DRAFT

Priority Vulnerable Species Habitat Data Analysis

Sonoran Desert Conservation Plan July 2000

MEMORANDUM

Date: July 12, 2000

To: The Honorable Chair and Members
Pima County Board of Supervisors

From: C.H. Huckelberry
County Administrator

Re: **Draft Priority Vulnerable Species Habitat Data Analysis**

Overview

In June of this year the biological consulting team for the Sonoran Desert Conservation Plan issued a 300 page draft report entitled *Priority Vulnerable Species* that compiled existing biological and management information for 56 plants and animals that are being studied and considered by the Science Technical Advisory Team for coverage under the Sonoran Desert Conservation Plan. Detailed vulnerable species accounts were drafted for 9 mammals, 8 birds, 7 reptiles, 7 plants, 6 fish, 2 amphibians, and invertebrates. The Science Team is now in the process of securing review of each compilation by species experts. The attached draft report entitled *Priority Vulnerable Species Habitat Data Analysis* builds from the June document by essentially translating written details of each species' natural and biological history to the geographic information system, where a computer survey of the landscape can take place much faster than surveys and expeditions in the field.

Dealing with the Problems Presented by Uneven Resource Information

One of the challenges presented by data collected over time by field biologists is that it tends to aggregate in areas where the surveyors have access. After this data is mapped, it becomes apparent that site location data often corresponds with major roadways. This result is likely not the complete or balanced picture of actual distribution. The attached draft report from Recon -- which is more important at this stage for the method it proposes than the initial results of mapping exercises -- deals with the problem of uneven resource information and provides this summary of the goals of the analysis:

- Understanding the component parts: "One of the goals of the habitat analysis was to use information in the vulnerable species report to develop a summary of habitat characteristics for each of the 56 priority vulnerable species. This summary is compiled in the form of a species-environment matrix where each characteristic (i.e., mixed grass scrub) of a variable (i.e., vegetation) is valued from low to high (1-3) for each species. Variables investigated include vegetation, hydrology, topography (elevation, slope, aspect), and cave/mine potential." (P. 1)

- Predicting distribution: "The second goal of the habitat data analysis was to use habitat values in the species-environment matrix to develop maps of the distribution of potential habitat for each species using GIS grid modeling techniques." (P. 1)

Dealing with the Problem of Having Resource Information Exist in a Vacuum

Another dilemma of approaches in conservation planning is that a gap often exists between the information compiled by the field or research biologists who gather descriptive data, and the information needed to make practical land use decisions that will result in species protection. The leap from description to prescription, or from an assembly of facts to a theoretical basis for species protection in a land management framework, is a difficult one.

The *Draft Priority Vulnerable Species Habitat Data Analysis* deals with this dilemma by describing the assumptions and data sources used to create the species-environment matrix (pages 2 through 10), describing GIS modeling methods (page 11), and describing the specific application of the model through a species-by-species analysis found on pages 12 through 84.

Through this detailed explanation of a highly technical exercise, the reader can see how a cross-walk is built between the two approaches to dealing with resource information that often stay isolated from one another. The Science Technical Advisory Team along with experts from the community will be able to add to this discussion by advising on matters such as what characteristics to include in assessing potential habitat for a given species, or in exercising judgment about how to assign weight to different characteristics. The basic framework for the discussion is provided, however. In addition, pages 85 through 88 explain how a conservation assessment can follow determinations about potentially suitable habitat. By overlaying the habitat area with GAP conservation status categories, the reserve planning status of each species can be mapped.

As a historical aside, this ability to integrate information, and deal with system level protection over site-level and species specific protection, did not exist forty years ago. In 1967, in a deceptively plain looking volume entitled *The Theory of Island Biogeography,* Robert MacArthur and E.O. Wilson joined forces to merge the aspirations of ecology with the mountain of descriptive information that had accumulated in the zoology and biology fields, into a "feasible general theory" that would lead to "a tradition of mathematical work devoted to biological problems." This is exactly what happened as their text became a centerpiece of discussion for the next quarter century in conservation biology, leading most recently to the breakthroughs in metapopulation analysis by Dr. Michael Gilpin. Dr. Gilpin -- along with other leading scientists in the area of mathematical modeling and geographic information systems -- is currently working with Pima County, the consulting team, and the Science Technical Advisory Team to develop a GIS decision support model based on the optimal assembly of patches of habitat.

Dealing with the Problems of Imperfect Resource Information

A summary of data gaps is provided on page 89 of the attached study. On pages 90 and 91, a discussion of the benefits and feasibility of GIS modeling is found, including these points:

- "One of the greatest advantages of using GIS for habitat models is the ability of the GIS to synthesize detailed information that would be impossible for a person to manually accomplish. We use only 9 layers of environmental information in these models -- many more could be used. Each layer has between 2 and 26 possible characteristics. This means that any particular place can have over 1 million combinations of environmental characteristics that describe the landscape. Across 5.9 million acres, even at the fairly course scale resolution used (23 acre cells), there are over 250,000 places (cells) to be evaluated. These are awesome computations!" (P. 90)

- "Another advantage of GIS models is that the assumptions used to produce GIS maps are accessible so that map reviewers and users understand how and why a map looks the way it does. These assumptions can be easily modified and input into the model so that map alternatives can be quickly compiled. A GIS can also be used to help determine model parameters by evaluating the association of known location data with habitat characteristics." (P. 90)

GIS mapping tends to clarify the status of data so that gaps can be identified and addressed. Because non-GIS based conservation planning is less accessible, the same data gaps go unnoticed and unaddressed -- but they would exist all the same.

Conclusion

The *Draft Priority Vulnerable Species Habitat Data Analysis* constructs preliminary GIS models and assesses habitat data for the priority vulnerable species of the Sonoran Desert Conservation Plan. The Science community will review and improve the quality of the information in discussions that will take place through the point of permitting, and on into the adaptive management phase of the conservation program. Although modeling is new territory for many, and metapopulation biology is a young field, these endeavors are rooted in the tradition of biogeography that gave rise to regional conservation planning itself. This flexible and sophisticated landscape level approach will assist in full implementation of all elements of the Sonoran Desert Conservation Plan, including everything from habitat and corridor conservation to ranch conservation.

E.O. Wilson, who 33 years ago successfully launched the "tradition of mathematical work devoted to biological problems" that benefits the Sonoran Desert Plan today, had this to say in the February 2000 editorial of *Conservation Biology*:

> "Cross-cutting databases open new avenues of useful analysis for the conservation biologist. When information on elevation, slope, vegetation cover, soil type, rainfall, and other biotic and abiotic properties of the study site are digitized, overlaid with one another, and matched with similar overlays from the surrounding region, the range of new and rare species can be predicted. At least a good guess can be made about where each in turn is most likely to occur. To single species searches and mapping can be added the already well-developed technique of gap analysis. With such information available, regional conservation planning becomes not only scientifically sound, but a great deal easier to achieve."

The attached draft from Recon, with its deceptively simple presentation style, is a welcome addition of complex and necessary GIS modeling to the Sonoran Desert Conservation Plan.

DRAFT
Priority Vulnerable Species: Habitat Data Analysis

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I. Introduction

As part of the work effort for the Sonoran Desert Conservation Plan (SDCP), RECON conducted a vulnerable species habitat data analysis. This report compiles the results of that effort. During the last several months, data has been compiled for species and habitats in Pima County as part of various SDCP-related tasks. Detailed descriptions of species and their habitats were compiled in the most recent report, "Priority Vulnerable Species Data Compilation," which includes literature and existing mapped locations for each of the 56 vulnerable species, together with general habitat potential maps developed as part of the GAP Analysis Program (GAP) where these maps exist.

One of the goals of the habitat analysis was to use information in the vulnerable species report to develop a summary of habitat characteristics for each of the 56 priority vulnerable species. This summary is compiled in the form of a species-environment matrix where each characteristic (i.e., mixed grass-scrub) of a variable (i.e., vegetation) is valued from low to high (1-3) for each species. Variables investigated include vegetation, hydrology, topography, and cave/mine potential. Characteristics of these variables are well understood for some species (such as a fish requiring a perennial stream), but many are not. In some cases, a "best guess" was recorded in the table cells of the species-environment matrix. The summary matrix is provided as an appendix in this report.

The second goal of the habitat data analysis was to use habitat values in the species-environment matrix to develop maps of the distribution of potential habitat for each species using geographic information system (GIS) grid modeling techniques. The valued habitat characteristics in the species-environment matrix served as model parameters for the draft habitat distribution models presented in this report. In a sense, the GIS is being used to predict potential habitat for each species based on the distribution of multiple habitat characteristics. However, we are in an exploratory phase of the habitat mapping process. The "predictions" made as to the distribution of species and their habitats in this analysis represent a first draft of potential distribution maps. More valuable perhaps than the maps resulting from these first models are the methods that have been developed in the process. These modeling methods will enable us to revise and refine species mapping by incorporating all geographic data and expert knowledge that becomes available, in an efficient and systematic manner. A discussion of the feasibility of using GIS is included together with conclusions and recommendations in this report.

For each species, important habitat characteristics are briefly described, followed by a description of model parameters, a map of the model results, and an assessment of the map including recommendations for improving the model. These species analyses follow a brief discussion of the species-environment matrix and GIS modeling methods.

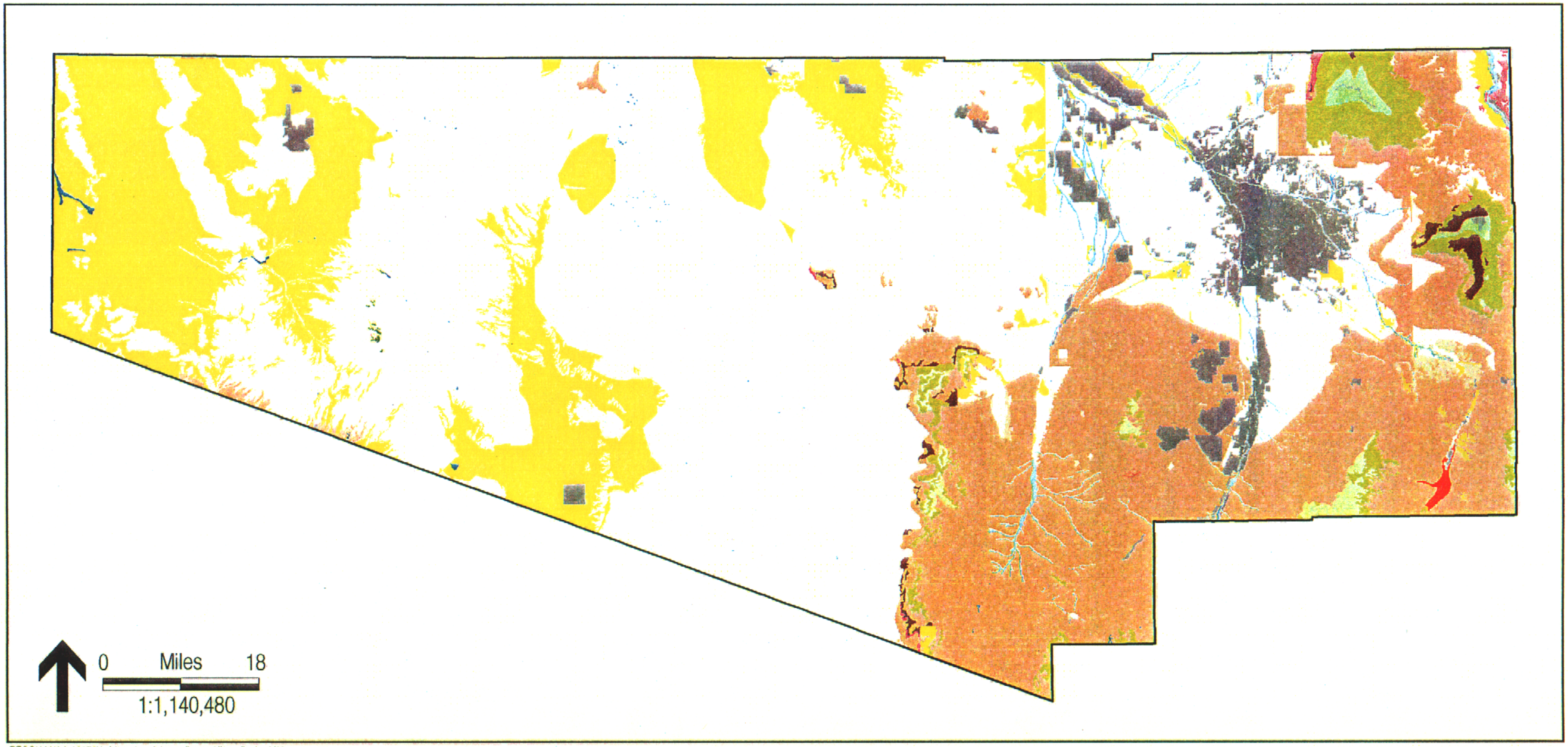
II. Species-Environment Matrix

Environmental variables included in this study are a combination of those that are most important for describing species' habitats and those that were available as GIS data. The most important environmental variables are available but mapping still needs to be improved, such as vegetation/land cover. Other variables, such as mine and cave locations, did not exist in a GIS, so a surrogate variable—carbonates—was developed and used in habitat analysis. In some cases, surrogates did not exist and the variable is not included in the analysis, such as the location of particular species like agaves.

Each variable is divided into multiple categories such as vegetation community types, elevation ranges, and hydrologic features. These categories or variable characteristics appear as columns in the species-environment matrix (Appendix A). Vulnerable species appear as rows in the matrix. For each species, all variable characteristics were scored 0-3 or "Mask" according to the value of that characteristic in defining suitable habitat in Pima County. A score of 0 was used to represent unsuitable habitat, where a species is not likely to occur. A score of 1 was used to represent low value potential habitat, where a species may occur but is not common. A score of 2 was used to represent medium value potential habitat, where a species is likely to occur. A score of 3 was used to represent high value potential habitat, where a species is most likely to occur. Characteristics representing unsuitable habitat that is a barrier to species were scored as "Mask" rather than 0. Mask areas are those that would make it impossible for a species to occur (such as upland areas for fish) and are therefore eliminated or "masked" from the analysis. Mask areas in one variable are considered unsuitable habitat in the final calculations, even if other variable characteristics are associated with suitable habitat. For example, the western yellow-billed cuckoo (*Coccyzus americanus occidentalis*) prefers riparian vegetation communities, so cottonwood-willow and mixed broadleaf vegetation types receive a score of 3 for high suitability. The western yellow-billed cuckoo may often use grassland vegetation and occasionally use shrub vegetation, so the mixed grass-scrub characteristic receives a score of 2 for medium suitability, and the shrub-scrub disclimax characteristic receives a score of 1 for low suitability. Vegetation characteristics that describe unsuitable habitat for the western yellow-billed cuckoo, such as saltbush, receive a score of 0. Characteristics that would prevent the western yellow-billed cuckoo from occupying an area include high elevation areas. Elevation categories from 1800 to 2800 are marked as "Mask" in the matrix and eliminated from the area of potential habitat in the analysis.

A. Vegetation

The vegetation variable contains 29 characteristics including vegetation communities and other land cover types (i.e., agriculture, urban) illustrated in Figure 1. Vegetation communities are based on the series-level Brown, Lowe, and Pase vegetation classification system. Other land cover types are based on GAP land cover classification. The vegetation data layer used for these analyses is a slightly modified version of the composite land cover developed for and described in the land cover data assessment report, March 2000. Conversion of this data layer to a grid with 308-meter cell resolution resulted in the loss of some detail. Some riparian areas, particularly those mapped as part of the Wildlife Habitat Inventory Project (WHIP) study, are as narrow as 30 meters. In order to capture this detail, cell size would need to be reduced to 30 meters or smaller. This can be done in the next phase of analysis; however, using 30-meter rather than 100-meter grid cells will require intensive processing.



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Habitat Modeling Variable: Vegetation

Vegetation Communities
(Composite Land Cover Map, RECON, June 2000)

122.41 Pinyon-Juniper
122.61 Douglas-Fir-Mixed Conifer
122.62 Pine
123.31 Encinal (Oak)
123.32 Oak-Pine
124.71 Mesquite
133.32 Manzanita
133.36 Mixed Evergreen Sclerophyll
143.14 Sacatan-Scrub
143.15 Mixed Grass-Scrub
143.16 Shrub-Scrub Disclimax
153.21 Creosotebush-Tarbush
153.26 Mixed Scrub
154.11 Creosote-Bursage
154.12 Paloverde-Mixed Cacti
154.17 Saltbush
223.21 Cottonwood-Willow
223.22 Mixed Broadleaf
224.52 Mesquite
224.53 Cottonwood-Willow
234.71 Mixed Scrub
244.71 Cattail
244.75 Saltgrass

Other Land Cover Types

999.0 Unclassified
999.1 Agriculture
999.2 Urban
999.3 Water
999.4 Bare Ground

Figure 1

B. Hydrology

The hydrology variable contains fields for hydrologic features as well as the land adjacent to these features. Perennial streams, intermittent streams, shallow groundwater, and springs are each represented by different GIS data layers. Upon inspection of known location data and possible associations with species habitat, adjacent habitat categories were added including area within one-half mile of intermittent streams, area within one mile of intermittent streams, area within one-half mile of perennial streams, area within one mile of perennial streams, area within greater than five miles of perennial streams, and area within one-half mile of springs. Stream and shallow groundwater coverages were obtained from the Pima Association of Governments, springs were obtained from Pima County Department of Transportation Technical Services, and adjacent habitat data layers were created by RECON. These are shown in Figure 2.

