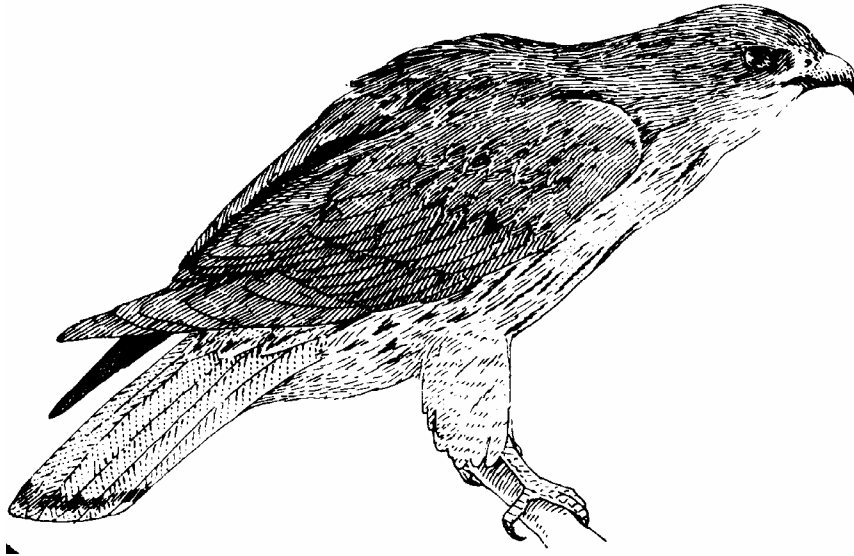


**California Wildlife Habitat Relationships Program  
California Department of Fish and Game**

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**HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO:  
RED-TAILED HAWK**



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June 1995

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HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO:  
RED-TAILED HAWK

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## PREFACE

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

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

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

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

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

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

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## ACKNOWLEDGMENTS

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.

## RED-TAILED HAWK (*Buteo jamaicensis*)

### HABITAT USE INFORMATION

#### General

The red-tailed hawk (*Buteo jamaicensis*) is an adaptable, and widespread diurnal predator. It is common as a permanent breeder, winter resident, or migrant throughout North America. The fourteen subspecies of the red-tailed hawk are found throughout North America south to Panama, the Virgin Islands, and Puerto Rico (Grinnell and Miller 1944; Bent 1946; Brown and Amadon 1968; Newton 1979; Robbins et al. 1983; Preston and Beane 1993). They breed throughout California, and winter in areas without heavy snow cover. Red-tailed hawks can be found in virtually all habitats from the lowest to highest elevations. Birds breeding at high elevations move downslope in the winter (Garrett and Dunn 1981; Zeiner et al. 1990).

#### Food

Red-tailed hawks are opportunistic and will concentrate on whatever prey is found in the local area. They will eat small mammals up to the size of hares (*Lepus* spp.), birds, reptiles, amphibians, fish, and some carrion (May 1935; Orians and Kuhlman 1956; Gates 1972; Lee and Brown 1980; Stallmaster 1980; Tolman 1990). Red-tailed hawks do most of their hunting from elevated perches. They also search by soaring and occasionally take prey in mid-air. Most feeding occurs in early morning or late afternoon (Clyde 1990; Zeiner et al. 1990; Preston and Beane 1993). Ballam (1984) found that red-tailed hawks in Arkansas make 72% of their foraging attempts from perches and 22% while soaring. Capture success rates were higher for perching (19%) than for soaring (6%).

In eastern and midwestern North America, game birds, small mammals and rabbits (*Sylvilagus* spp.) dominate red-tailed hawk diets. In Wisconsin, Gates (1972) found that red-tails hunted large numbers of ring-necked pheasant (*Phasianus colchius*) in winter when mammalian prey was protected by snow cover. During the breeding season the bird's primary food items were ring-necked pheasant, cottontail rabbits (*Sylvilagus floridanus*), red-winged blackbirds (*Agelaius phoeniceus*), and domestic chickens. Other medium sized birds and small to medium sized mammals were also eaten. In Wisconsin, Orians and Kuhlman (1956) had similar results with ring-necked pheasant and eastern cottontail comprising the majority of the diet. In Missouri, Toland (1990) found mammals comprised 71.4% of the total prey items and 89.4% of the biomass, and birds comprised 18% of the prey items and 7.7% of the biomass. Cotton rats (*Sigmodon hispidus*) were the most frequent mammal taken (19%) but eastern cottontails contributed the most biomass (44%). The prey species delivered to nestlings most often were cotton rat, prairie vole (*Microtus ochrogaster*), eastern cottontail, eastern fox squirrel (*Sciurus niger*), and southern bog lemming (*Synaptomys cooperi*). A wide variety of birds, mammals, and reptiles were eaten along with a small number of fish and invertebrates.

