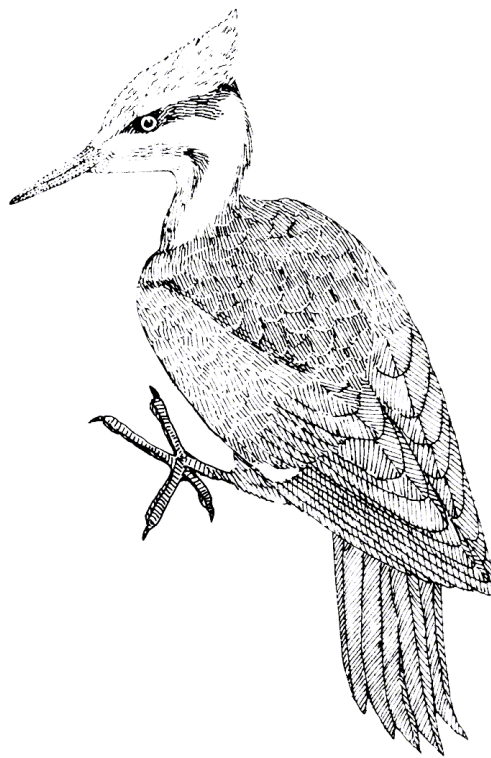


**California Wildlife Habitat Relationships Program
California Department of Fish and Game**

**HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO:
PILEATED WOODPECKER**



CWHR Technical Report No. 16
Sacramento, CA
June 1995

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PILEATED WOODPECKER

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Suggested Citation: Timossi, I. C., E. L. Woodard, and R. H. Barrett. 1995. Habitat suitability models for use with ARC/INFO: pileated woodpecker. Calif. Dept. of Fish and Game, CWHR Program, Sacramento, CA. CWHR Tech. Report No. 16. 26 pp.

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.

We thank Barry Garrison, Karyn Sernka, and Sandie Martinez of the California Department of Fish and Game for their assistance in typing, editing, and producing this report.

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PILEATED WOODPECKER (*Dryocopus pileatus*)

HABITAT USE INFORMATION

General

The pileated woodpecker (*Dryocopus pileatus*) inhabits both coniferous and deciduous forests, but it is restricted to areas containing mature, dense, productive stands (Bock and Lepthien 1975). These woodpeckers are widely distributed in forests of eastern North America. In the west, however, they are restricted to Washington, Oregon, northern California, and the Rocky Mountains to northern Idaho and northwestern Montana (McClelland 1979). Their absence in the central and southern Rocky Mountains is due to a lack of dense, highly productive forests characterized by rapid maturation and decay (Bock and Lepthien 1975). In California, they are uncommon yearlong residents of mature conifer-dominated habitats in the North Coast, Cascade, and Sierra Nevada ranges (Zeiner et al. 1990). Critical components of pileated woodpecker habitat are large snags, high snag densities, large trees, diseased trees, and dense forest stands (Bull 1975).

Food

Pileated woodpeckers depend heavily on carpenter ants (*Camponotus* spp.) and other wood-boring insects for food (McClelland 1979; Bull 1980; Bull et al. 1992a). A study of the stomach contents of 80 pileated woodpeckers taken across the United States during an entire year showed that animal foods comprised about 73% of the diet (Beal 1911). More than one-half of the animal food consisted of ants, and beetles were the next most abundant food item. Wild fruits comprised the majority of the vegetable material consumed.

Pileated woodpeckers in Oregon fed by excavation (subcambial penetration) approximately two-thirds of the time, while scaling bark in search of insects was the other feeding behavior (Bull 1980). In northeastern Oregon, pileated woodpeckers foraged by excavating (53%), pecking in bark (32%), gleaning (10%), and a combination of these techniques (5%) (Bull and Holthausen 1993). Woodpeckers in Virginia fed primarily by pecking (no subcambial penetration) and excavating during the breeding season, but excavation techniques were used more than 70% of the time during the winter months (Conner 1979). This seasonal variation and narrowing in breadth of foraging techniques is due to the availability and location of prey items during winter months (Conner 1979, 1981).