C. Topography

Many habitat characteristics can be attributed to topography or landform. Topographic data contains information about how high a place is relative to sea level, how steeply sloped or flat the land is, and which direction a slope faces. All of these determine in part biophysical variables such as air temperature, precipitation, solar insolation, and soil moisture, which directly affect the distribution of vegetation and species habitats. For this reason, topography is a critical component of habitat modeling. Three topographic environmental variables were considered in this analysis—elevation, slope, and aspect—all of which were derived from USGS Digital Elevation Model (DEM) data.

1. Elevation

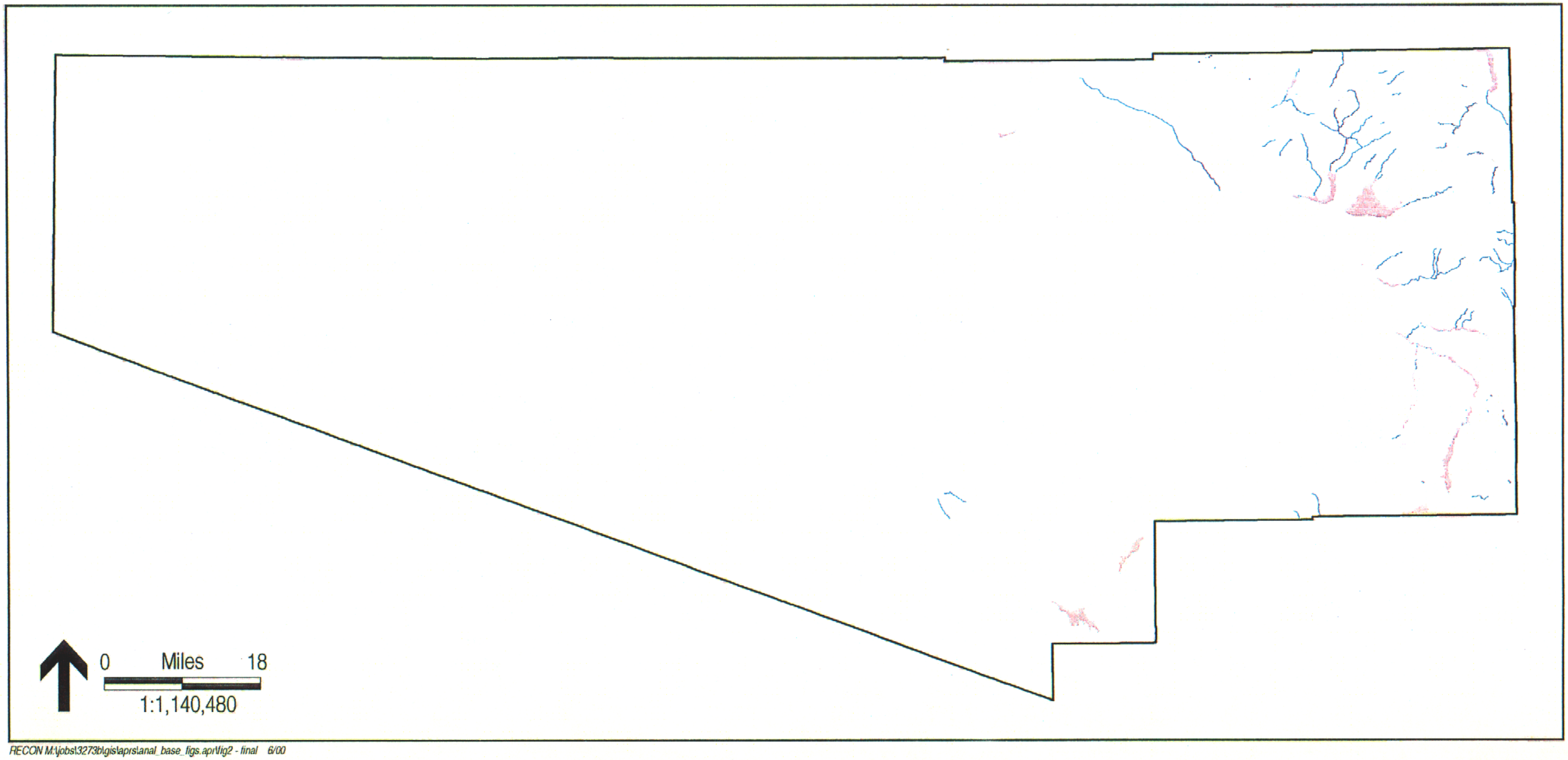
The elevation variable is divided into 200-meter increments for the full range of elevation represented in Pima County—about 300 meters to 2800 meters above mean sea level (Figure 3). Two hundred meters is an appropriate range for scoring habitat for most species, although 100-meter increments would refine the model for some species.

2. Slope

The slope variable was originally divided into one category for every one degree of slope. However, species' preferences or habitat suitability was not known at this fine scale. So qualitative slope categories—flat, moderate, and steep—were valued for species (Figure 4). Based on default slope classification break points and the distribution of known locations of species, a pattern emerged that caused us to expand this classification. It appears that many species are located on flat or gently sloped land within a relatively short distance of moderate to steep slopes. Therefore, categories of flat land within one-half mile and two miles of moderate to steep slopes were added as characteristics to the slope variable.

3. Aspect

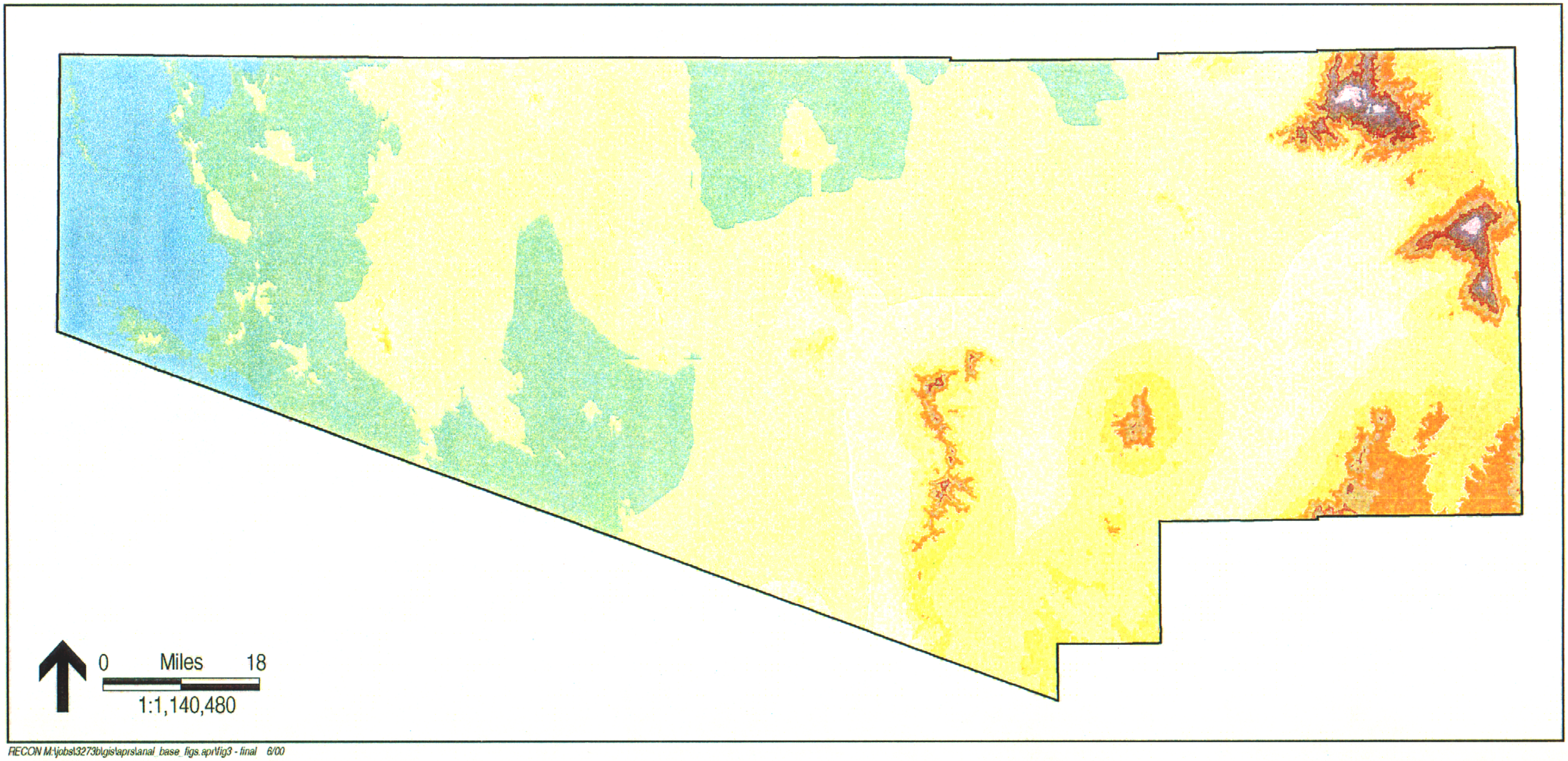
Aspect may be important for a few species and was assessed for only those species with known location data. Where known location data appeared to be correlated with aspect on inspection of map overlays, aspect characteristics were valued accordingly for that species. Aspect categories are flat, north, northeast, east, southeast, south, southwest, west, and northwest (Figure 5).



Habitat Modeling Variable: Hydrology

- Shallow Groundwater (PAG, January 2000)
- Perrenial Streams (PAG, January 2000)
- Intermittent Streams (PAG, January 2000)
- Springs (Pima County DOT Technical Services)

Figure 2

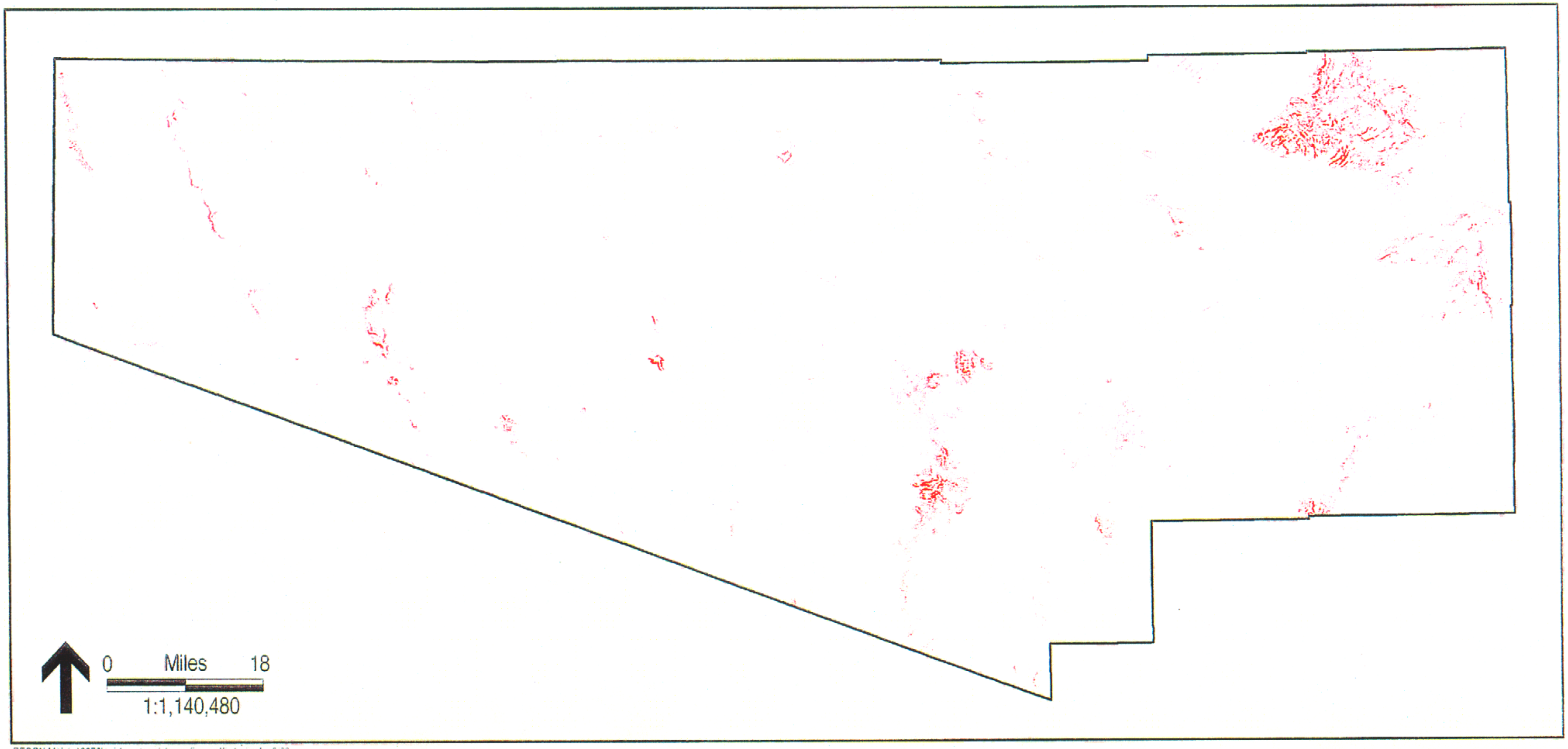


Habitat Modeling Variable: Elevation

Elevation Above Mean Sea Level (in meters)
(USGS DEM)

- 195-400
- 401-600
- 601-800
- 801-1,000
- 1,001-1,200
- 1,201-1,400
- 1,401-1,600
- 1,601-1,800
- 1,801-2,000
- 2,001-2,200
- 2,201-2,400
- 2,401-2,600
- 2,601-2,800

Figure 3

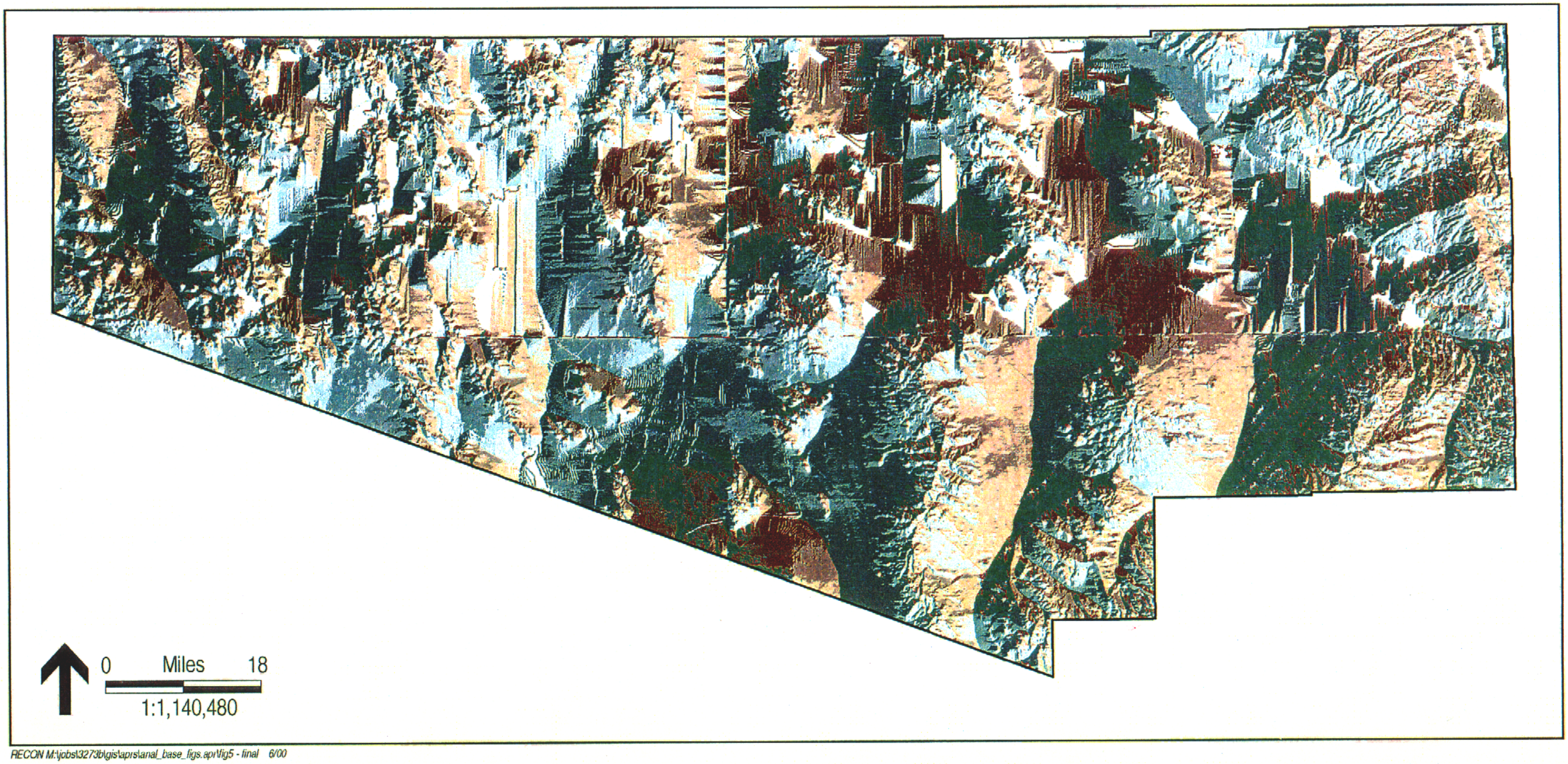


Habitat Modeling Variable: Slope

Slope Classes
(USGS DEM)

