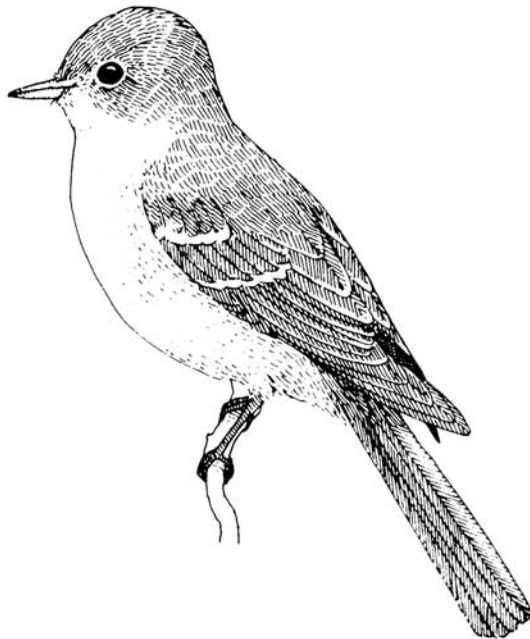


**California Wildlife Habitat Relationships Program
California Department of Fish and Game**

**HABITAT SUITABILITY MODELS FOR USE WITH ARC/INFO:
WILLOW FLYCATCHER**



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WILLOW FLYCATCHER

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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.

WILLOW FLYCATCHER (*Empidonax traillii*)

HABITAT USE INFORMATION

General

Willow flycatchers (*Empidonax traillii*) breed in riparian and mesic upland thickets in the United States and southern Canada. Their winter range extends from Veracruz and Oaxaca south to Panama (American Ornithologists' Union 1983). Historically, willow flycatchers were common summer residents throughout California, breeding wherever extensive willow (*Salix* spp.) thickets occurred (Grinnell and Miller 1944). However, over the last four decades they have been extirpated as breeding birds over much of their range in California (Serena 1982). Today, they are rare to locally uncommon summer residents in wet meadow and montane riparian habitats at 600-2,500 m (2,000-8,000 ft) in the Cascade and Sierra Nevada ranges (Zeiner et al. 1990). Willow flycatchers also occur along the Kern, Santa Margarita, and San Luis Rey rivers (Remsen 1978; Garrett and Dunn 1981; Serena 1982; Unitt 1987). Sierra Nevadan populations have declined, and the species is becoming scarce in the Yosemite region (Gaines 1977; Serena 1982). In the spring and fall, willow flycatchers are fairly common transients throughout the state's riparian willow habitats (McCaskie et al. 1979; Garrett and Dunn 1981).

The loss and degradation of California's riparian habitats have been identified as the principal reason for the statewide reduction of the willow flycatcher population and the concomitant contraction of its breeding range (Remsen 1978; Serena 1982). Nest parasitism by the brown-headed cowbird (*Molothrus ater*) and habitat modification caused by livestock grazing also have been suggested as contributing significantly to population reductions (Gaines 1977; Serena 1982; Beedy and Granholm 1985; Sharp 1986; Taylor 1986; Taylor and Littlefield 1986).

The willow flycatcher has been included on the Audubon Blue List since 1980 in the northeastern and southwestern borders of its breeding range (Arbib 1979). The Pacific Southwest Region of the U. S. Forest Service and Region 1 of the U.S. Fish and Wildlife Service have designated it as a Sensitive Species. In 1990, the willow flycatcher was listed as a State Endangered Species by the California Fish and Game Commission.

Food

Willow flycatchers are "sit-and-wait" predators that catch insects on the wing. Two foraging strategies are employed: (1) hawking where the bird sallies forth from a perch to capture flying insects; and (2) aerial gleaning where the bird picks insects from vegetation (Verbeek 1975). Hawking is the most common feeding activity in Washington (Frakes and Johnson 1982) and in California (Sanders and Flett 1989a). Relatively high perches (≥ 3 m [10 ft]) were used by hawking males in Washington (Frakes and Johnson 1982), while females perched and foraged from lower branches. Willow flycatchers shift their foraging perches every few minutes and occasionally use perches outside of their breeding territories (Sanders and Flett 1989a). When feeding

young, willow flycatchers may forage as far as 100 m (330 ft) from their territories (Sanders and Flett 1989a).