In the western and northern portions of North America, ground squirrels (*Spermophilus* spp.) and rabbits dominate the diet when available. In areas where ground squirrels and rabbit populations are low, snakes and other reptiles are important food items. In California, Fitch et al. (1946) found small mammals and reptiles to be the most important prey items delivered to the nest. Prey items delivered to 14 nests over 3 yr included 380 California ground squirrels (*Spermophilus beecheyi*), 79 pocket gophers (*Thomomys bottae*), 62 Audubon cottontails (*Sylvilagus auduboni*), 13 woodrats (*Neotoma fuscipes*), 10 kangaroo rats (*Dipodomys heermanni*), 8 Merriam chipmunks (*Eutamias merriami*), 7 small mice and squirrels, 11 California Quail (*Callipepla californicus*), 4 scrub jays (*Aphelocoma coerulescens*), 8 other small birds, 17 whiptails (*Cnemidophorus tesselatus*), 14 gopher snakes (*Pituophis melanoleucus*), 8 Gilbert skinks (*Eumeces gilberti*), and 4 other reptiles. A study of hawk pellets in the same area found similar species being eaten by the adults except for a small number of invertebrates such as grasshoppers, beetles, and Jerusalem crickets (*Stenopelmatus* spp.) in the adult diet. In Oregon, ground squirrels (*S. Beldingi* and *S. Townsendii*) were the most common prey item (Janes 1984) followed by Audubon cottontails and pocket gophers (*T. talpoides*). In Alberta, snowshoe hares (*Lepus americanus*) and Richardson's ground squirrels (*S. richardsonii*) dominated the diet with other small mammals and birds reported (Meslow and Keith 1966; Luttich et al. 1970). In south-central Montana, Richardson ground squirrels, cottontail rabbits, voles, and magpies (*Pica pica*) dominated the diet (Seidensticker 1970). MacLaren et al. (1988) found a similar result in southwestern Wyoming. In central Washington, Stinson (1980) found snakes to be the most common item fed to chicks (76% of items delivered). The most common species delivered were racer (*Coluber constrictor*) and gopher snakes. Knight and Erickson (1976) found a similar result in north-central Washington with snakes representing 41.3% of all prey items brought to the nest and 49.2% of the biomass. Ground squirrels were not present in the study area and lagomorphs were rare.

#### Water

Red-tailed hawk water requirements are probably met from food (Zeiner et al. 1990).

#### Cover

Red-tailed hawks are found in open areas with scattered, elevated perch sites in a wide range of altitudes and habitats. They feed in grasslands and grass/shrub stages of most habitats. They are also commonly found feeding in agricultural fields. They roost in trees, sometimes in dense conifer stands (Zeiner et al. 1990, Preston and Beane 1993).

In a study of mixed conifer forest in the Sierra Nevada, Franzreb and Ohmart (1978) found that harvested areas were used by red-tailed hawks more often than non-harvested areas. In Arizona, wintering red-tailed hawks were found most often in broadleaf riparian, agricultural, pinyon (*Pinus* spp.)-juniper (*Juniperus* spp.), and grassland habitats (Parker and Campbell 1984). In Idaho, a study of two geologically similar areas along the Snake River, one agricultural and the other non-cultivated, showed similar red-tailed hawk populations in the two areas (Howard and Sather-Blair 1983). Rice and Smith



(1986) found red-tailed hawks hunting significantly more often in ungrazed grassland than in grazed grassland in southeastern Arizona.

## Reproduction

Red-tailed hawks usually nest in large trees near openings in mature woodlands especially those dominated by deciduous trees. They occasionally nest on cliffs or low ledges. The nest is usually 9-27 m (30-90 ft) above the ground in trees, but the nest can be higher on cliffs. They are flexible in their choice of nest sites occasionally using human-made structures, shrubs, or cacti. They nest in small groves of trees in open habitat, and occasionally in isolated trees. Nests are normally built high in the tree for easy access by the adults (Orians and Kuhlman 1956; Benarz and Dinsmore 1982; Speiser 1990; Toland 1990; Zeiner et al. 1990; Morris 1993; Yahner and Grimm 1993).