- Low
- Medium
- High

Figure 4



Habitat Modeling Variable: Aspect

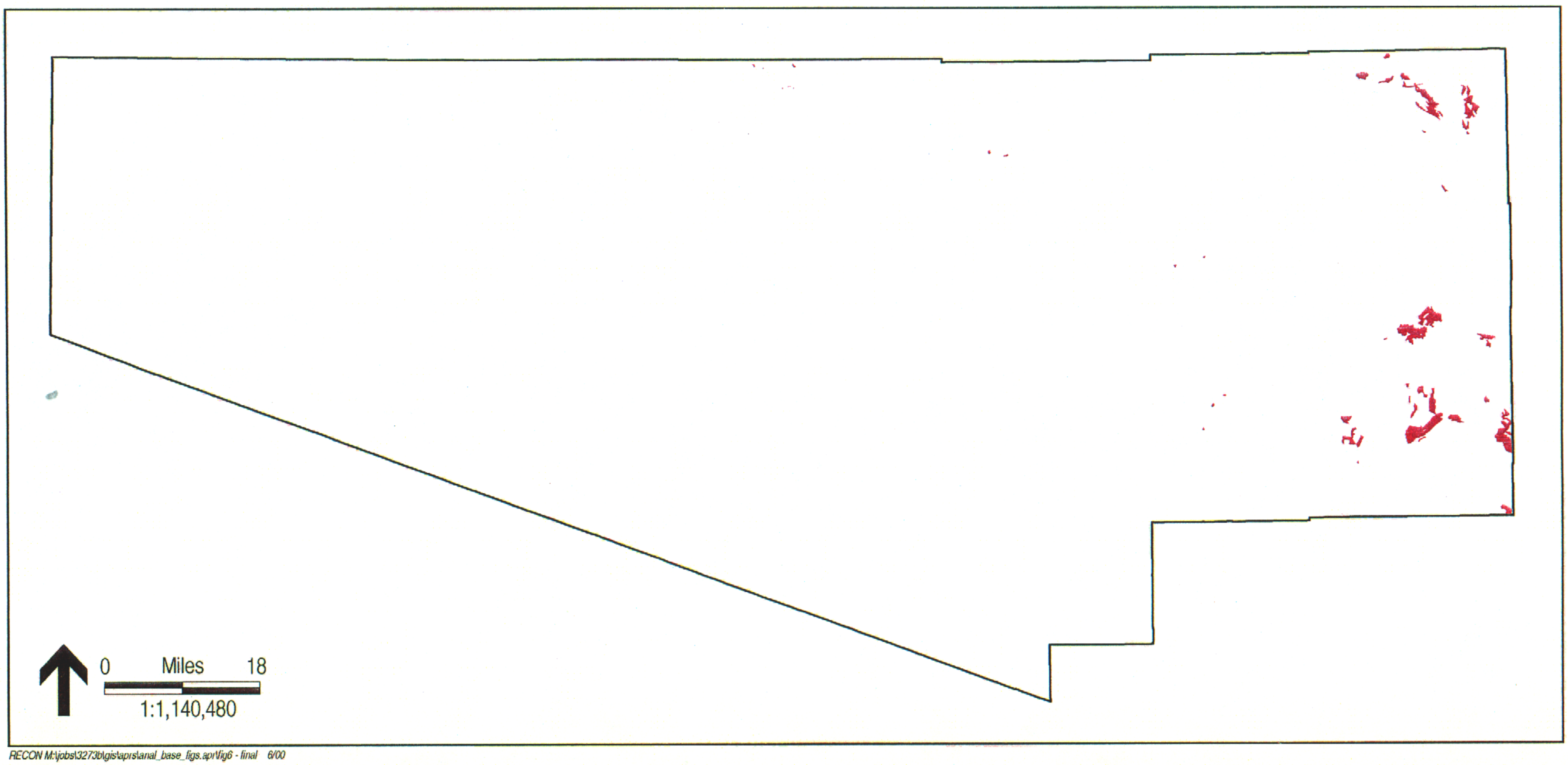
Slope Aspect
(USGS DEM)

- Flat
- North
- Northeast
- East
- Southeast
- South
- Southwest
- West
- Northwest

Figure 5

D. Cave and Mine Potential

Several priority vulnerable bat species require mines and caves for roosting, so this variable is included in habitat models. Currently, mine and cave locations are not available in GIS, so a carbonates GIS layer is used as a surrogate variable. This layer was combined from two USGS coverages of carbonate geology mapped at 1:250,000 scale and 1:500,000 scale (Figure 6). The carbonate units represented by this combined coverage represent those which were prioritized for conservation due to their age, physical structure, and/or association with certain plants and animals by The Nature Conservancy (TNC) Sonoran Desert experts workshop in 1999 (Fonseca, pers. comm. 6/2/00). These units do not represent all carbonates in the county, nor do they represent particular carbonate areas with a high degree of accuracy. Fonseca (pers. comm. 6/2/00) notes that the two coverages represent slightly different areas that express uncertainty about the exact areas of carbonates better than either one separately; therefore, the two coverages are used together in the habitat models.



Habitat Modeling Variable: Carbonates

Carbonate Geology
(USGS combined coverages, 1:250,000 scale and 1:500,500 scale)

Carbonates

Figure 6

III. GIS Modeling Methods

The species-environment matrix summarizes model parameters for each of the environmental variables that comprise priority vulnerable species habitat. Each variable exists as a data layer covering the entire county and is comprised of a regular grid of cells 308 meters on a side. (The cell size was determined by the DEM layer.) Habitat scores for species are stored in an attribute named "value" for each cell within a grid. Grids that comprise habitat for a species are then overlaid. In the GIS this means they are literally "stacked" on top of one another. Grid cells line up so that when grids are summed, stacks of grid cell values are summed across the extent of Pima County. The result is a new grid that represents a summary of habitat scores for a given species.

Cells in the summary grid that have low values represent areas that have low habitat suitability, while cells with high values represent high habitat suitability. It is important to note that one or more variables may be responsible for low habitat scores. For example, an overall habitat score of 3 in a particular cell may be derived from elevation, slope, and vegetation characteristics that each score 1 (1 + 1 + 1 = 3). Alternatively, an overall habitat score of 3 may be derived from elevation and slope scores of 0 and a vegetation score of 3 (0 + 0 + 3 = 3). For this reason it is important to choose only the variables most appropriate to describing habitat for the species in question. A more refined model would also investigate whether or not it is important to weight variables relative to one another. In the example above, vegetation may be the critical factor in determining suitable habitat for the species in question. If this is the case, the second scenario (where vegetation scored very high) should be considered more highly suitable habitat than the first (where vegetation scored low). This can be incorporated into the model by using a multiplier on the vegetation variable. If vegetation were twice as important as elevation and slope in determining suitable habitat, then the summary grid cell in the first scenario would be 4 (1 + 1 + 2). The summary grid cell in the second scenario would be 6 (0 + 0 + 6). By incorporating a multiplier on certain variables, the summary grid representing habitat suitability is largely determined by the critical factors of habitat.

IV. Species Potential Habitat Models and Data Analysis

A. Introduction

This section of the report discusses each of the priority vulnerable species in terms of important habitat characteristics, habitat model parameters, an assessment of the resulting map, and recommendations for improving the model. A map of modeled potential habitat follows the discussion for each species. The matrix summarizing the parameters modeled for each species is found in Appendix A.

B. Species Analysis

1. Mexican long-tongued bat (*Choeronycteris mexicana*)

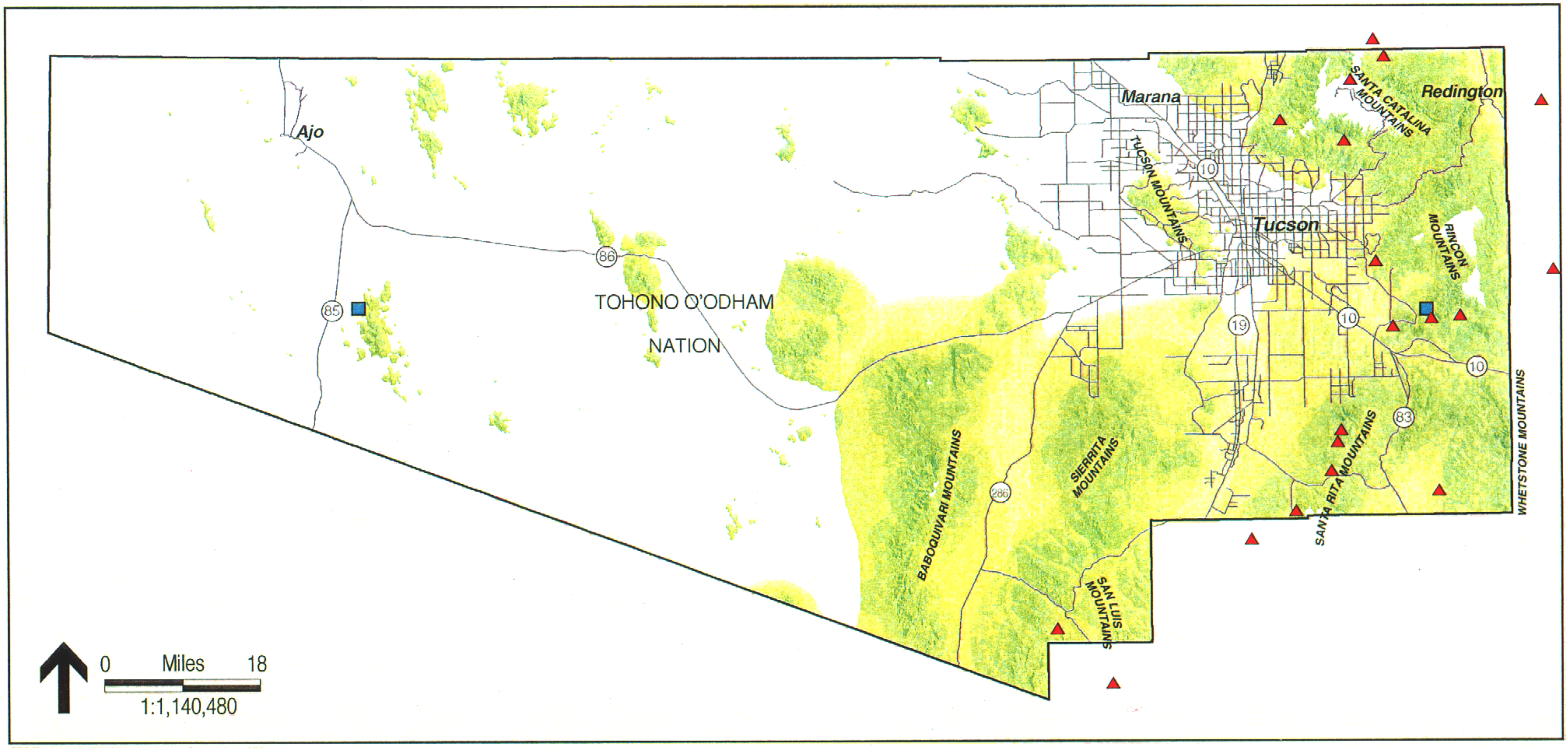
This species requires a cave or mine for roosting, feeds on nectar and pollen, and does not require water. Known food sources include agaves and saguaros but may also include any of the abundant nectar resources found in Pima County. The Mexican long-tongued bat is known from the canyons of mixed oak-conifer forests in mountain ranges surrounded by desert. This bat is known to roost at Colossal Cave Mountain Park, is expected in the Rincon Mountains, and has recently been found at Organ Pipe Cactus National Monument.

These habitat characteristics are primarily described by landform and vegetation variables. Elevation ranges of potential habitat for the Mexican long-tongued bat are 800 to 2000 meters, with the majority of HDMS and SWCA known locations in the 1000- to 1300-meter range. Habitat is associated with mountain ranges, which is best-defined by moderate to steep slopes in the GIS data set. Known locations also appear to be strongly associated with aspect, with almost all known location data points occurring on west- and southwest-facing slopes. Aspect is not known to be an important component of habitat for this species, but it may be coincident with other important habitat features. Due to its strong association with known locations, aspect is included in the model. The carbonates data layer is also highly valued and included in the model for this species since it is associated with mines and caves. Mexican long-tongued bat likely inhabits oak and oak-pine forests but may also occur in pine communities at higher elevations. This species may also occur in manzanita, mixed evergreen sclerophyll, and paloverde-mixed cacti. Many HDMS records are located in mixed grass-scrub and some in sacaton-scrub, but these occurrences may be coincident with other variables such as roost site, since these vegetation types are expected to be lower value habitat. These vegetation types are scored as low value since the areas they cover are already moderately valued in the elevation variable.

Habitat characteristics for Mexican long-tongued bat are scored in data layers for each variable then summed as follows:

Elevation + Slope + Aspect + Carbonates + Vegetation = Potential Habitat

Potential habitat is shown in Figure 7. The habitat model for Mexican long-tongued bat does a good job of identifying areas where these bats are known or expected. Large areas of moderate and high potential habitat are located in the Santa Catalina Mountains, Colossal Cave Mountain Park, the Santa Rita Mountains, and the Sierrita Mountains where there are known locations. Other moderate and high potential habitat areas include the San Pedro side of the Catalinas, the Rincon Mountains, the eastern end of the Santa Ritas in the Empire-Cienega Resource



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Mexican Long-tongued Bat *(Choeronycteris mexicana)* Modeled Potential Habitat

Pima County Boundary

Major Road or Highway

Modeled Potential Habitat (RECON, June 2000)

No Potential

Low Potential

Medium Potential

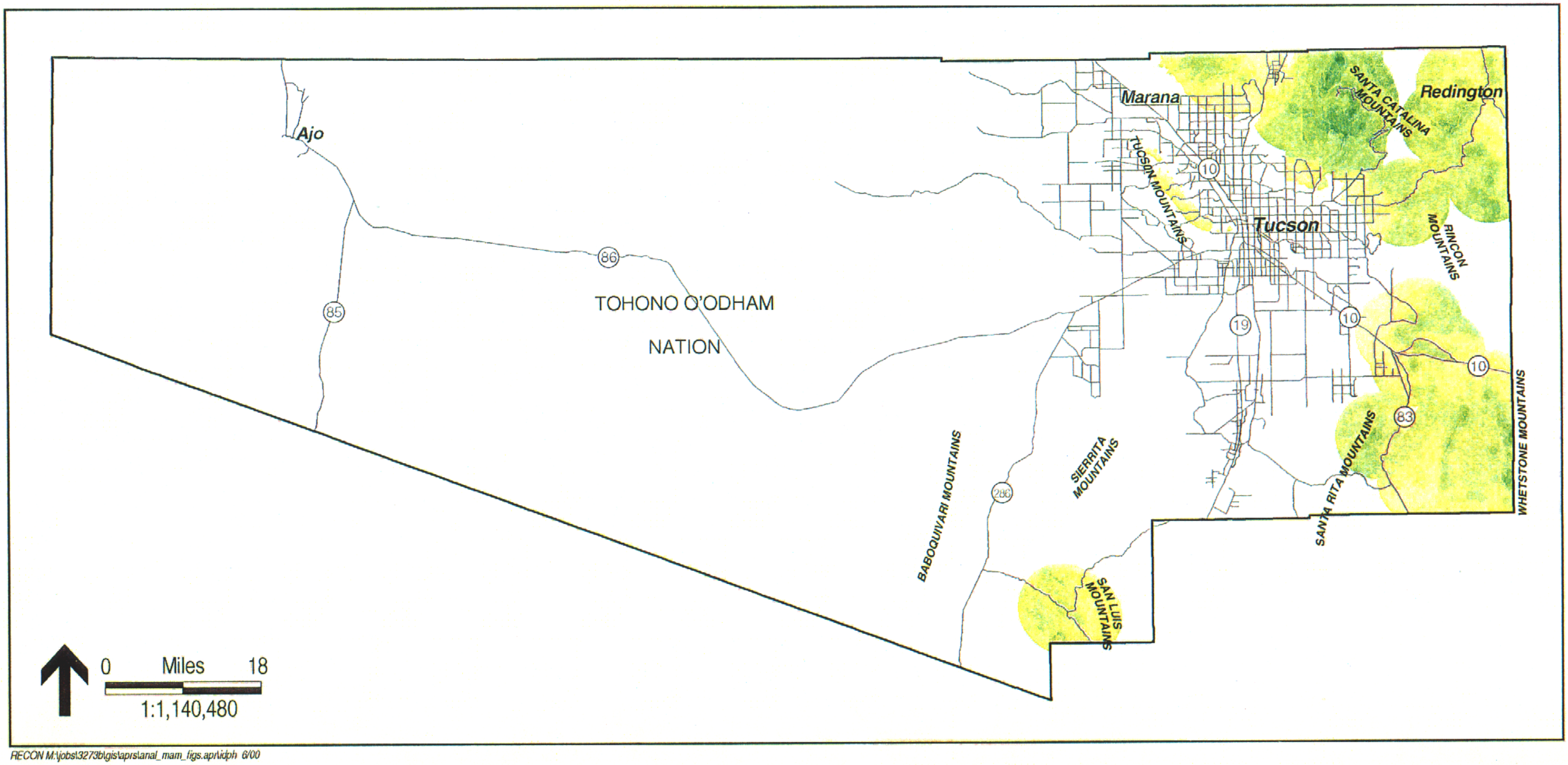
High Potential

Known Locations

(SWCA, 2000)

(HDMS, 2000)

Figure 7



Allen's Big-eared Bat *(Idionycteris phyllotis)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat (RECON, June 2000)
- No Potential
- Low Potential
- Medium Potential
- High Potential

Figure 8

and Rincon Creek areas. The Rincon Mountains, Baboquivari Mountains, and the Sierrita Ranch area are classified as no habitat since they are far from perennial water sources. Organ Pipe Cactus National Monument is classified as no habitat due to low elevation and distance to water.

