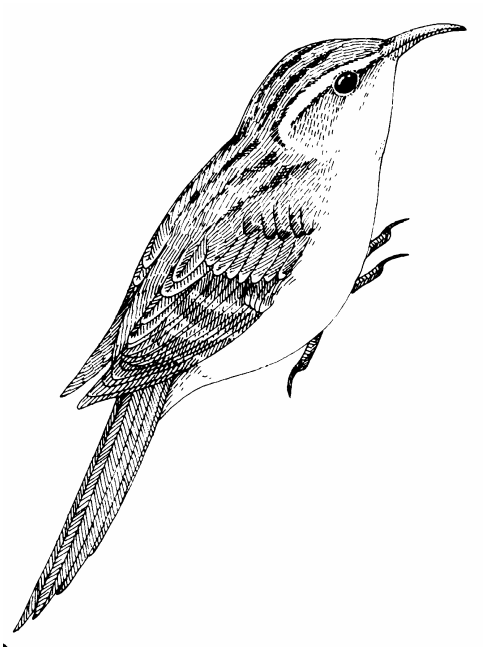
California Wildlife Habitat Relationships Program
California Department of Fish and Game

HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO: BROWN CREEPER



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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.

ACKNOWLEDGMENTS

The primary credit for this document must go to the field biologists and naturalists that have published the body of literature on the ecology and natural history of this species. They are listed in the References section. Ecological information of this sort is generally very expensive and time-consuming to obtain. Yet this basic ecological understanding is exactly what is needed most if the goal of accurately predicting changes in distribution and abundance of a particular species is ever to be achieved. The CWHR System is designed to facilitate the use of existing information by practicing wildlife biologists. We hope it will also stimulate funding for basic ecological research. Funding for producing this model was provided by the California Department of Forestry and Fire Protection and the University of California Agricultural Experiment Station.

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BROWN CREEPER (*Certhia americana*)

HABITAT USE INFORMATION

General

The range of the brown creeper (*Certhia americana*) includes all of the continental United States, southern Canada, extending to Alaska along the Pacific coast, and eastern and central Mexico. In California, it is a common to uncommon resident in montane habitats throughout the state, and in coastal conifer habitats south to San Luis Obispo County. There is downslope movement to interior and coastal foothills and lowlands in fall and winter. Brown creepers may winter above normal breeding elevation in conifer habitats in the Sierra Nevada (Gaines 1977b). Creepers prefer dense, mature hardwood-conifer habitats, especially in winter (Grinnell and Miller 1944; Garrett and Dunn 1981; Robbins et al. 1983).

Food

Brown creepers glean insects, their larvae, and other invertebrates, from the bark of tree trunks and branches. They use their long, slightly decurved bill to pick food items from cracks, crevices, and the bark surface (Davis 1978). Seeds may be eaten in the eastern U.S. They typically spiral up a tree trunk from the base while feeding (Bent 1948). Brown creepers have been observed caching food (Lima and Lee 1993).

In a study in the Sierra Nevada, brown creepers consumed 100% animal matter including species of Hemiptera, Coleoptera, and Diptera (Dahlsten et al. 1985). Mariani and Manuwal (1990) found a positive correlation between creeper abundance and the abundance of spiders in the southern Washington Cascades. Otvos and Stark (1985) found that in British Columbia, beetles (Coleoptera) were the most important component of brown creeper diets representing 63% of the total volume, with bark beetles (Scolytidae) being most prevalent. Pseudoscorpionida, Arachneida, and Hemiptera accounted for 23% of the diet volume.

Brown creepers show no tree species preference when foraging (Airola and Barrett 1985; Franzreb 1985; Lundquist and Manuwal 1990). In a study of winter tree use in the Sierra Nevada, foraging birds utilized Douglas-fir (*Pseudotsuga menziesii*), incense-cedar (*Calocedrus decurrens*), ponderosa pine (*Pinus ponderosa*), sugar pine (*P. lambertiana*), and white fir (*Abies concolor*) (Morrison et al. 1989). Brown creepers may increase their use of incense cedar during the winter (Morrison et al. 1985). Brown creepers forage primarily on live trees (Raphael and White 1984; Morrison et al 1987; Lundquist and Manuwal 1990). Lundquist and Manuwal (1990) found them foraging in trees 50 cm (19 in) dbh or larger, more than expected, in both winter and summer. Franzreb (1985) also reported a preference for tall (> 27 m [85 ft]) trees.