In Missouri, Toland (1990) found them nesting primarily in American sycamores (*Platanus occidentalis*) and oaks (*Quercus* spp.). In Wisconsin, Orians and Kuhlman (1956) found them nesting primarily in elms (*Ulmus americana*). In southern California, Wiley (1975) found them nesting primarily in sycamores (*Platanus racemosa*) and oaks (*Quercus* spp.). In Washington, Speiser (1990) found them nesting only in black cottonwood (*Populus balsamifera*) and red alder (*Alnus rubra*).

Courtship begins as early as January in areas with warmer climates such as California. They breed from March to July with a peak in May and June (Wiley 1975; Zeiner et al. 1990). Both the male and female carry nest material to the nest, but the females do most of the actual nest construction (Toland 1990). The nest consists of twigs and small branches lined with grass, shredded bark, pine needles and other plant material. Adults frequently deposit fresh twigs in the nest (Fitch et al. 1946). Toland (1990) found that most red-tailed hawks maintained two nests within their territory and used each approximately half of the time. The clutch contains 2-5 eggs, but 2-3 eggs is the average. Eggs are laid in March and April. Incubation lasts 28-32 days, and the semialtricial young fledge in 40-45 days. Red-tailed hawks are usually permanently paired (Fitch et al. 1946; Harrison 1978; Zeiner et al. 1990).

Henny and Wight (1972) estimated that temperate latitude red-tailed hawk populations must produce 1.3-1.4 young per breeding attempt to maintain population stability. Gates (1972) reported a fledging rate of 1.8 young per successful clutch with an overall reproductive success of 1.1 fledged young per breeding pair in Minnesota. In Missouri, Toland (1990) found an overall reproductive success of 1.9 young fledged per nest. In Wisconsin, Orians and Kuhlman (1956) found overall nest success was 1.8 and 1.1 young fledged in each of two years of study, respectively. In southern California, Wiley (1975) found an overall average nest success of 1.6 young fledged. Reproductive success was lower for nests within 0.25 mi of a public road than for those further away. Wiley (1975) found a large proportion of nest failures (9 of 14) were due to taking of the young by humans for falconry. In Oregon, overall success was 1.5 fledged young (Janes

1984a). Along the Columbia River in north-central Washington, Knight et al. (1982) found nest success rates of 1.6 young fledged per attempt.

### Interspersion and Composition

Red-tailed hawk home ranges vary depending on location, topography, habitat, and prey availability (Zeiner et al. 1990). Home ranges are defended against conspecifics, hawks of other species, and eagles (Fitch 1946; Janes 1984). Craighead and Craighead (1956) found average home ranges of 365 ha (903 ac) in Michigan and 207 ha (512 ac) in Wyoming. In southeastern Colorado, Anderson and Rongstad (1989) found home range sizes of 1,780 ha (4,387 ac) using a 95% ellipse around telemetry locations. In Wisconsin, Peterson (1979) found home range sizes for each season as follows: fall - male 390 ha (964 ac) and female 123 ha (304 ac); winter - male 157 ha (388 ac) and female 167 ha (413 ac); spring - male 163 ha (403 ac) and female 85 ha (210 ac); summer - male 117 ha (289 ac) and female 117 ha (289 ac).

Janes (1984a; 1984b) found red-tailed hawk territories to be very stable as only four significant (> 10%) territory size adjustments were detected during a 10 yr period. Females showed greater territory fidelity than males. In California, Fitch et al. (1946) calculated that red-tailed hawk territories varied from 30-80 ha (74-198 ac). They found 0.8 breeding pairs/km<sup>2</sup> (2.0/mi<sup>2</sup>). In Minnesota, Gates (1972) found 0.17 pairs/km<sup>2</sup> (0.44/mi<sup>2</sup>) in the winter, and in the breeding season 0.09 pairs/km<sup>2</sup> (0.24/mi<sup>2</sup>). In Missouri, Toland (1990) found 0.14 pairs/km<sup>2</sup> (0.36/mi<sup>2</sup>), while in Alberta, an average of 0.13 birds/km<sup>2</sup> (0.34 birds/mi<sup>2</sup>) were reported (Luttich et al. 1971). Runyan (1987) found 0.28 pairs/km<sup>2</sup> (0.73/mi<sup>2</sup>) in British Columbia. In Colorado, density of occupied nests was 0.18/km<sup>2</sup> (0.46/mi<sup>2</sup>) (McGovern and McNurney 1986). In Washington, Speiser (1990) found 0.14 nests/km<sup>2</sup> (0.36/mi<sup>2</sup>).