Pileated woodpeckers choose foraging habitats with high densities of logs and snags, dense canopies, and tall shrub cover (Bull and Meslow 1977). Although they foraged on snags, stumps, and logs with diameters exceeding 18 cm (7 in) (Bull and Meslow 1977), pileated woodpeckers preferred logs greater than 25 cm (10 in) in diameter and greater than 15 m (49 ft) in length (Bull 1980). In western Oregon, the height and dbh of 31 snags used by foraging woodpeckers averaged 27 m (90 ft) and 104 cm (41 in),

respectively (Mannan et al. 1980)

Bull (1980) reported that pileated woodpeckers in Oregon spent 36% of their feeding time foraging on logs, 35% on live trees, and 29% on snags. Similarly, Bull and Holthausen (1993) found that pileated woodpeckers spent 38% of their feeding time in foraging on logs, 18% on live trees, 38% on snags, and 6% on stumps. In Oregon, Mannan (1984) found that pileated woodpeckers fed almost exclusively on dead wood, with 55% of foraging sites located on snags and the remainder on logs. Bull (1980) found that foraging sites on the ground were in dead and decayed material, most of which had less than 25% of the bark, branches, and needles remaining. The majority of snags used for foraging were greater than 51 cm (20 in) dbh, while only 46% of live trees used for foraging exceeded that diameter.

Pileated woodpeckers in Virginia foraged mostly on dead wood in mature forest habitats (Conner 1980). Pileated woodpeckers foraged extensively on fallen logs in a recently burned pine forest in Mississippi (Schardien and Jackson 1978). Tree stumps greater than 0.3 m (1 ft) in height are used extensively as foraging sites throughout North America (R. Conner, pers. comm.). Use of snags for foraging increased during the winter months in Montana as logs and stumps became snow-covered (McClelland 1979). Bull and Holthausen (1993) noted a change in foraging strata when snowpacks exceeded 5 cm (2 in) in depth with use of live trees increasing from 17% to 22%, use of dead trees increasing from 35% to 55%, use of logs decreasing from 41% to 18%, and use of stumps decreasing from 7% to 5%. When snowpacks were less than 5 cm (2 in), pileated woodpeckers wiped the snow off logs with their bills before feeding, and winter food supply was probably the limiting factor for pileated woodpeckers in the study area. However, Bull and Meslow (1977) noted in Oregon that feeding habitat was probably not as critical as nesting habitat.

Water

Pileated woodpeckers have been observed to drink water before roosting for the night (Kilham 1959), and Pfitzenmeyer (1956) noted copious water consumption during the nesting season. Pileated woodpeckers in Virginia did not nest farther than 150 m (492 ft) from water, and most nests were within 50 m (164 ft) of water (Conner et al. 1975). The average distance between water sources was 600 m (1,969 ft). The distribution of pileated woodpeckers in Virginia may have been due to the fact that mesic environments produce more large trees at a faster rate than xeric sites (Conner et al. 1975).

Cover

Cover requirements of the pileated woodpecker are similar to their reproductive habitat requirements. Therefore, cover requirements are described in the following section.

Reproduction

Pileated woodpeckers are primary cavity nesters and require large snags or live trees for their nest sites (Bull 1980). In Oregon, these woodpeckers selected nest snags in areas of dense forest (Bull and Meslow 1977) as did birds in California (Harris 1982). Typically, each pair excavates a new nest cavity approximately 15 m (45 ft) high in a snag or live tree every spring. As many as three nest sites may be created in a season (Thomas et al. 1979), and sometimes several nest cavities may be excavated in the same tree (Hoyt 1957). Occasionally, nest cavities that have been excavated during the previous season may be used (Bull et al. 1992b). Pileated woodpeckers have the strongest year-round pair bond of any North American woodpecker (Kilham 1979), and pairs appear to occupy the same location in successive years (Kilham 1959).

Nest excavation begins as early as March 27 in Maryland (Kilham 1974), but the peak of May through June reported by Zeiner et al. (1990) is undoubtedly more representative for California. Harris (1982) noted that breeding dates varied from mid-May in coastal California to May through late-July in montane sites.

Kilham (1979) and Harris (1982) reported that the male completes the nest excavation, and Kilham (1973) observed a male roosting in a nest hole under excavation. The lean of the nest tree dictates the location of the cavity entrance, which is typically placed on the under surface (Bull 1975; Harris 1982). Most nest cavities measure 35-45 cm (14-18 in) in depth (Bent 1939). Hoyt (1957) and Kilham (1959, 1979) found that pileated woodpeckers often use abandoned nest trees for yearlong roost sites.