Areas of predicted habitat are more broadly distributed than the probable range of this species since specific habitat requirements are not well understood for this species and some variables are not very well mapped. An improved model would include better mapping of mines, caves, and water since these are all critical habitat elements for Allen's big-eared bat. Research on proximity to water required by this species would also help improve the habitat model.

3. Western red bat (*Lasiurus blossevillii*)

The western red bat has been found to occur in walnuts, sycamores, and cottonwoods along riparian corridors at middle elevations in central and southeastern Pima County. They are known to roost in cottonwood trees and several other leafy tree and shrub species and forage up to 1000 meters from roost sites. Western red bats are thought to migrate along river and stream valleys with riparian deciduous woodland vegetation.

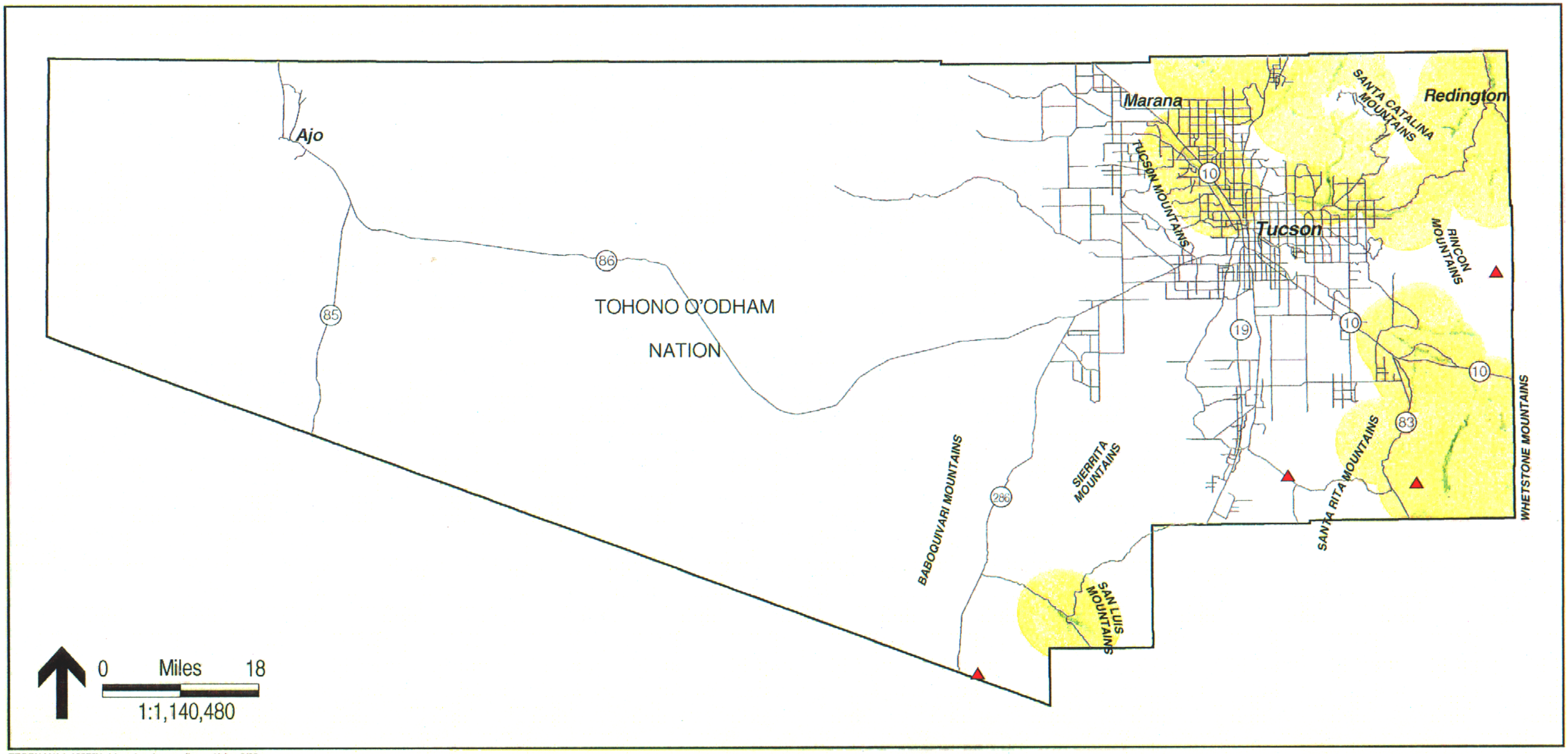
The potential distribution for this species is primarily influenced by vegetation and hydrology variables, together with elevation and slope. Cottonwood willow and mixed broadleaf communities provide the highest value habitat for the western red bat. Mesquite and agriculture are included as low value habitat since these may be used where they occur in or adjacent to an occupied riparian corridor. The four locations mapped in Pima County do not appear to occur in riparian habitats—presumably because riparian communities are not well mapped at present. It is unclear whether this species requires streams or habitat adjacent to streams. Both are valued in the model, along with shallow groundwater that is associated with riparian habitat. Springs are valued as habitat wherever they fall near a riparian corridor. Western red bats are known to occur at mid elevations, from 600 to 2200 meters. Known locations in Pima County occur at elevations from 1000 to 1300 meters, but this cannot be considered significant since there are so few observations. Habitat for the western red bat is situated in flat or gently sloped areas along drainages.

Habitat characteristics for western red bat are scored in data layers for each variable then summed as follows:

> Elevation + Slope + Perennial Streams + Intermittent Streams + Springs + Shallow Groundwater + Vegetation = Potential Habitat

Potential habitat is shown in Figure 9. The habitat model for western red bat shows narrow bands of potential habitat along riparian corridors in eastern Pima County. Larger areas of moderate potential habitat include Sutherland Wash, Canada del Oro, and Tanque Verde Creek. Modeled high potential habitat occurs along San Pedro River, Sabino Creek, Rincon Creek, Cienega Creek, and Arivaca Creek.

Areas of predicted habitat are close to what would be qualitatively assessed for this riparian-dependent species. A better understanding of the vegetation communities this species uses would help refine potential habitat. For example, this species may use urban trees, but this has not been documented. Improved riparian mapping will also provide a better basis for habitat modeling. Research should also be conducted on the water requirements of this species. Is



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Western Red Bat *(Lasiuris blossevillii)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
▲ (HDMS, 2000)

Figure 9

water a critical element of habitat on its own or does water simply dictate the distribution of riparian habitat, which is the real critical factor? Additional information on migratory habitat would also help improve the picture of the distribution of western red bat in Pima County. Based on the current modeled distribution, where potential habitat is disconnected, it is unclear how individuals might move through the county. The role of slope in determining habitat for the western red bat should also be examined. Moderate to steep slopes reduced the value of habitat in some areas of the Catalinas, and this may not be an accurate picture of potential distribution for this species.

4. Western yellow bat (*Lasiurus xanthinus = ega*)

This bat roosts in palm trees and riparian deciduous trees. They have been netted above water holes, but it is not clear whether they were drinking or foraging. The western yellow bat is a tropical species whose range barely extends northward into the U.S. It is thought to be increasing, primarily in urban areas where it uses planted fan palms. It is also possible that this species has declined in the Tucson valley as a result of historic loss of riparian woodland and that the population has shifted to palm trees in the absence of riparian deciduous trees.

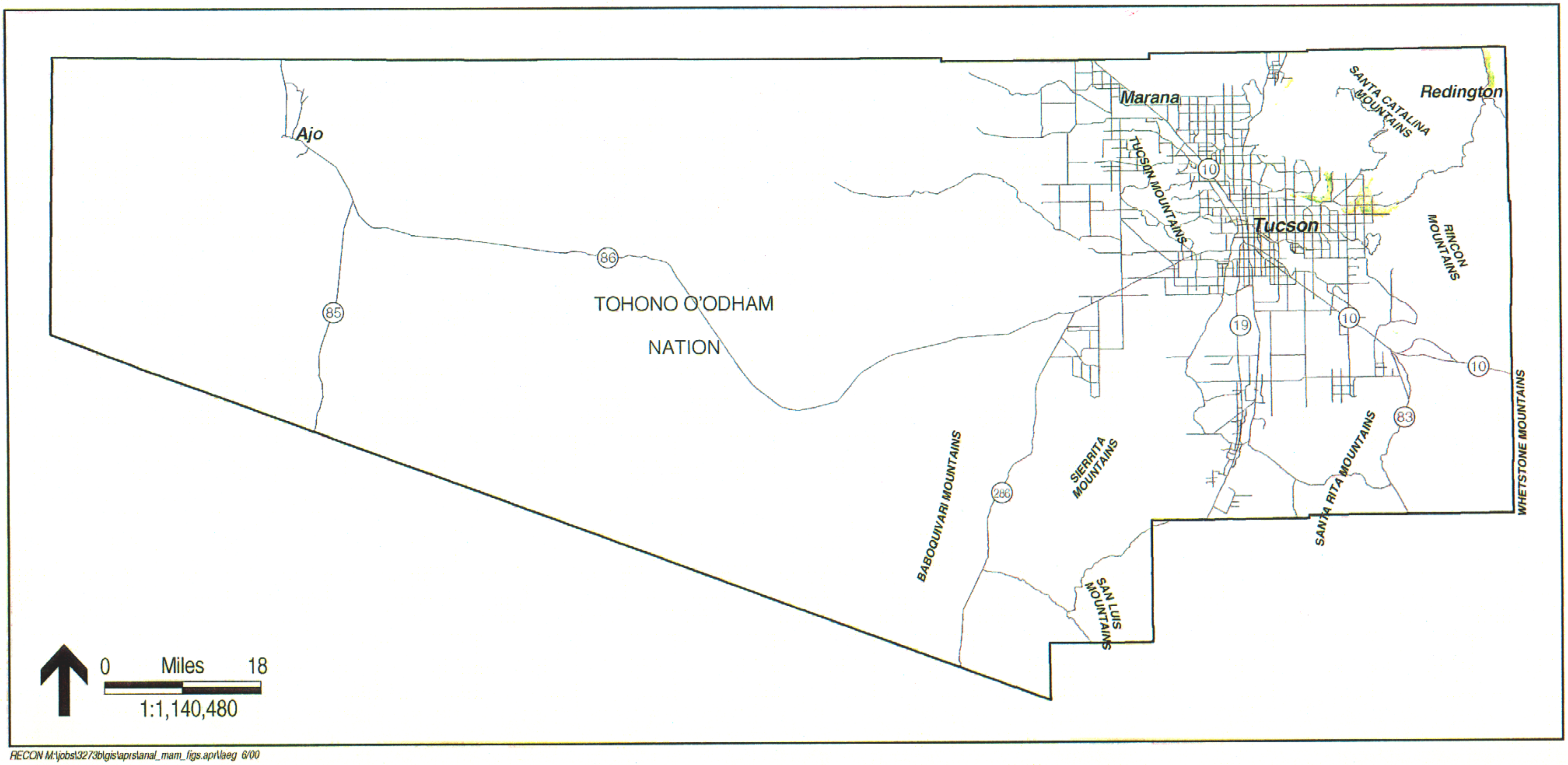
Vegetation is the key variable that dictates the distribution of western yellow bats. Urban areas are assigned a medium habitat value since this species is known to occur here. Cottonwood willow and mixed broadleaf communities are also valued as medium potential habitat. Other communities associated with riparian areas, agriculture, and mesquite are assigned a low habitat value. Hydrologic variables are also important since this species is known to use adjacent habitat and may also require water. Areas inside and close to perennial and intermittent streams, springs, and shallow groundwater are valued as potential habitat. Elevation and slope may be important for this species since it is thought to inhabit only lowland valleys.

Habitat characteristics for western yellow bat are scored in data layers for each variable then summed as follows:

> Elevation + Slope + Perennial Streams + Intermittent Streams + Springs + Shallow Groundwater + Vegetation = Potential Habitat

Potential habitat is shown in Figure 10. The habitat model for western yellow bat shows narrow bands of potential habitat along riparian corridors in eastern Pima County, but only in lower elevation areas. Potential habitat for the western yellow bat includes most of the same riparian corridors as those shown for western red bat, except that the higher elevation headwaters of Sabino Creek and Cienega Creek are excluded and portions of the Santa Cruz River are included in western yellow bat habitat. Large urban areas are also shown as habitat for the western yellow bat.

Because this species is rare and largely unrecorded for Pima County, it is difficult to evaluate how well this model predicts habitat. The model does predict habitat at Colossal Cave, where the species is expected to occur. The model does not differentiate Agua Caliente Park, another predicted locale, from the surrounding urban area. It is likely that riparian areas shown are potential habitat; however, they may all be low value. The entire Tucson metropolitan area is valued as medium potential habitat, which is misleading. A better model would show high value in low density residential and parks only and low value elsewhere in the metropolitan area.



Western Yellow Bat *(Lasiuris ega)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
- No Potential
- Low Potential
- Medium Potential
- High Potential

Figure 10

These urban classes will be added to land cover in the next phase of work and could be used in a revised model. Improved riparian mapping and an improved understanding of the importance of water for this species could also be used to refine the habitat model.

5. Lesser long-nosed bat (*Leptonycteris curasoae yerbabuena*)

This migratory bat species only comes into the U.S. in the spring, and it depends on mines and caves for roosting and organ pipe cactus, agaves, and saguaros for feeding. While caves and especially abandoned mines are a critical component of habitat, only a few are known to be used. An abandoned adit in Copper Mountain, in Organ Pipe Cactus National Monument, houses the largest known maternity roost in North America. Elevation range (hence vegetation community) is seasonally dependent. In addition to feeding on flower nectar, lesser long-nosed bats also use hummingbird feeders in suburban areas.

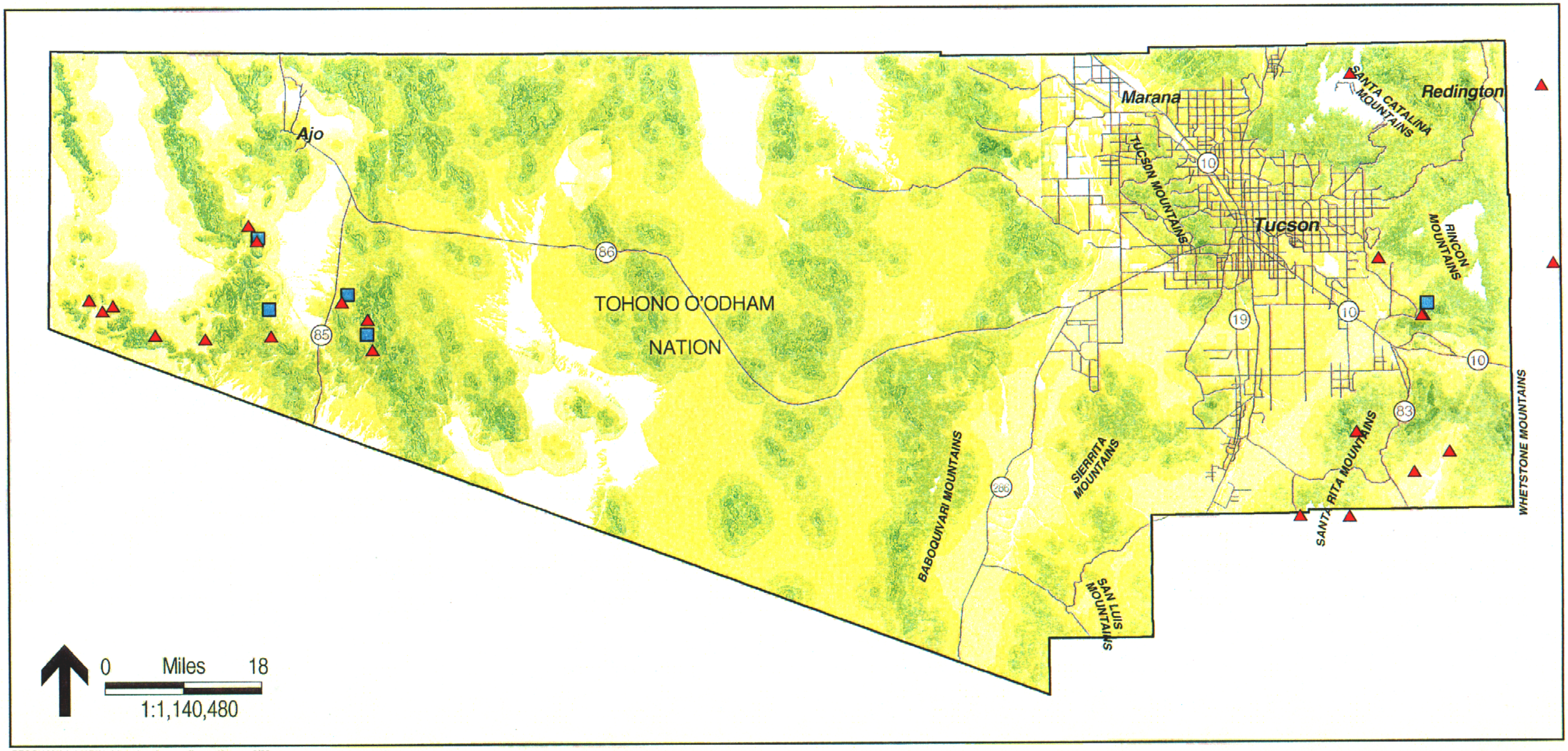
These habitat characteristics are described by landform and vegetation variables. Elevation ranges from 200 to 2000 meters for this species, depending on the season. Caves and abandoned mines are associated with moderate to steep slopes in mountain ranges and carbonate substrates, both of which are valued as potential habitat in the model. Higher elevation vegetation communities, including pinyon-juniper, pine, oak, oak-pine, and manzanita, as well as lower elevation types—mixed evergreen sclerophyll, mixed grass-scrub, and shrub-scrub disclimax—all comprise suitable but low value habitat for the lesser long-nosed bat. Paloverde-mixed cacti and urban areas comprise medium value habitat.