Great horned owls (*Bubo virginianus*) often use red-tailed hawk nests from the previous breeding season. When this happens, the resident hawks build a new nest or move to an alternate nest. Predation by great-horned owls on red-tailed hawks was found to be insignificant (Toland 1990).

Red-tail hawks are sympatric with Swainson's hawks (*B. Swainsoni*) in many areas. In most encounters Swainson's hawks appear to be dominant, often taking over peripheral portions of established red-tailed hawk territories (Janes 1984; Janes 1994). They are also sympatric with ferruginous hawks (*B. regalis*) and use similar food resources (Restani 1991).

### Special Considerations

In a study in western Wyoming, Craighead and Mindell (1981) found that the red-tailed hawk population had declined from 1947 to 1975, and nesting success decreased from 1.7 young fledged per pair to 0.7 young fledged per pair. Average clutch size had also

decreased from 2.3 eggs to 2.1 eggs. Considerable development of highways, buildings and an increase of human visitation rates to the nesting area from a few dozen to 75,000 were thought to be important factors.

Red-tailed hawk populations in the Midwest have increased over the past four decades despite the increased fragmentation and urbanization of the landscape. Many hawks are nesting in urban areas and using man-made structures such as power poles as nest sites (Stout and Anderson 1993). Observations at Hawk Mountain Sanctuary in north-eastern Pennsylvania also indicates a slight increase in red-tailed hawk populations in the eastern United States (Nagy 1977).

Knight and Kawashima (1993) found that red-tailed hawks were more common along power lines in the Mojave Desert than in nearby control areas. A similar study in southern Idaho and Oregon found that adding platforms increased the attractiveness of the powerline poles as nest sites for raptors (Steenhog et al. 1993). The power lines and utility poles provide perch and nesting sites in areas where these resources may be limited. However, power lines and utility poles also represent a hazard to hawks because of the possibility of electrocution, collision and/or shooting because of increase access for humans (Williams and Colson 1987).

The red-tailed hawk's use of orchards for perch and foraging sites in the winter exposes them to insecticide residues used during the orchard's dormant season. Studies in California have shown that hawks may be exposed to insecticide residues both orally and through their feet. There was enough exposure that it could be detected on their feet and in their excreta. Their blood cholinesterase levels were found to be depressed (White 1995).

## 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 red-tailed hawks in California.

#### *Season.*

This model is designed to predict the suitability of habitat for red-tailed hawks throughout the year. Predictions, however, may be most accurate for breeding habitats.

#### *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 red-tailed hawks 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 red-tailed hawks throughout the year was not found in the literature. This model assumes two home ranges is the minimum area required to support a population of breeding red-tailed hawks.

#### *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 is 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 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, and 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.*

Red-tailed hawks 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 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	24,366	79,940
Day to Day Distance/ Home Range radius	1,015	3,331

Area variables:	Hectares	M <sup>2</sup>	Acres	Ft <sup>2</sup>
Home Range	324	3,237,600	800	34,848,000
Core Habitat	∃ 162	∃ 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. **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 ( $\exists$  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 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 red-tailed hawks were found.

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## APPENDIX 1: Red-Tailed Hawk Macro

```
/*      RED-TAILED HAWK

/* rhamodel.aml - This macro creates an HSI coverage for the
/*      red-tailed hawk.

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

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

/* Revision: 7/1/95

/* -----

/* 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 = B123

&setvar .Measure [translate %.Measure%]

&if %.Measure% = METERS &then
&do
&setvar Homerange    = 3237600
```

```

    &setvar DayPay      = 1015
    &setvar DispersePay = 24366
    &setvar AcreCalc    = 4047
&end
&else
&if %Measure% = FEET &then
    &do
        &setvar Homerange    = 34848000
        &setvar DayPay        = 3331
        &setvar DispersePay   = 79940
        &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.

Geom = %.WHRgrid%.%SpecCode%_G

/*

&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 get 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