In a study of bird feeding heights, Airola and Barrett (1985), found that brown creepers prefered to forage at a medium height in trees relative to other birds studied, while Raphael and White (1984) and Morrison et al. (1987) found that they foraged in lower positions. Brown creepers forage primarily on the trunk. Percent of trunk use has been reported as 100% in summer (Airola and Barrett 1985), 80% in summer (Morrison et al. 1987), and 75-95% in winter (Lundquist and Manuwal (1990). This latter study found them foraging on portions of the tree with no limbs more than 70% of the time with less time spent on the lower crown, mid-crown and upper crown.

Water

No information was found.

Cover

Brown creepers frequent dense, old-growth coniferous forest (Verner and Larson 1989). They also use deciduous trees in riparian and hardwood habitats, particularly along the coast and in winter (Garrett and Dunn 1981).

Beedy (1981) found that brown creepers prefer closed canopy mixed-conifer and red fir forests (*Abies magnifica*) to open canopy forest of the same type. Liverman (1988) also found a correlation between brown creeper abundance and canopy closure.

In a study of forest stands managed with even versus uneven-aged strategies, Morrison (1992) found no significant difference in brown creeper abundance between the two treatments. In a study of forest fragmentation, Keller and Anderson (1992) found that brown creepers were absent from fragmented forest stands. However, Rosenberg and Raphael (1986) found no correlation between stand size and brown creeper presence. In Washington, Mariani and Manuwal (1990) found brown creeper abundance positively correlated with large Douglas-fir trees.

Reproduction

Brown creepers build nests behind loose bark, or rarely in a tree cavity. They typically nest in an old-growth incense cedar, coastal redwood (*Sequoia sempervirens*), pine (*Pinus* sp.) or fir (*Abies* sp. or *Pseudotsuga* sp.), or a snag. The nest is a loose cup of twigs, roots, moss and grass that is lined with feathers, fine bark and wool. The base may be built up with twigs, and the nest is built by both sexes. The breeding season is March to mid-August, with peak activity from mid-May to mid-June. Clutch size ranges from 4-8 eggs, and usually is 5-6 eggs. Incubation is done by the female alone and lasts 14-17 days. The young are tended by both parents (Bent 1948; Davis 1978; Harrison 1978; Ehrlich et al. 1988).

In Nevada County, nest tree height averaged 27 m (85 ft) and ranged from 6-48 m (18-142 ft). Nest height averaged 2.2 m (7 ft) and ranged from 0.3-6.5 m (1-20 ft). Average nest tree dbh was 68 cm (26.6 in) and ranged from 35-164 cm (14-64 in) (Raphael and White 1984).

Brown creepers are rarely parisitized by brown-headed cowbirds (*Molothrus ater*). Davis (1978) reported one nest parasitized by cowbirds that was later abandoned by the parents. Friedman (1963) found a pair of brown creepers feeding a brown-headed cowbird fledgling.

Interspersion and Composition

Brown creepers flock with other species during the winter but break up into pairs during the spring and summer breeding period. In the Sierra Nevada, Morrison et al. (1986) found them in association with mountain chickadees (*Parus gambeli*), chestnut-backed chickadees (*P. rufescens*), and pileated woodpeckers (*Dryocopus pileatus*).