Water

Water is always present on willow flycatcher territories in the form of running water, pools of standing water, or saturated soils (Serena 1982; Kings River Conservation District 1985a; Harris et al. 1986; Sanders and Flett 1989a, 1989b). In the Sierra Nevada, 20 of 22 territories encompassed part of the Little Truckee River, and the other two were within 11 m (36 ft) of the river (Sanders and Flett 1989a). In Colorado, the mean distance between nest sites and open water was 10.7 m (35.3 ft), and an average of 9.9% of each territory was covered by water (Sedgwick and Knopf 1992). Water is always available during the early stages of breeding and pair formation, but it may not be present at the later stages of the breeding cycle (Stafford and Valentine 1985; Harris et al. 1986; Sanders and Flett 1989a).

Cover

The willow flycatcher is associated throughout its range with dense, patchily-distributed shrub cover (King 1955). They require the presence of thickets of small trees or shrubs (Bent 1942; Berger and Parmalee 1952; King 1955; Stein 1958; Graber et al. 1974). In the Sierra Nevada, willow flycatchers are found only in broad, flat meadows that generally are larger than 8 ha (20 ac) and contain scattered willow thickets (Serena 1982; Harris et al. 1986; Sanders and Flett 1989b). They typically shun willow thickets on steep terrain or narrow bands of willows bordered by coniferous forests (Sanders and Flett 1989b).

Several authors describe openings as an important component of willow flycatcher habitat (Grinnell and Storer 1924; Meanley 1952; King 1955; Walkinshaw 1966). In Washington, willow flycatchers were observed on the edges of openings and thickets that were located in open, park-like areas (King 1955). In Colorado, bushes used for nests and song perches were separated from adjacent willow bushes by average distances of 3.8 and 5.1 m (12.5 and 16.8 ft), respectively (Sedgwick and Knopf 1992). Willow cover on 22 territories (mean territory size 0.34 ha [0.85 ac]) in the Sierra Nevada averaged 44% (Sanders and Flett 1989a). In Colorado, willow cover on territories (mean territory size 0.32 ha [0.8 ac]) based on nest sites averaged 49%, while cover on territories based on song-perch sites averaged 44% (Sedgwick and Knopf 1992). Willow flycatchers were observed only in areas of the Sierra Nevada where the willow cover was

at least 2 m (6.6 ft) tall (Harris et al. 1986). Nest and song-perch bushes in Colorado averaged 3.4 m (11.2 ft) and 4.7 m (15.5 ft) tall, respectively (Sedgwick and Knopf 1992).

Reproduction

Willow flycatchers arrive in Sierran meadows in early to mid-June, with pair formation and establishment of breeding territories occurring by late June (Sanders and Flett 1989a). Nest building usually begins within a week of pair formation (Stafford and Valentine 1985), and the first egg may be laid before the nest lining is complete. Young typically fledge by mid-July and the birds disperse from the breeding territories by late August (Sanders and Flett 1989a). Nests consist of open cups and may be lined with fine grasses, feathers, or wool. In the central Sierra Nevada, nests were placed in willows at an average height of 1.1 m (3.6 ft) above ground and at an average distance of 2.3 m (7.6 ft) from the edge of the willow clump (Sanders and Flett 1989a).

Interspersion and Composition

Male willow flycatchers establish territory boundaries prior to pair formation and maintain them early in the season by singing from elevated perches. Territorial overlap between adjacent males is minimal. Territory sizes for 15 paired males ranged from 0.1-0.4 ha (0.2-0.9 ac) and averaged 0.2 ha (0.5 ac) in eastern Fresno County, California (Kings River Conservation District 1985b). On the Little Truckee River in the central Sierra Nevada, 22 territories ranged from 0.1-0.9 ha (0.2-2.2 ac) and averaged 0.4 ha (0.8 ac) (Sanders and Flett 1989a). In Michigan, 73 territories averaged 0.7 ha (1.7 ac) (Walkinshaw 1966).

Special Considerations

Livestock grazing can indirectly affect willow flycatcher habitat by altering the vegetation and hydrology of montane meadows. Cattle and sheep may consume the lower branches and shrub layers of streamside vegetation and consume or trample young riparian plants (Taylor 1986). Foliar density and structure of riparian vegetation can be affected, particularly from the ground up through a height of 1.5 m (4.9 ft). This level encompasses the preferred nest height for the willow flycatcher. In Utah, Duff (1979) found that exclusion of livestock yielded an increase in this favored portion of willows. In Oregon, Taylor and Littlefield (1986) found that populations of willow flycatchers and their willow habitat recovered with reduced cattle use. They also found that willow flycatchers were present in high numbers only on those transects with high shrub volume which were either undisturbed or rarely used by cattle.