Habitat characteristics for lesser long-nosed bat are scored in data layers for each variable then summed as follows:

Elevation + Slope + Carbonates + Vegetation = Potential Habitat

Potential habitat is shown in Figure 11. The model for this bat species does predict medium and high potential habitat for most of the areas from which this species is known, including Cabeza Prieta National Wildlife Refuge, Organ Pipe Cactus National Monument, several locations in the Santa Rita and Santa Catalina Mountains, Colossal Cave, and Saguaro National Park East. Many other areas are also predicted as potential habitat by this model. With the wide range of elevations and vegetation communities used by this species, many more areas in the county appear to be habitat for this species that do not appear in modeled habitat for the other nectivorous species—Mexican long-tongued bat. High potential habitat is predicted in the Santa Rita experimental range and Colossal Cave where this species is known. High potential habitat is also predicted for the Cienega Creek side of the Santa Rita Mountains and the San Pedro River side of the Santa Catalina Mountains where this species has no mapped locations. Low potential habitat is predicted for two-thirds of the county.

An improved model would include better mapping for mines and caves. The slope and carbonates variables do a poor job of predicting these locations at lower elevations throughout the county. Areas predicted as high potential where mapped locations do not exist should be further investigated. If it is concluded that these are not high potential habitat, then variables discriminating these areas should be researched and incorporated into the model. Mapped distribution of agaves and saguaros as well as additional information on the geography of foraging behavior would also help better define habitat away from roosts. Further investigation should also include the influence of urban areas on this species. If hummingbird feeders are determined to be an important resource for the lesser long-nosed bat, certain types of urban



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Lesser Long-nosed Bat *(Leptonycteris curasoae yerbabuenae)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(SWCA, 2000)
(HDMS, 2000)

Figure 11

areas such as low density residential should be more highly valued than other urban types in an improved land cover data layer. Additional environmental associations may be further investigated by acquiring and mapping other known location data. Cockrum and Petryszyn (1991) compiled all the known records of the species for the northwestern portion of its range, including Pima County, which could be incorporated into a GIS data layer.

6. California leaf-nosed bat (*Macrotus californicus*)

This species is known from caves, mines, and rock shelters, mostly in Sonoran desert scrub. This species is well adapted to the desert and forages for insects primarily along washes. This species' need for water is not clearly understood; however, it is occasionally found over water where it may be drinking or foraging. Known locations in Pima County include occurrences at Tucson Mountain Park, Colossal Cave Mountain Park, Coronado National Forest, Organ Pipe Cactus National Monument, and Cabeza Prieta National Wildlife Refuge.

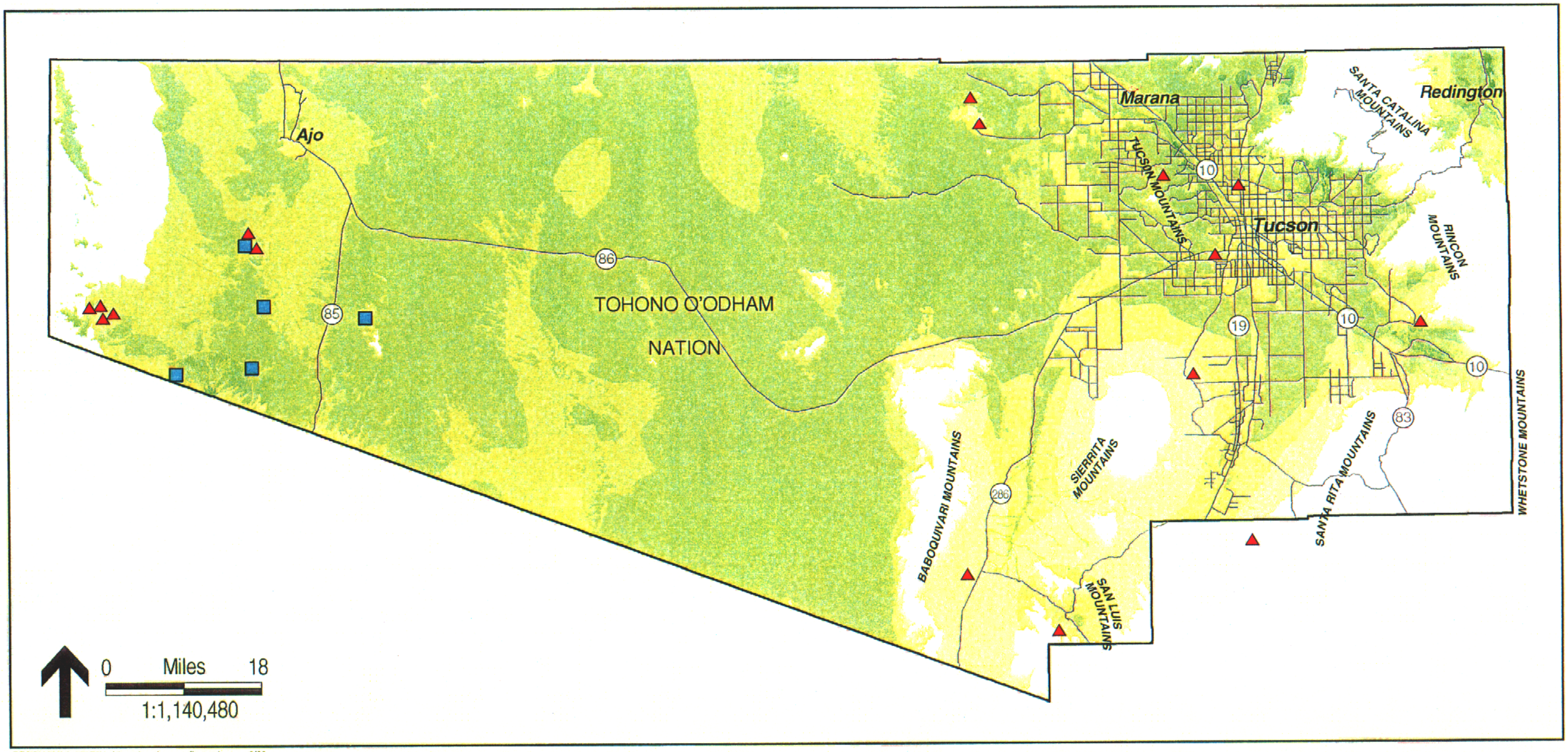
The habitat characteristics are primarily described by landform, hydrology, and vegetation variables. Elevation ranges of potential habitat for the California leaf-nosed bat range from 195 to 1400 meters, with the majority of HDMS and SWCA known locations in the 200- to 1000-meter range. Potential areas for mines and caves are best represented in the current data sets by slope and carbonates data layers. Important hydrology layers include perennial streams, intermittent streams, and springs. Based on known associations with vegetation communities, land cover types that are most likely to provide habitat for the California leaf-nosed bat include creosote-bursage, paloverde-mixed cacti, creosotebush-tarbush, and mixed scrub. Other low value types include shrub-scrub disclimax, mixed evergreen sclerophyll, encinal (oak), and mixed grass-scrub.

Habitat characteristics of California leaf-nosed bat are scored in data layers for each variable then summed as follows:

> Elevation + Perennial Streams + Intermittent Streams + Springs + Vegetation = Potential Habitat

Potential habitat for the California leaf-nosed bat is shown in Figure 12. The model for this bat species does predict medium and high potential habitat for most of the areas from which this species is known. Other areas predicted as higher potential habitat by this model include areas near washes in Tortolita fan, Tanque Verde Creek, Rincon and Cienega Creeks, the San Pedro River valley, and Green Valley along the Santa Cruz River. Low to medium potential habitat is predicted throughout Sonoran desert scrub vegetation communities.

The model may overpredict habitat along watercourses, some of which may not be suitable. A better model would appropriately value hydrology and adjacent habitat variables based on a better understanding of this species' requirement for water. An improved model would also include better mapping for mines, caves, and rock shelters that are critical components of habitat for the leaf-nosed bat. The slope and carbonates variables do a poor job of predicting these locations, especially at lower elevations throughout the county. These variables were included in an earlier model but were removed since they appeared to skew model results.



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California Leaf-nosed Bat *(Macrotus californicus)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat (RECON, June 2000)
- No Potential
- Low Potential
- Medium Potential
- High Potential

Known Locations
- (SWCA, 2000)
- (HDMS, 2000)

Figure 12

7. Merriam's mouse (*Peromyscus merriami*)

This species depends on riparian woodland and dense mesquite forests including mesquite bosques and thick stands of cholla, prickly pear, paloverde, and grasses. Although there is no specific information regarding home range requirements or foraging behavior, it is believed that this species is dependent on large mesquites and may also require a mixture of other plants such as cacti, paloverde, and grasses. This species could potentially exist in mesquite bosques that are present in Organ Pipe Cactus National Monument, Saguaro National Park, Buenos Aires National Wildlife Refuge, Empire-Cienega Natural Resource Conservation Area, Coronado National Forest, Cienega Creek County Preserve, and Colossal Cave County Park.

The habitat characteristics are described by landform, hydrology, and vegetation variables. Elevation ranges of potential habitat for Merriam's mouse are between 0 and 1400 meters, with the majority of SWCA known locations in the 800- to 1200-meter range. The important hydrology layer is shallow groundwater. Based on known associations with vegetation communities, land cover types that are most likely to provide habitat for this species include paloverde mixed-cacti, mesquite, and mixed scrub. The important slope and landform variables are flat areas with valley fill.

Habitat characteristics of Merriam's mouse are scored in data layers for each variable then summed as follows:

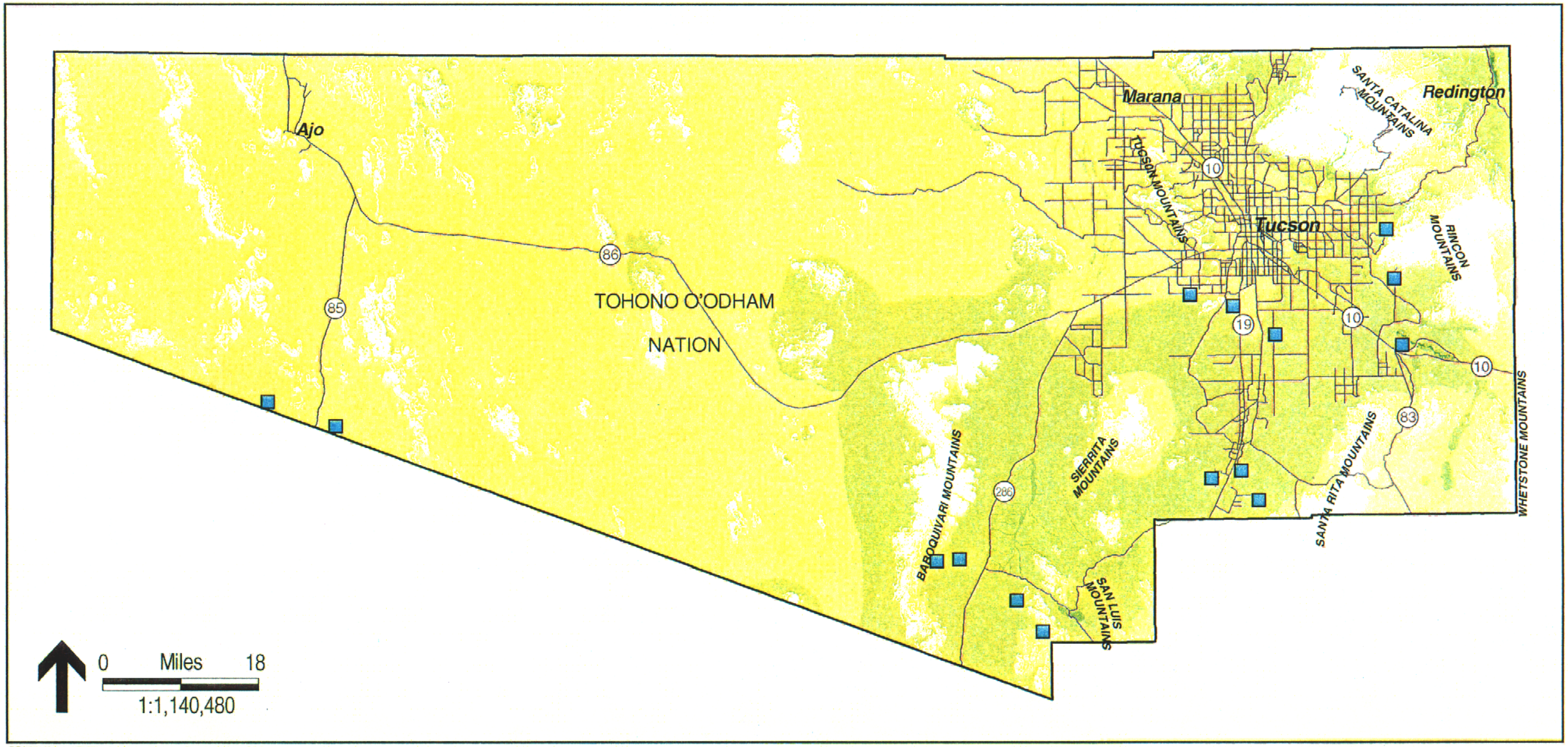
> Elevation + Slope + Perennial Streams + Shallow Groundwater + Vegetation = Potential Habitat

Potential habitat is shown in Figure 13. The model for Merriam's mouse does predict medium and high potential habitat for most of the areas around known location data, with the exception of Organ Pipe Cactus National Monument mouse locations. These locations appear to be associated with saltbush, which is modeled as no habitat for this species. Areas of medium potential habitat are located throughout mid-elevation areas of mixed grass-scrub even though this vegetation type was scored as no habitat for this species, since elevations of 800-1200 meters were scored high. High potential habitat areas are all located along riparian corridors. Most HDMS records for Merriam's mouse fall within several miles of the main riparian channels in Avra Valley, Green Valley, and Cienega-Rincon.

General patterns of predicted habitat fit the known location data available from HDMS. This may be somewhat artificial, however, since the apparent association between known location data and elevation were used to score elevation classes. The value of elevation for this species should be further investigated. Most HDMS records fall close to but not within areas of high potential habitat predicted along riparian corridors. This is largely due to the fact that the grid coverage of vegetation, with its course grid cell size (308 meters), does not capture the narrow washes mapped by the Wildlife Habitat Inventory Project. If cell size were reduced, these mixed scrub washes would appear as high potential habitat in the mid-elevation areas. Improved riparian mapping will also give us a better picture of where this species occurs.

8. Pale Townsend's big-eared bat (*Plecotus townsendii pallescens*)

This species is known to use caves and mines for roosting over a wide range of elevations and vegetation communities. This species appears to be limited by roosts that are relatively free from disturbance. Although the foraging range is not well understood, this species feeds primarily on insects and requires water for drinking. Vegetation communities where pale



Merriam's Mouse *(Peromyscus merriami)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(SWCA, 2000)

Figure 13

Townsend's big-eared bat can be found include Sonoran desert scrub, Madrean evergreen woodland, and coniferous forests. In Pima County, this species is known to use Colossal Cave Mountain Park, Tucson Mountain Park, Organ Pipe Cactus National Monument, and Saguaro National Park.

The habitat characteristics are described by landform, hydrology, and vegetation variables. Elevation ranges of 1000 to 2800 meters are scored as medium potential since these appear to be associated with known location data. This species is also known to occur in lower elevations, so ranges between 195 and 1000 meters were scored as low potential in the model. Potential areas for mines and caves are best represented in the current data sets by slope and carbonates data layers. There appears to be a weak association between known locations and southwest aspect, so slope was also included in the model. Important hydrology layers include perennial streams, intermittent streams, and springs. Based on known associations with vegetation communities, land cover types that are most likely to provide habitat for pale Townsend's big-eared bat include encinal (oak), oak-pine, mixed grass-scrub, pinyon-juniper, Douglas-fir–mixed conifer, pine, shrub-scrub disclimax, creosote-bursage, and paloverde mixed-cacti. Other low value types include manzanita, mixed evergreen sclerophyll, and sacaton scrub.