Franzreb (1978) reported home range sizes of 2.3-6.4 ha (5.7 to 15.8 ac) in Michigan. Population densities per 40 ha (100 ac) have been variously reported. In the Sierra Nevada, Bock and Lynch (1970) reported 1.7 pairs in burned and 3.6 pairs in unburned yellow pine stands, while Beedy (1981) reported 41/50 birds in open/closed canopy mixed conifer and 17/44 birds in open/closed canopy red fir (*Abies magnifica*) forest. In giant sequoia (*Sequoiadendron giganteum*) forests, Kilgore (1968) found 5-26 pairs, while in Marin County, California, 24 birds were reported for bishop pine (*Pinus muricata*) -mixed forests (Stewart 1974). In Michigan, Davis (1978) found 29 pairs in swamp and 4 pairs in upland habitats, while in northeastern Oregon, Mannan and Meslow (1984) found 0.5 birds in managed forests and 16-19 birds in old-growth forests. In Wyoming, 1.4 birds were reported in high-elevation spruce-fir (*Picea* spp.) forests (Keller and Anderson 1992); 8 and 9 pairs were reported from ponderosa pine, fir, pine-aspen (*Populus tremuloides*) forests respectively in Arizona (Haldeman et al. 1973).

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 occupied by brown creepers in California.

Season.

This model is designed to predict the suitability of habitat for brown creepers throughout the year. Model predictions, however, are probably 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 brown creepers 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 brown creepers during the breeding season was not found in the literature. This model assumes two home ranges is the minimum area required to support a brown creeper 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.

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 it's 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 it's 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.

Brown creepers do not require water.

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 became 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. 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. 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 in size, 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	2,110	6,923
Day to Day Distance/ Home Range radius	88	288

Area variables:	Hectares	M^2	Acres	Ft^2
Home Range	2.43	24,282	6	261,360
Core Habitat	≥ 4.86	≥ 48,364	≥ 12	≥ 521,720

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. **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.

2. **Identify Potential Colony Habitat**: using the coverage from Step 1, determine which regions are one to two home ranges in size. These are Potential Colonies.

3. **Identify Potential Day Use Habitat**: using the coverage derived in Step 1, determine which areas qualify as Potential Day to Day Habitat.

4. **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.

5. **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 4) and the Core Habitat (Step 1).

6. **Identify Colony Habitat**: based on the Cost Distance Grid (Step 5), 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.

7. **Create the Core + Colony Grid**: combine the Core Habitat (Step 1) and the Colony Habitat (Step 6) 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.

8. **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 7).

9. **Add Other Habitat**: large areas (≥ two home ranges) 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 8), 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.

10. **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

Home Range Size.

The home range of a species may vary greatly depending on the habitat being evaluated. This model requires a single home range estimate be applied to all habitat types.

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 resources 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 for brown creepers were found.