Willow flycatchers are susceptible to direct nest disturbance by cattle (Stafford and Valentine 1985; Sanders and Flett 1989; Valentine 1987; Valentine et al. 1988). The precarious placement of nests near the edges of willow clumps makes nests vulnerable to physical disturbance by cattle.

The willow flycatcher is parasitized by the brown-headed cowbird (Bent 1942; Walkinshaw 1966; Berger and Parmelee 1952; Gaines 1977; Garrett and Dunn 1981; Harris et al. 1986; Sanders and Flett 1989a; Sedgwick and Knopf 1988). Nest parasitism by cowbirds has been suggested as a cause of the willow flycatcher's decline in California

(Remsen 1978). Studies at low elevations in southern California suggest that the willow flycatcher is susceptible to cowbird parasitism (Hanna 1928; Rowley 1930). Of 150 instances of willow flycatcher parasitism by brown-headed cowbirds, 41 reports were from southern California (Friedmann 1963). Intense parasitism was reported in 1987 on the Kern River Preserve with 13 to 16 of 19 nests parasitized by cowbirds (Harris in press).

Nesting failures due to cowbirds appear to be a major factor in lowland populations, but there is less evidence for cowbird parasitism in the higher elevations of the Sierra Nevada. In the northern Sierra, two instances of parasitism have been reported. One observation is from the Lacey-Perazzo Meadow area (Sanders and Flett 1989) and the other is from Lake Tahoe (Gaines 1977). No records of parasitism are reported from the southern Sierra Nevada (Stafford and Valentine 1985, Valentine et al. 1988).

Brown-headed cowbirds are associated with pack stations and groups of cattle in eastern Fresno County, California (Stafford and Valentine 1985). In the northern Sierra, cowbirds accompany sheep that arrived after the willow flycatchers have completed nesting in mid-July (Sanders and Flett 1989a). Observations at pack stations in the Sierra National Forest and at other western Sierra stations indicate that cowbirds seldom frequent pack stations before horses are brought in for the summer (Verner and Ritter 1983). An increase in willow flycatcher nest parasitism may occur if the arrival of cowbirds precedes or coincides with the peak of egg laying.

On the Sierra National Forest, cowbird abundance declined rapidly with increasing distance from human-based food sources such as pack stations, campgrounds, and towns (Verner and Ritter 1983). Cowbirds were found to be rare even in preferred habitats (meadows and riparian systems) more than 10 km (6 mi) from human developments.

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 willow flycatchers in California.

Season.

This model is designed to predict the suitability of habitat for willow flycatchers during the breeding season.

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 willow flycatchers 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 willow flycatchers during the breeding season was not found in the literature. This model assumes two home ranges is the minimum area required to support a willow flycatcher population during the breeding season.

Verification level.

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

Model Description

Overview.

This model uses CWHR habitat type as the main factor determining suitability of an area for this species.

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

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

Cover component.

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

Distance to water.

Willow flycatchers nest in riparian vegetation. No other water requirement was found for this species.

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 in size.

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	1,218	3,997
Day to Day Distance/ Home Range radius	51	167

Area variables:	Hectares	M ²	Acres	Ft ²
Home Range	.81	8,094	2	87,120
Core Habitat	∓ 1.62	∓ 16,188	∓ 4	∓ 174,240

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 (\geq 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

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

Fowler et al. (1991) developed a habitat capability model for the willow flycatcher. The model addressed the life requisites of the willow flycatcher during the breeding season in the Sierra Nevada. The four variables used in the model were: presence of water in the meadow or riparian area; meadow size; riparian deciduous shrub cover; and foliar cover density.

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APPENDIX 1: Willow Flycatcher Macro

```
/*      WILLOW FLYCATCHER

/* wflmodel.aml - This macro creates an HSI coverage for the
/*      Willow Flycatcher.

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

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

/* Revision: 2/10/95

/* -----

/* convert .ID to uppercase for info manipulations

&setvar .ID [translate %.ID%]

/* Start Grid

grid

/*

&type (1) Initializing Constants...

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

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

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

/* 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 = B315

&if %.Measure% = Meters &then
&do
    &setvar Homerange    = 8094
    &setvar DayPay       = 51
    &setvar DispersePay  = 1218
    &setvar AcreCalc     = 4047
```

```

&end
&else
&if %.Measure% = Feet &then
&do
&setvar Homerange    = 87120
&setvar DayPay       = 167
&setvar DispersePay  = 10000
&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

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

&return