The tree species chosen for the nest site is highly variable in North America given the extensive distribution of the pileated woodpecker. In northeastern Oregon, Bull et al. (1992b) found the tree species used as nest trees was 81% ponderosa pine (*Pinus ponderosa*), 11% western larch (*Larix occidentalis*), and 6% grand fir (*Abies grandis*). Although several authors (Conner et al. 1975; Miller and Miller 1980; Harris 1982) have reported nests in live trees, the vast majority of cavities are excavated in snags (Grinnell and Miller 1944; Conner et al. 1975; Bull 1975, 1980, 1987; Bull and Meslow 1977; Mannan et al. 1980; Harris 1982; Bull et al. 1992b). Pileated woodpeckers are strong excavators and can excavate in sound dead wood (Bull 1980). Conner (1977) observed that the birds do not select the softest part of the sapwood for excavating nest entrances and related this behavior to predator protection for nestlings, while Bull (1987) suggested that excavating in sound wood reduces the probability that the snag will break at the nest site. Several authors (Conner et al. 1975; Conner 1977; Harris 1983; Bull 1987) have indicated that fungal heart-rot is an important attribute of pileated woodpecker nest trees, and Conner (1977) suggested that the presence of heart-rot reduces the energy costs of excavation. Broken tops and limbs have been implicated as important stimulators of heart rot in nest trees (Bull 1975, 1980; Harris 1983; Bull et al. 1992b).

Available literature indicates that pileated woodpeckers in western coniferous forests prefer snags that exceed 76 cm (30 in) in diameter and 21 m (70 ft) in height for nesting. A summary of nest tree characteristics from seven studies is presented in Table 1. In Montana, snags used for roosting had diameters and heights similar to those used for nesting (McClelland 1979). In contrast, Bull et al. (1992b) found that tree species, condition, dbh, and number of entrance holes differed between nest and roost trees. Roost trees were typically large-diameter live or dead trees with a hollow interior formed as the result of decay rather than by excavation by the woodpeckers. Bull et al. (1992b) found that 46% of the roost trees were in live grand fir, 22% were in dead ponderosa pine, 15% were in dead grand fir, 13% were in live western larch, and 1% were in Engelmann spruce (*Picea engelmannii*). Average dbh and height of roost trees were 71 cm (28 in) and 22 m (73 ft), respectively (Bull et al. 1992b). Nest and roost trees also differed in slope position and in surrounding forest type. The majority (75%) of nest trees were located on the upper third of the slope, while only 43% of roost trees were found there. Almost all (93%) of the roost trees occurred in grand fir forest-type, characterized by the presence of grand fir, Douglas-fir (*Pseudotsuga menziesii*), western larch, ponderosa pine and lodgepole pine (*Pinus contorta* var. *murrayana*), whereas only 67% of nest trees were found there (Bull et al. 1992b).

Many investigators have documented the pileated woodpecker's preference for mature forests with closed canopies and scattered patches of large snags (Conner 1973; Conner et al. 1975; Bull 1975, 1980, 1987; Bull and Meslow 1977; Thomas et al. 1979; Verner and Boss 1980; Mannan et al. 1980; Shiamamoto and Airola 1981; Harris 1982). In northeastern Oregon, Bull and Holthausen (1993) recommended that woodpecker management areas consist of 75% grand fir forest type, at least 25% of which should be old growth and the remainder be mature. Furthermore, at least 50% of the area should have 60% canopy closure, and at least 40% of the area should remain unlogged. Suitable habitat should be in contiguous units of at least 364 ha (910 ac), with 8 snags/ha (20 snags/ac) and 100 logs/ha (250 logs/ac) (Bull and Holthausen 1993). Snags should be 51 cm (20 in) dbh and logs 38 cm (15 in) in diameter.