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APPENDIX 1: Brown Creeper Macro

```
/*          BROWN CREEPER

/* rtomodel.aml - This macro creates an HSI coverage for the
/*              Brown creeper in the California Sierra.

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

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/* Note:  the user of this macro must have a thorough understanding
/*       of ARC/INFO GRID before attempting to interpret this macro.
/*       (See the ARC/INFO GRID Command References manual, ESRI,
/*       Redlands, CA).

/*       The user must also have access to the documentation which
/*       accompanies this macro:  Habitat Suitability Models for Use
/*       with ARC/INFO:  Brown creeper.

/* Revision: 1/15/95

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

/* 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.

/*   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 = B512

&if %.Measure% = Meters &then
  &goto Meters
&else
  &goto Feet

&label Meters

&setvar Homerange      = 24282
&setvar DayPay         = 88
&setvar DispersePay    = 2110
&setvar AcreCalc       = 4047
&goto Begin

&label Feet

&setvar Homerange      = 261360
&setvar DayPay         = 288
&setvar DispersePay    = 6923
&setvar AcreCalc       = 43560

&label Begin

&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 (%.ID%Geom) for the species by
/*    copying these values from the WHR grid.

%.ID%Geom = %.WHRgrid%.%SpecCode%_G

/*

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

/*    Create a grid (%.ID%Merge) merging Medium and High
/*    value cells from the Geometric mean grid (%.ID%Geom),
/*    while leaving the value of other cells (Low and None) unchanged.
/*    Merge by changing the value of all medium cells to High.
/*    This creates of grid of high value habitat (potential core) and
/*    low value habitat.

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

/*

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

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

%.ID%Region = regiongroup(%.ID%Merge)

/*

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

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

%.ID%ZoneArea = zonalarea(%.ID%Region)

/*

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

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

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

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

/*

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

/*    Extract areas from the zonal area grid (%.ID%zoneArea)
/*    possibly suitable for colonization (%.ID%ColTemp).
/*    Colony areas are defined as Low or Medium+High zones
/*    in the Merge grid (%.ID%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 (%.ID%Colony).

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

%.ID%Colony = con(isnull(%.ID%ColTemp),0,%.ID%ColTemp)

/*

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

/*    Create a grid based on the values in the zonal
/*    area grid (%.ID%ZoneArea) and merge grid (%.ID%Merge)
/*    suitable for day-to-day use (%.ID%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 (%.ID%Merge) with an area of less than one home
/*    range (%Homerange%). Set their value = 1.

if ((%.ID%Merge > %Low% and %.ID%ZoneArea <= %Homerange%) or ~
    (%.ID%Merge == %Low% and %.ID%ZoneArea < %Homerange% * 2))
  %.ID%DayToDay = 1
else
```

```
  %.ID%DayToDay = 0
endif

/*

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

/*     Using the merge grid (%.ID%Merge), create a cost grid (%.ID%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 (%.ID%Merge == %None%)
   %.ID%Cost = 4
else if (%.ID%Merge == %Low%)
   %.ID%Cost = 2
else if (%.ID%merge == %High%)
  %.ID%Cost = 1
endif

/*

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

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

%.ID%CostDist = CostDistance(%.ID%Core,%.ID%Cost)

/*

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

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

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

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

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

/*     Set all NODATA cells to zero in %.ID%ZoneMin to produce
```

```
/*     %.ID%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 %.ID%Col.

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


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

%.ID%ColDist = con(%.ID%Colony > 0,%.ID%CostDist,0)
%.ID%ZoneReg = regiongroup(%.ID%Colony)
%.ID%ZoneMin = zonalmin(%.ID%ZoneReg,%.ID%ColDist)
%.ID%ColZer1 = con(isnull(%.ID%ZoneMin),0,%.ID%ZoneMin)

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

%.ID%ColZer2 = con(isnull(%.ID%Col),0,%.ID%Col)

/*

&type (12)  Creating Core + Colony grid...
/*     If colonies exist....
/*     Create a grid (%.ID%ColCore) that combines the core