Habitat characteristics of pale Townsend's big-eared bat are scored in data layers for each variable then summed as follows:

> Elevation + Slope + Aspect + Carbonates + Perennial Streams + Intermittent Streams + Springs + Vegetation = Potential Habitat

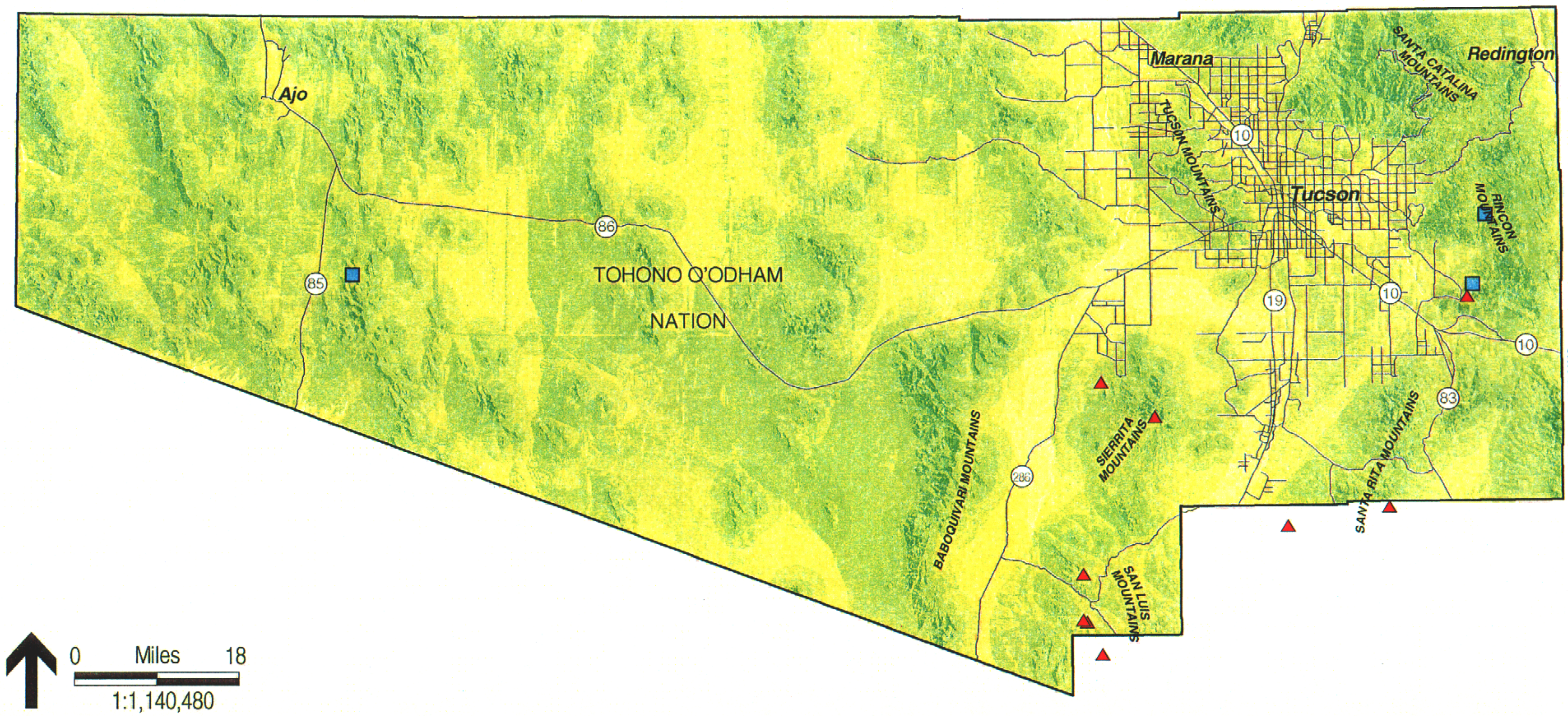
Potential habitat for this species is shown in Figure 14. The model for this bat species does predict medium and high potential habitat for most of the areas from which this species is known. Many other areas throughout the county are also predicted as higher potential habitat by this model, largely due to higher scores assigned to steep slopes and high elevation vegetation types.

This model overpredicts habitat for pale Townsend's big-eared bat, due primarily to the poor surrogates used for mines and caves. These are critical for this species but are not well described by steep slopes, especially at low elevations. Vegetation scores also need to be reexamined. The species-environment matrix scores for pale Townsend's big-eared bat rank Sonoran desert scrub types higher than semidesert grasslands. The pattern of known location data shows the opposite to be true, but this pattern may not be real since it is comprised of so few data points.

9. Arizona shrew (*Sorex arizonae*)

This species is known only from high elevations, generally near surface water and along drainages in mountain canyons. This species is associated with downed woody debris where it forages on arthropods and earthworms. There may be an association with water, but water by itself is not a sufficient condition for its presence. There are no records for this species in Pima County. All potentially suitable habitat for this species is within Saguaro National Park and Coronado National Forest.

The habitat characteristics for the Arizona shrew are described by landform, hydrology, vegetation, and elevation. This species prefers sky island communities, which consist of high elevations ranges from 2400 to 2600 meters. Although high elevations are typically associated



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Pale Townsend's Big-eared Bat *(Plecotus townsendii pallescens)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(SWCA, 2000)
(HDMS, 2000)

Figure 14

with steep slopes, this species is known to occur in mountain canyons with valley fill and little slopes. So, flat areas in the slope data set were considered to be important when modeling the potential distribution for this species. Important hydrology layers include shallow groundwater and springs and even perennial and intermittent streams. Land cover types that are most likely to provide habitat for this species includes pinyon-juniper, Douglas-fir–mixed conifer, pine, encinal (oak), and oak-pine, although they are not of high importance.

Habitat characteristics of Arizona shrew are scored in data layers for each variable then summed as follows:

Elevation + Slope + Perennial Streams + Springs + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 15. Predicted habitat for the Arizona shrew is in high elevation areas primarily in the Santa Catalina and Rincon Mountains. Within these areas, water and slope play a large role in differentiating low, medium, and high potential habitat. Low potential habitat is predicted in spring areas in a small part of the Sierritas; this was not expected.

The general pattern of potential habitat predicted for Arizona shrew is accurate. This species is only known from higher elevations, although it is not currently known from Pima County. Patterns within these high elevation areas should be further examined, perhaps by using species-environment associations from known locations outside the county. Known locations from surrounding counties should also be examined to assess the likely dispersal routes into Pima County.

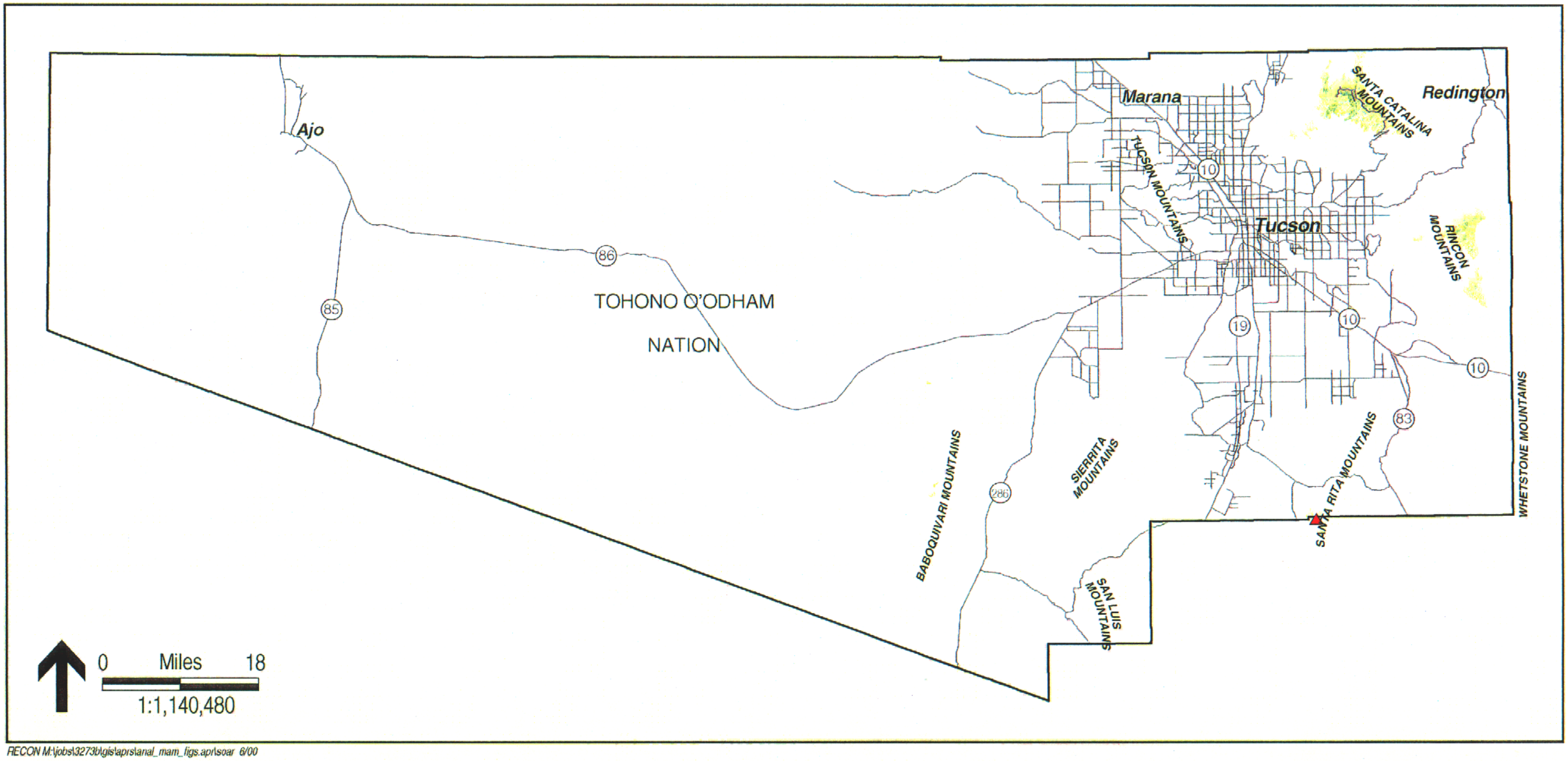
10. Rufous-winged sparrow (*Aimophila carpalis*)

This is species is typically monogamous and nonmigratory, occupying territories year-round. Although there is little information on home range requirements, this species requires flat or gently hilly Sonoran desert scrub, Sinaloan thorn scrub, and grasslands with scattered trees or shrubs. Territories typically include some wash and riparian habitat. This species depends on seeds and arthropods for food. Most known records for the rufous-winged sparrow are from undisturbed areas; however, small populations are known to persist in suburban areas. This species apparently has the ability to utilize residential, rural, and park situations including farmland irrigation ditches. Pima County contains most of the U.S. population for this species and it is fairly widespread in appropriate habitat in Saguaro National Park, Buenos Aires National Wildlife Refuge, the Empire-Cienega Resource Conservation Area, and the Santa Catalina District of the Coronado National Forest.

The habitat characteristics are described by landform, slope, and vegetation variables. Medium potential habitat for this species ranges from 400 to 1600 meters with low potential just above and below these ranges. Flat areas are scored as medium potential habitat for rufous-winged sparrow, and moderate to steep slopes are scored as no habitat. Land cover types that are most likely to provide habitat for rufous-winged sparrow include mixed grass-scrub and sacaton scrub. Other low value land cover types include mixed scrub, shrub-scrub disclimax, and paloverde-mixed cacti.

Habitat characteristics of rufous-winged sparrow are scored in data layers for each variable then summed as follows:

Elevation + Slope + Vegetation = Potential Habitat



Arizona Shrew *(Sorex arizonae)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
▲ (HDMS, 2000)

Figure 15

Potential habitat for this species is shown in Figure 16. Modeled potential habitat is distributed throughout the county except for high elevation areas. Grassland areas appear as higher potential than Sonoran desert scrub based on medium and low scores assigned to these types. Low elevation areas in the western portion of the county appear as low potential habitat. This species is known to be broadly distributed in Pima County as the model predicts. Riparian types may be undervalued (scored as no habitat) and should be reexamined. The entire Tucson valley is scored as medium potential, which is probably not the case. This species would benefit from discriminating among urban land cover types. There are no HDMS records available for this species, so comparisons of point location data cannot be made. There are records for this species in the breeding bird atlas, which are recorded by 15-minute USGS quadrangles. These data should be incorporated into GIS for several species so that their usefulness in modeling can be examined. They may be important for scoring the relative value of regions, after modeling habitat based on environmental parameters.

11. Burrowing owl (*Athene cunicularia hypugaea*)

This species is predominantly monogamous and migratory to some extent. The critical requirement for burrowing owls is the presence of other burrowing animals, such as prairie dog colonies. Because there are no known prairie dog colonies in Pima County, this species is extremely rare within the county. While the burrowing owl is capable of digging, it rarely does so, and prefers to nest in preexisting holes from other burrowing animals such as round-tailed ground squirrels and tortoises. This species has the ability to inhabit rural and suburban areas including open grasslands, pastures, croplands, fields, golf courses, cemeteries, and moderately grazed areas.

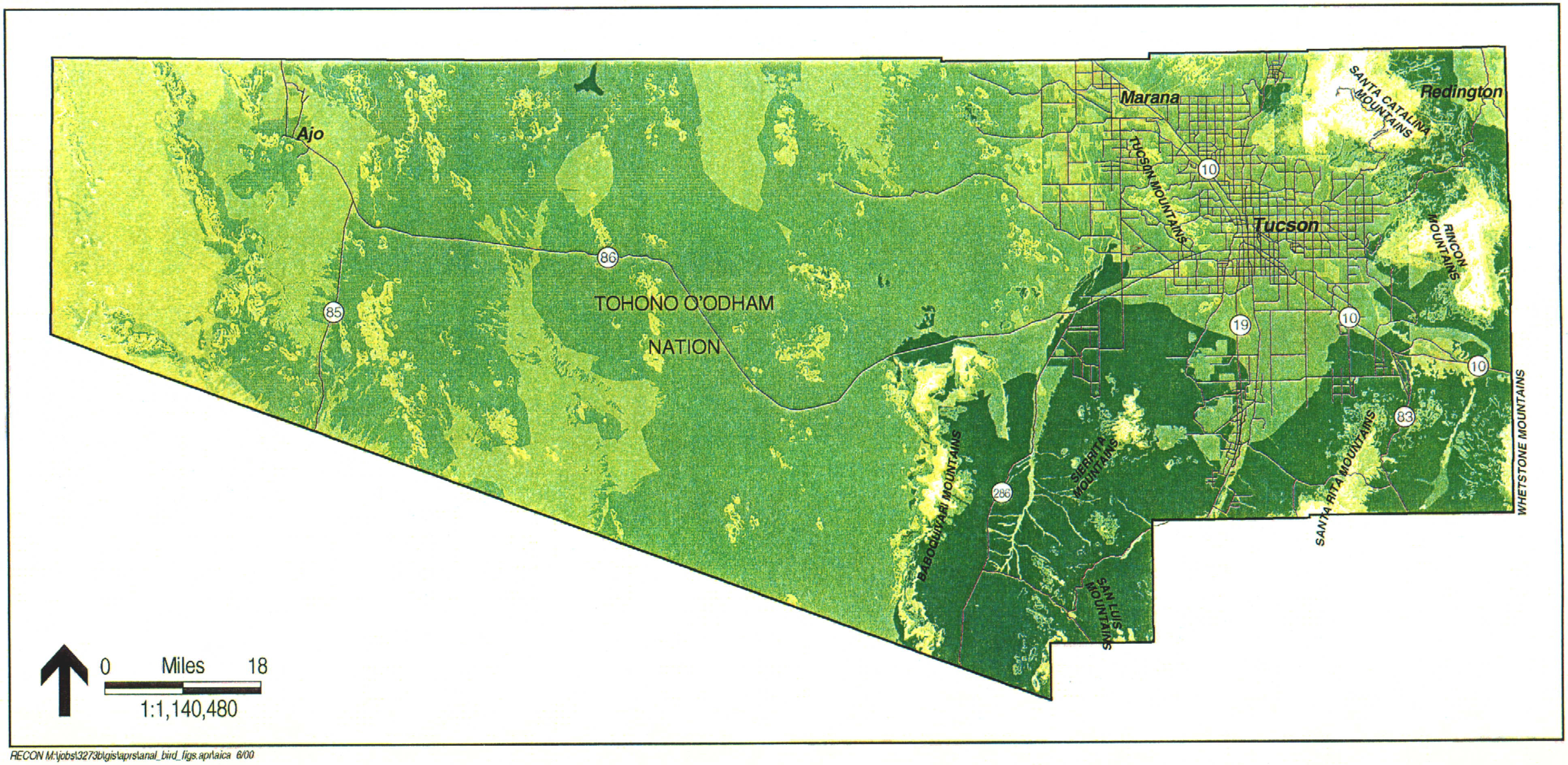
The habitat characteristics are primarily described by landform and vegetation variables. Elevation ranges of potential habitat for this species are 200 to 1000 meters and, to a lesser degree, 0 to 200 meters. Because this species prefers valley fill for burrows, flat areas are scored as high potential habitat. Because this species shows no strong associations with vegetation communities, land cover characteristics that the burrowing owl may use are all scored as low potential habitat. Land cover types included in the model are sacaton-scrub, mixed grass-scrub, shrub-scrub disclimax, mixed scrub, and creosote-bursage.