Table 1. Pileated Woodpecker Nest Tree Characteristics

Location	N	Mean dbh cm (in)	Mean height m (ft)	Mean hole height m (ft)	Author
California	24	66.0 (26)	24.1 (79)		Harris (1982)
Oregon	105	84.0 (34)	28.0 (92)	15.0 (49)	Bull (1987)
Oregon	62	76.2 (30)	28.0 (92)		Bull (1980)
Oregon	13	76.2 (30)	21.0 (69)		Bull and Meslow (1977)
Oregon	7	78.7 (31)	13.7 (45)		Mannan (1984)
Montana	11	74.9 (30)	28.0 (92)	15.2 (50)	McClelland (1979)

Interspersion and Composition

The minimum area needed by a pair of pileated woodpeckers is influenced by the availability of foraging substrates, nest and roost trees, and possibly free water. Kilham (1976) found that winter home ranges averaged 70 ha (175 ac) in Georgia and suggested that the breeding home-ranges were the annual home ranges (Kilham 1979). Mannan (1984) mapped nonbreeding home ranges of 400-520 ha (1,000-1,300 ac) in Oregon. In northeastern Oregon, mated pairs of pileated woodpeckers had home ranges averaging 407 ha (1,018 ac), while birds that had lost their mates had home ranges averaging 597 ha (1,493 ac) (Bull and Holthausen 1993). In coastal Oregon, home ranges for individual adult birds averaged 478 ha (1,195 ac) and home ranges for pairs were larger (Mellen et al. 1992).

Special Considerations

Habitat for the pileated woodpecker in the Rocky Mountains is diminishing as the average forest age is reduced by timber harvesting (McClelland 1979). Silvicultural thinning may negatively affect these woodpeckers due to a loss of decayed trees that provide woodpecker nest and roost sites, and habitat for carpenter ants (Conner et al. 1975). The habitat of pileated woodpeckers in the east may also be threatened by intensive forest harvesting practices (Conner 1980). A cutting rotation in eastern forests of 80 years would probably provide adequate foraging habitat (Conner 1980), but a 150-year rotation may be needed for nesting habitat (Conner 1978).

Unmanaged, mature stands usually have adequate numbers of snags for resident woodpeckers (Bull et al. 1980). In managed forest stands, snags can be maintained by killing trees or by leaving trees to die. Woodpeckers can then be managed at selected population levels.

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 pileated woodpeckers in California.

Season

This model is designed to predict the suitability of habitat for pileated woodpecker 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 pileated 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 pileated woodpecker was not found in the literature. This model assumes two home ranges is the minimum area required to support a pileated 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 for the pileated woodpecker.

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

There is evidence that pileated woodpeckers require free water during the breeding season. This model downgrades all area one suitability level if further than 2,030 m (6,660 ft) from 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.

Although pileated woodpeckers 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	24,366	79,940
Day to Day Distance/Home Range Radius	1,015	3,331
Distance to water	2,030	6,660

Area variables:	Hectares	M ²	Acres	Ft ²
Home Range	323	3,237,600	798	34,848,000
Core Habitat	346	3,475,200	7,596	39,686,000

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 2,030 m (6,660 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 areas 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 to Day 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 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 1 if it is utilized and a 0 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 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

Conner and Adkisson (1976) developed a discriminant function model for the pileated woodpecker that can be used to separate potential nesting habitat from other habitat. The model requires basal area, number of stems, and canopy height of trees. Schroeder (1983) developed a habitat suitability index model that predicted year-round suitability for pileated woodpeckers. The model used several variables that measured tree canopy, number of large trees, number of stumps and logs, number of medium and large snags and average dbh of medium and large snags.

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APPENDIX 1: Pileated Woodpecker Macro

```
/*      PILEATED WOODPECKER

/* pwomodel.aml - This macro creates an HSI coverage for the
/*      Pileated 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...

/* Homorange: the size of the species' homorange.

/* 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 = B308

```

```

&if %.Measure% = Meters &then
  &do
    &setvar Homerange    = 3237600
    &setvar DayPay       = 1015
    &setvar DispersePay  = 24366
    &setvar Waterdist    = 2030
    &setvar AcreCalc     = 4047
  &end
&else
  &if %.Measure% = Feet &then
    &do
      &setvar Homerange  = 34848000
      &setvar DayPay     = 3331
      &setvar DispersePay = 79940
      &setvar Waterdist  = 6660
      &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

/*
```

&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
```

```
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 imbedded
/* 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) Quitting 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
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