/*     (%.ID%Core) and colony (%.ID%Colony) grids.
/*     This grid will be used to analyze day-to-day use.


if (%.ID%Colony == 1)
  %.ID%ColCore = 1
else
  %.ID%ColCore = %.ID%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 (%.ID%CostDis2)
/*    from the nearest core or colony area source (%.ID%ColCore).
/*    Otherwise just copy the %.ID%CostDist grid to use for Day-to-Day
/*    analysis.
```

```
&if not [exists %.ID%ColTemp -vat] &then
  %.ID%CostDis2 = %.ID%CostDist
&else %.ID%CostDis2 = CostDistance(%.ID%ColCore,%.ID%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 (%.ID%ColZer2) to produce the
/*     %.ID%Day1 grid.

/*     Use the Core + Colony Cost grid (%.ID%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 (%.ID%DayToDay) with
/*     a cost less than or equal to DayPay and greater than zero.

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

&if not [exists %.ID%ColTemp -vat] &then
   &goto SkipCol2

if (%.ID%CostDis2 <= %DayPay% and %.ID%CostDis2 > 0)
  %.ID%Day1 = %.ID%DayToDay
else
  %.ID%Day1 = %.ID%ColZer2
endif

&goto Continue

&label SkipCol2

if (%.ID%CostDis2 <= %DayPay% and %.ID%CostDis2 > 0)
  %.ID%Day1 = %.ID%DayToDay
else
  %.ID%Day1 = %.ID%Core
endif

&label Continue

&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 mark any low value areas with an area > HR * 2 to
```

```
/*     create %.ID%Low using the Geometric mean (%.ID%Geom) grid
/*     and the Zone Area (%.ID%ZoneArea) grid.

/*     if %.ID%Low is all nodata, skip the rest of these steps.

/*     Add the medium and high grid cells that are less than 1 HR in
/*     size and are not used day-to-day to the %.ID%Low grid to
/*     create %.ID%LowPlus

/*     Split all %.ID%LowPlus areas into separate regions (%.ID%LowReg)

/*     Calculate the area of the regions (%.ID%LowArea).

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

/*     Change any null values in %.ID%Util to zeros (%.ID%LowZero).


if (%.ID%Geom == %Low% and %.ID%ZoneArea >= %Homerange% * 2)
  %.ID%Low = 1
endif

&if not [exists %.ID%Low -vat] &then
   &goto SkipLow

if ((%.ID%CostDis2 >= %DayPay%) and (%.ID%Geom > 1) and ~
    (%.ID%ZoneArea < %Homerange%))
  %.ID%LowPlus = 1
else
  %.ID%LowPlus = %.ID%Low
endif

%.ID%LowReg = regiongroup(%.ID%LowPlus)

%.ID%LowArea  = zonalarea(%.ID%LowReg)

if (%.ID%LowArea >= %Homerange% * 2)
  %.ID%Util = 1
else
  %.ID%Util = 0
endif

%.ID%LowZero = con(isnull(%.ID%Util),0,%.ID%Util)


/*

&type (16) Adding other utilized habitat...

/*     Add the Other Utilized habitat (%.ID%LowZero) to the %.ID%Day1 coverage
/*     to produce the %.ID%All coverage.
```

```
if (%.ID%LowZero == 1)
  %.ID%All = %.ID%LowZero
else
  %.ID%All = %.ID%Day1
endif

&goto Value

&label SkipLow

%.ID%All = %.ID%Day1

&label Value

&type (17) Creating a Value grid...

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

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

/*

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

/*

&type (18)  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 %.ID%Collow.

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

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


/*     Then change nulls to zero in %.ID%ValZero

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

&if not [exists %.ID%ColTemp -vat] &then
```

```
   &goto SkipCol3

if (%.ID%ColZer1 >= %DayPay% * 3)
  %.ID%Collow = %Low%
else
  %.ID%Collow = %.ID%Value
endif

%.ID%ColZer3 = con(isnull(%.ID%Collow),0,%.ID%Collow)

if ((%.ID%CostDist > %DayPay% * 4) and (%.ID%ColZer3 > 0) and ~
    (%.ID%DayToDay == 1))
  %.ID%Day2 = 1
else
  %.ID%Day2 = %.ID%ColZer3
endif

&goto HSI

&label SkipCol3

%.ID%Day2 = %.ID%Value

&label HSI

%.ID%valzero = con(isnull(%.ID%Day2),0,%.ID%Day2)

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

/*

&type (19)  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 (20)  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

&goto NODELETE

/*

&type  (21) Killing all intermediate coverages before ending macro...


&label NODELETE

/* &goto OKEND

grid

kill %.ID%Geom
kill %.ID%Merge
kill %.ID%Region
kill %.ID%ZoneArea
kill %.ID%Core
kill %.ID%ColTemp
kill %.ID%Colony
kill %.ID%DayToDay
kill %.ID%Cost
kill %.ID%CostDist
kill %.ID%ColDist
kill %.ID%ZoneReg
kill %.ID%ZoneMin
kill %.ID%ColZer1
kill %.ID%Col
kill %.ID%ColZer2
kill %.ID%ColCore
kill %.ID%CostDis2
kill %.ID%Day1
kill %.ID%Low
kill %.ID%LowPlus
kill %.ID%LowReg
kill %.ID%LowArea
kill %.ID%Util
kill %.ID%LowZero
kill %.ID%All
kill %.ID%Value
kill %.ID%Collow
kill %.ID%ColZer3
kill %.ID%Day2
kill %.ID%valzero
```

```
q

&goto OKEND

&label END
&type **
&type **
&type NO CORE AREA S EXIST, EXITING MACRO
&type **
&type **

kill %.ID%Core
kill %.ID%Region
kill %.ID%ZoneArea
kill %.ID%Merge
kill %.ID%Geom

quit

&label OKEND

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

&return
_
```