Habitat characteristics of burrowing owl are scored in data layers for each variable then summed as follows:

Elevation + Slope + Vegetation = Potential Habitat

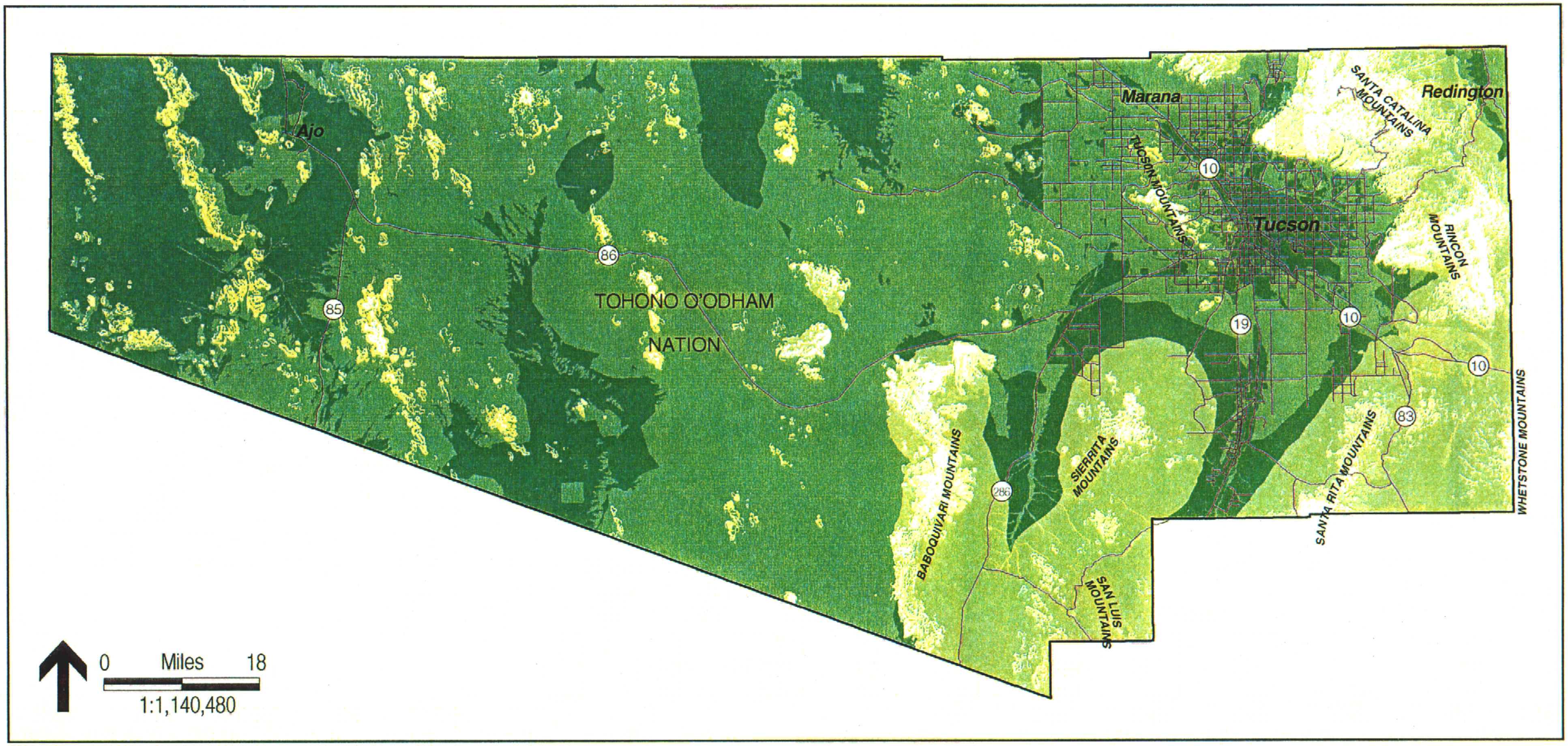
Potential habitat for this species is shown in Figure 17. According to the model, habitat for the burrowing owl is potentially distributed throughout the county excluding middle to higher elevations and steep slopes. Sonoran desert scrub areas appear to be more important than grasslands due to higher scoring of low elevation areas. Where mixed grass-scrub or creosote-bursage vegetation intersects with low elevations, high potential habitat is predicted, such as Altar Valley and Green Valley in the east and much of the Cabeza Prieta area in the west. The entire Tucson valley also appears as high potential habitat.

There are no known locations for burrowing owl available in GIS with which to compare this model. The model appears to exclude appropriate areas but overpredicts potential habitat. This species would benefit from differentiating urban land cover types. Known locations of burrowing owl and also desert tortoise may provide some insight to refining the model. It should also be noted that modeled low, medium, and high potential habitat are relative for the species. A map



Rufous-winged Sparrow *(Aimophila carpalis)*
Modeled Potential Habitat

Figure 16



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Burrowing Owl *(Athene cunicularia)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Figure 17

that shows medium potential everywhere may be misleading for a species that is rare throughout the county.

12. Swainson's hawk (*Buteo swainsoni*)

This species hunts for small mammals, reptiles, insects, and birds in open plains and grasslands. While it is versatile in its selection of nesting sites, it is known to nest in semidesert grassland, savanna grassland, and grassland intermixed with open desert scrub. Often, Swainson's hawk is seen in agriculture fields foraging for grasshoppers as it migrates. The importance of water to its migratory routes is uncertain; however, migrating hawks are regularly sighted in river valleys. There are two confirmed breeding pairs in Pima County, one on the Buenos Aires National Wildlife Refuge and one on the Tohono O'odham Nation. There are nine other potential breeding pairs in Pima County.

The wide range of habitat characteristics utilized by Swainson's hawk is best described by vegetation, slope, and elevation variables. This species can occupy low elevations of 0 to 1000 meters but prefers mid-range elevations of 1000 to 1800 meters with little to no slope. There is a strong association between this species and mixed grass-scrub. Other low value land cover types that can potentially support this species include paloverde-mixed cacti, mixed scrub, sacaton-scrub, and shrub-scrub disclimax.

Habitat characteristics of Swainson's hawk are scored in data layers for each variable then summed as follows:

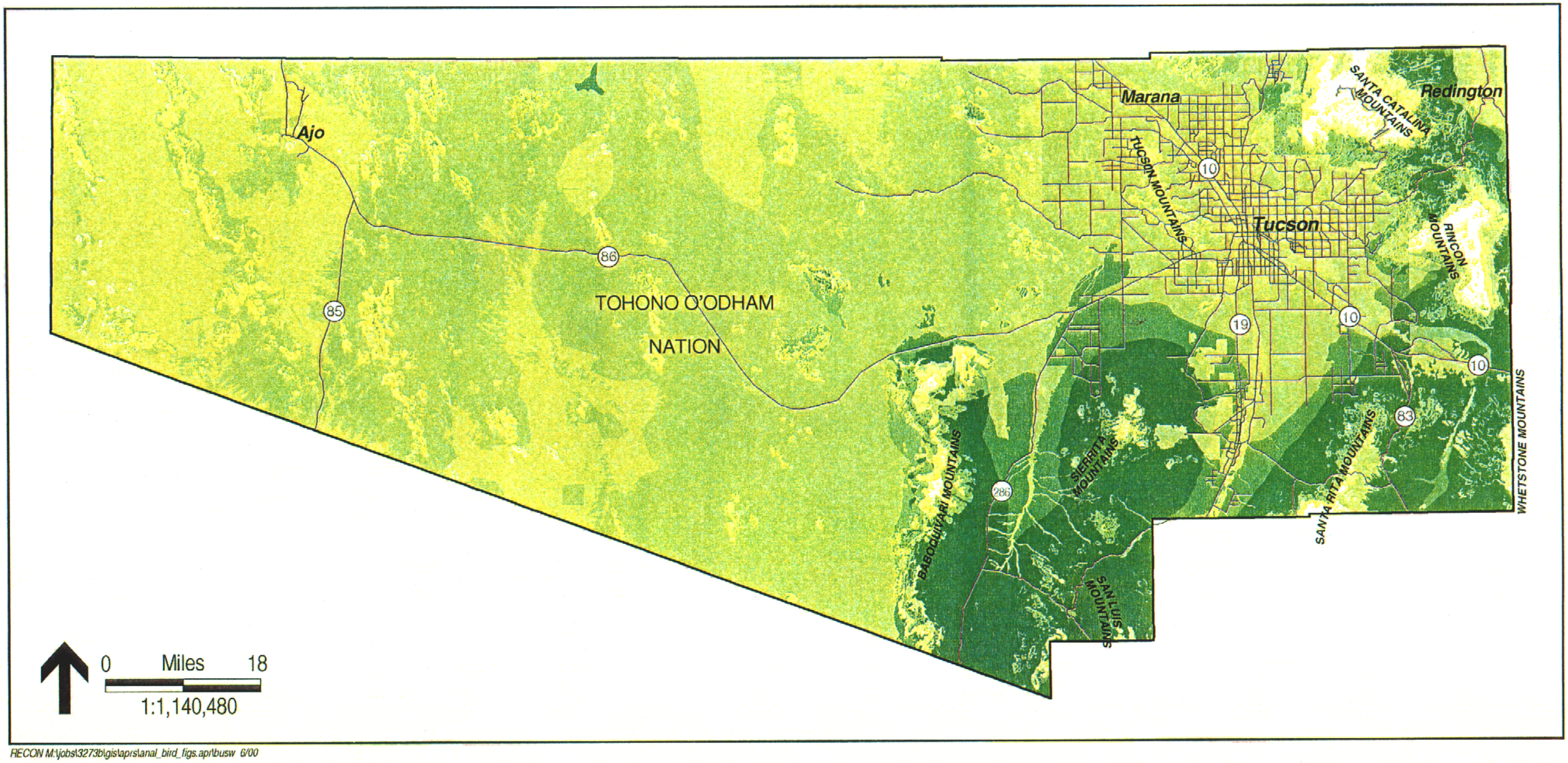
Elevation + Slope + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 18. The strong association between this species and mixed grass-scrub is apparent in the distribution of modeled habitat. The southern portions of Altar Valley, Upper Santa Cruz, and Cienega-Rincon appear as high potential habitat due to vegetation and elevation scores. Low to medium potential habitat is predicted throughout the county except in high elevation areas.

Known location data is not available in GIS and this species is rare and broadly distributed in Pima County. Some attention should be given to assuring that vegetation types are appropriately scored since this variable accounts for most of the differences in patterns of predicted habitat.

13. Western yellow-billed cuckoo (*Coccyzus americanus* ssp. *occidentalis*)

This species is strictly a summer resident in Arizona. Although migratory routes are poorly known, it is likely that riparian corridors are important since food sources are found there. This species requires mature Sonoran riparian deciduous forest, cottonwood-willow, Sonoran riparian scrub, and well-developed mesquite bosques. Permanent water may not be necessary. Mature cottonwood-willow riparian habitat is utilized by this species for breeding and foraging for insects and berries. It seems that the quality of habitat is more important than the quantity of habitat, since greater numbers of this species are found in dense riparian woodlands rather than in areas with less dense vegetation. This species has been found at Cienega Creek, Arivaca Creek, San Pedro River, Tanque Verde Wash, Rincon Creek, and some of the pecan orchards in Green Valley. In addition, suitable habitat is known to occur on the Empire-Cienega Resource Conservation Area and Cienega Creek County Park, and many areas of potentially suitable habitat have not been recently surveyed.



Swainson's Hawk *(Buteo swainsoni)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Figure 18

The habitat characteristics are described by vegetation, hydrology, elevation, and, to a lesser extent, slope variables. Elevation ranges of potential habitat for this species are 0 to 1800 meters, but the majority of HDMS known locations are in the 800- to 1400-meter range. This species is associated with little to no slope, so the flat slope characteristic was important in determining the potential distribution for this species. The current data set for streams and shallow groundwater shows a strong association with the HDMS known occurrences of the western yellow-billed cuckoo, probably because of the association between riparian communities and water. The most important vegetation communities for this species are cottonwood-willow, mesquite and mixed broadleaf riparian. Agriculture is scored as medium potential habitat. Because this species is associated only with riparian areas, all areas outside of potential habitat in the vegetation, shallow groundwater, and streams layers were considered no habitat. Therefore, slope and elevation only influenced potential habitat within potential habitat defined by the more critical environmental variables. Habitat characteristics of western yellow-billed cuckoo are scored in data layers for each variable then summed as follows:

> Elevation + Slope + Perennial Streams + Intermittent Streams + Shallow Groundwater + Vegetation = Potential Habitat

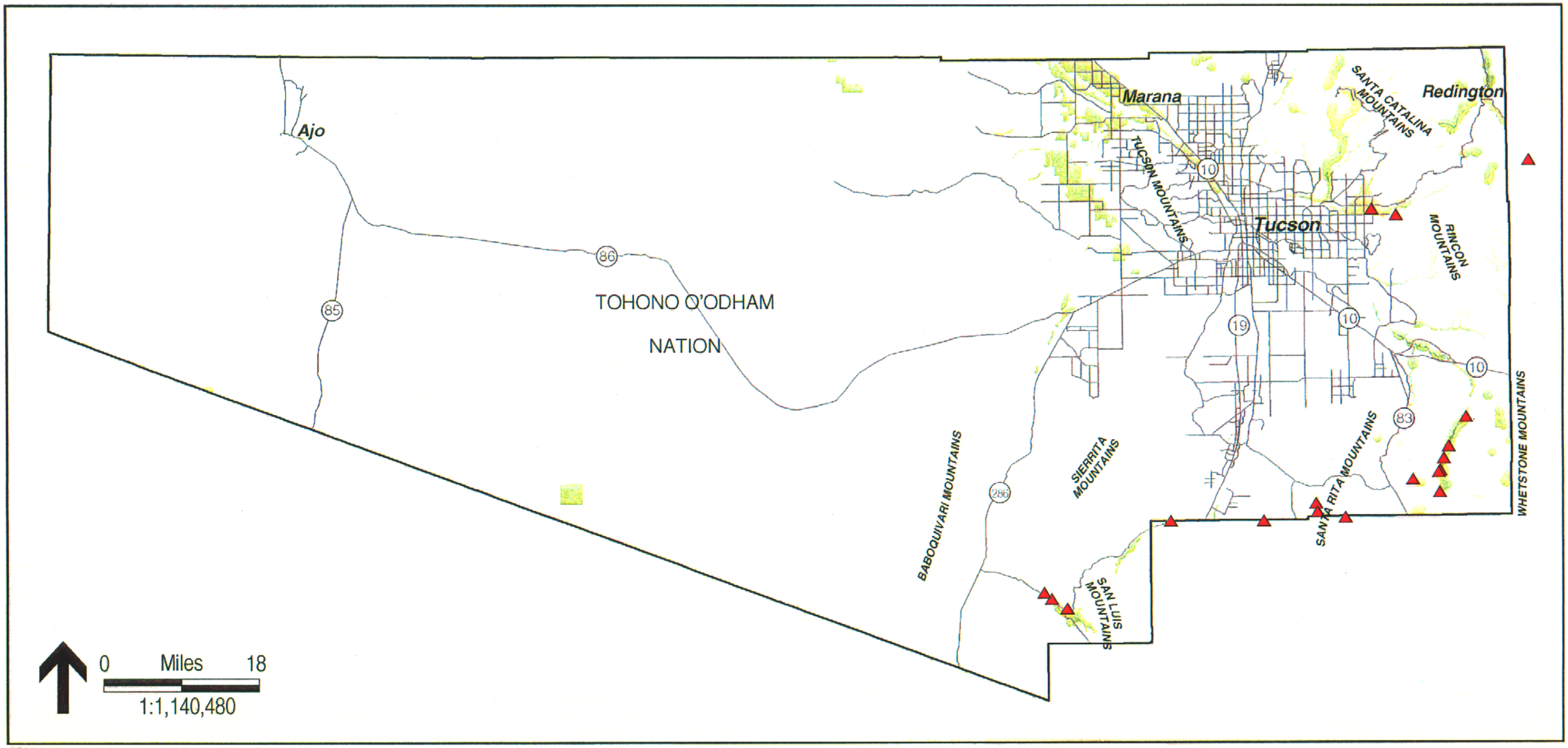
Potential habitat for this species is shown in Figure 19. Modeled potential habitat for this species shows almost all potential habitat occurring near streams and riparian areas in the eastern third of the county. High potential habitat appears only in close proximity to perennial streams.

Most known location data for this species falls within predicted potential habitat. Most records are located in the southern part of the county, probably moving along riparian corridors into Santa Cruz. High potential habitat is also predicted for Cienega Creek and Sabino Creek, although there are no HDMS records for these areas. Low potential habitat is predicted for all agricultural areas, although this should be refined to include only certain types of agriculture.

14. Southwestern willow flycatcher (*Empidonax traillii extimus*)

This species is known from riparian communities including dense stands of tamarisk. Although this migratory bird is known to pass through the area, there are no breeding records for this species in Pima County. Apparently, suitable habitat is not present in Pima County, but there seem to be areas of suitable habitat outside Pima County that remain unoccupied. Further research is needed to develop better understanding of habitat suitability.

The potential habitat for this species can be described by vegetation, hydrology, slope, and elevation variables. Elevation range spans 0 to 2000 meters; however, the preferred range is between 400 and 1000 meters. Hydrology data sets that are important to this species include intermittent and perennial streams, shallow groundwater, and, to a lesser extent, springs. Based on known associations with vegetation communities, land cover types that are most likely to provide habitat for this species include cottonwood-willow riparian and mixed broadleaf riparian. Riparian communities are typically associated with flat slopes, so the flat characteristic in the slope variable is important to identify potential habitat for this species. Only riparian areas are considered potential habitat for this species, so all areas outside of appropriate vegetation and hydrology classes were eliminated or "masked" from the analysis. Habitat characteristics of southwestern willow flycatcher are scored in data layers for each variable then summed as follows:



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Western Yellow-billed Cuckoo *(Coccyzus americanus occidentalis)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(HDMS, 2000)

Figure 19

Elevation + Slope + Perennial Streams + Intermittent Streams + Springs + Shallow Groundwater + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 20. Modeled habitat potential for southwestern willow flycatcher is distributed much the same as habitat for western yellow-billed cuckoo, except that agricultural areas are absent from willow flycatcher habitat. This follows closely with what would be predicted for this species, although this species is not found in the county. Researchers know there are other factors involved in limiting the distribution of this species. Perhaps investigation of environmental factors at similar occupied and unoccupied sites outside the county will provide some clues.

15. Cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*)

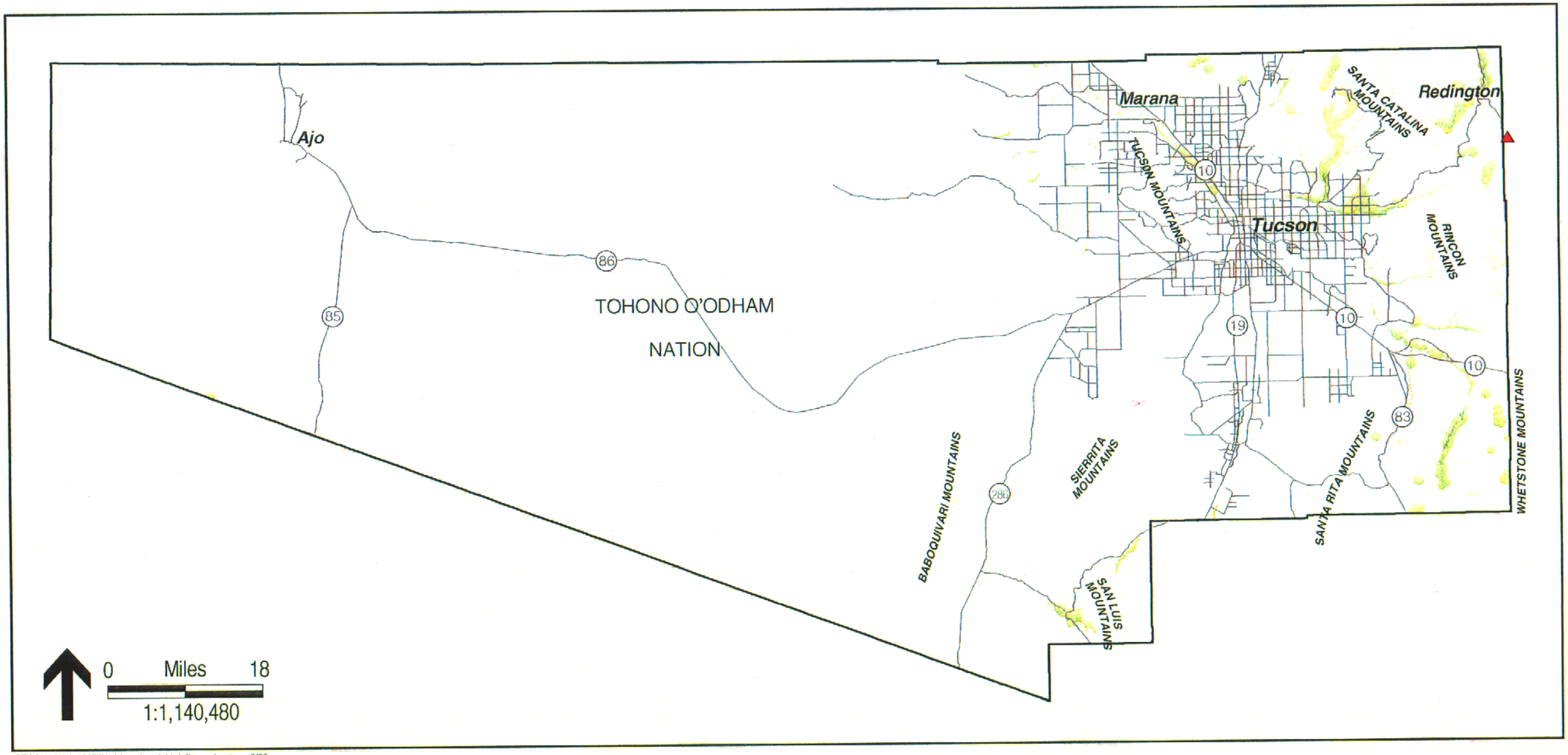
This species can occupy a wide range of vegetation, but it does require a suitable nest hole, either naturally occurring or abandoned woodpecker holes in trees or saguaro cacti. This species is highly territorial and a suitable home range typically includes a nest hole, prey species, and some configuration of vegetation. An opportunistic predator, the cactus ferruginous pygmy-owl feeds on birds, small mammals, lizards, and insects. Habitat requirements are not understood, and owls have been found over a high range of vegetation communities. This makes it difficult to identify what specific habitat characteristics are selected by the owls. Historically, this species occupied riparian areas and may have occupied desert scrub. Currently, this species has been found in Sonoran desert scrub and transition areas between desert scrub and desert grassland. The cactus ferruginous pygmy-owl has been documented from Organ Pipe Cactus National Monument, Tohono O'odham Nation, Buenos Aires National Wildlife Refuge, the Altar Valley, northwest Tucson, and east of the Tucson Mountains.

The habitat characteristics are primarily described by elevation and vegetation variables. Although habitat requirements are not well understood, the historic occurrences of this species in riparian areas and the current occurrences in Sonoran desert scrub areas can be selected in the vegetation data set to pinpoint potential habitat areas. The most important land cover type characteristic is paloverde-mixed cacti. Mixed grass-scrub was also considered in the model at a medium level of importance. The current known locations from the HDMS database show associations with mesquite, creosote-bursage, cottonwood-willow, and riparian mixed-scrub, so these were considered in the model at a low level of importance. The elevation range for potential suitable habitat is from 200 to 1200 meters, with most known locations occurring between 400 and 1200 meters.

Habitat characteristics of cactus ferruginous pygmy-owl are scored in data layers for each variable then summed as follows:

Elevation + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 21. Low to medium potential habitat is predicted throughout the county except in mid to high elevation areas. The distribution of paloverde-mixed cacti plays a large role in the pattern of high potential habitat, which is distributed in the Tucson valley outside of urban areas, throughout much of the Tohono O'odham Nation, and west in Organ Pipe Cactus National Monument up through the Growler Mountains.



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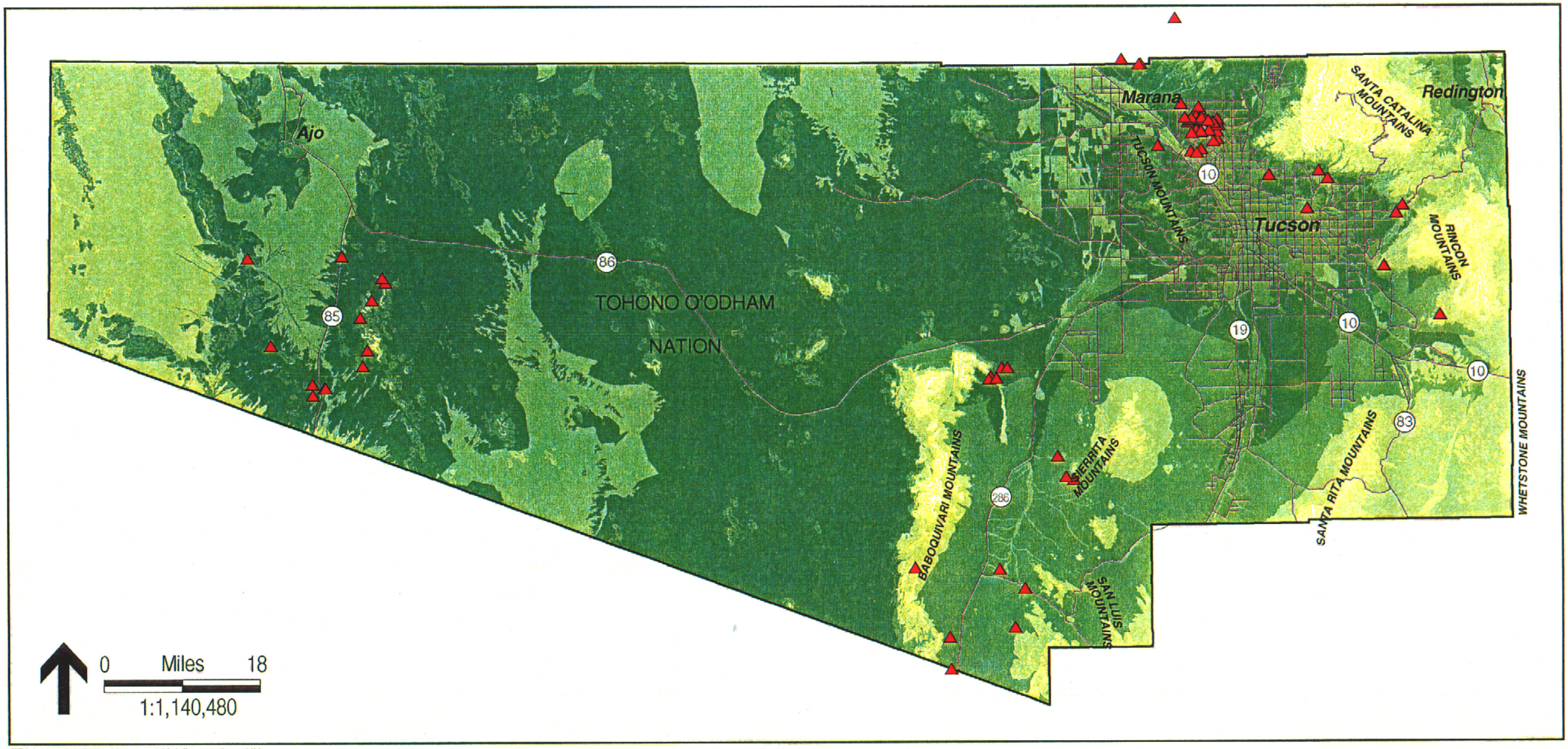
Southwestern Willow Flycatcher *(Empidonax traillii extimus)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(HDMS, 2000)

Figure 20



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Cactus Ferruginous Pygmy-owl *(Glaucidium brasilianum cactorum)*
Modeled Potential Habitat

Pima County Boundary

Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)

No Potential

Low Potential

Medium Potential

High Potential

Known Locations
(HDMS, 2000)

Figure 21

General patterns of predicted distribution for the cactus ferruginous pygmy-owl are probably accurate. HDMS records for this species fall primarily in areas of predicted high potential habitat in Organ Pipe, Altar Valley, and Tortolita fan. Altar Valley appears as slightly lower for potential habitat than other areas since mixed grass-scrub scores as medium potential. Other large areas of mixed grass-scrub through Green Valley are apparently unoccupied, so there may be another important factor involved in determining owl distribution in this vegetation community. High potential habitat areas in the Tucson Mountains and south Tucson that have no HDMS records should also be investigated for environmental factors that should be incorporated to refine the model.

16. <u>Abert's towhee (*Pipilo aberti*)</u>

Abert's towhee is a monogamous bird that forages for insects and seeds, primarily in Sonoran riparian deciduous woodland and riparian scrubland communities. Dense shrubbery appears to be the critical element, and if it is present, this bird may be in a range of settings. Abert's towhee is considered to be a riparian obligate species, but the specific type of riparian association upon which it is obligate is not defined and may vary from xeroriparian to hydroriparian. The dependency appears to be more on vegetation density and structure than on species of vegetation or presence of water. Abert's towhees are found in all known low elevation riparian sites in Pima County. This species is known from Saguaro National Park, Organ Pipe Cactus National Monument, Buenos Aires National Wildlife Refuge, the Empire-Cienega Resource Conservation Area, Coronado National Forest, Santa Cruz River Park, Tucson Mountains Park, Cienega Creek Park, Agua Caliente Park, and many urban parks.

Habitat characteristics for this species are described by vegetation, slope, hydrology, and elevation. Elevation ranges span from 100 to 1200 meters, with a preference for the 400- to 1000-meter range. Lower slope and flat areas appear to be more important to this species than moderate slope areas. The most important hydrology data sets are perennial and intermittent streams and shallow groundwater. Springs may be of some importance for this species but not as important as streams and shallow groundwater. Potential suitable habitat is best described by riparian vegetation characteristics including cottonwood-willow, mixed broadleaf, mesquite, and riparian mixed-scrub. Cattail may also be an important land cover type, so it was considered in the model at a medium importance level. Other low-level land cover types that could potentially provide habitat for Abert's towhee include mixed grass-scrub, paloverde-mixed cacti, saltbush, sacaton-scrub, and shrub-scrub disclimax.

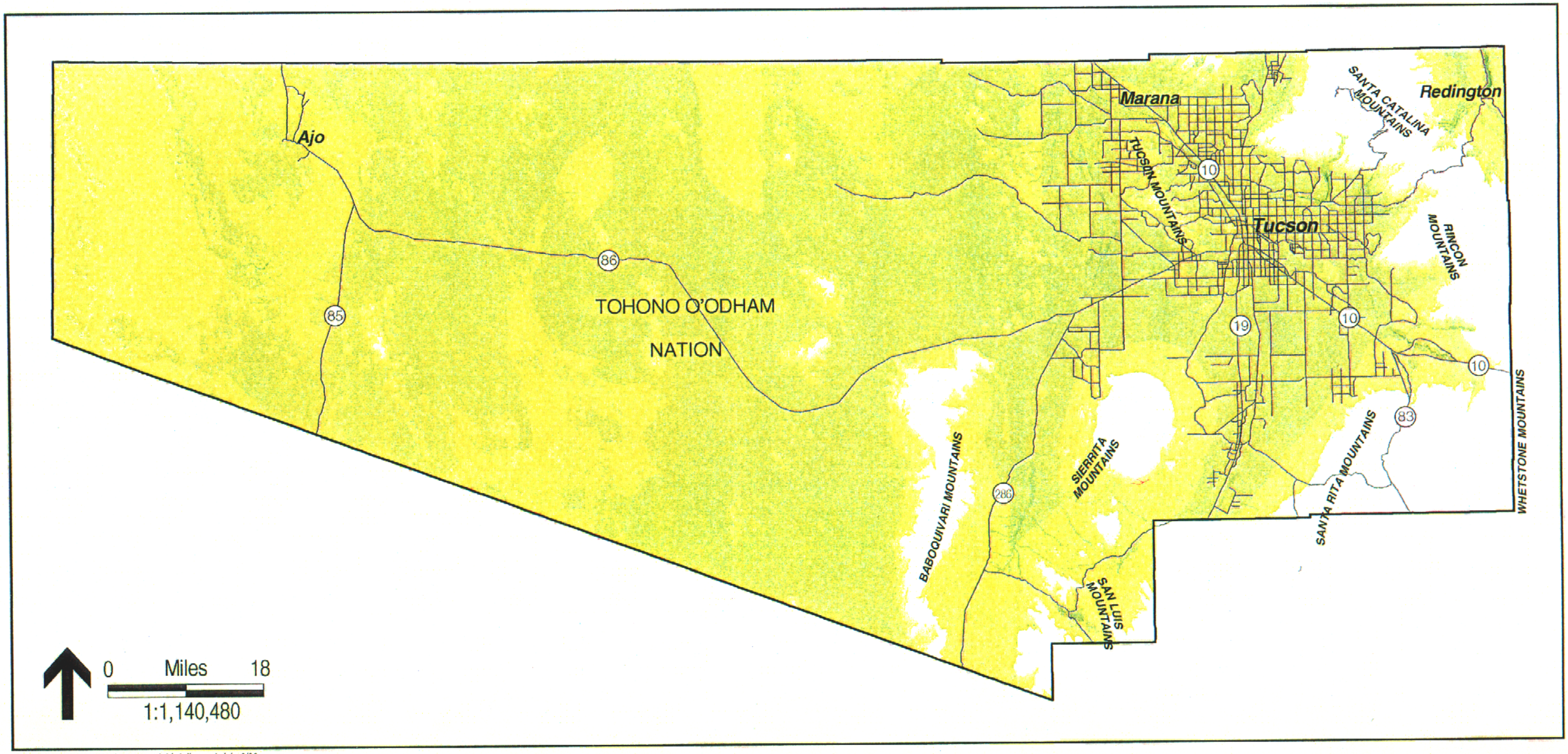
Habitat characteristics of Abert's towhee are scored in data layers for each variable then summed as follows:

> Elevation + Slope + Perennial Streams + Intermittent Streams + Springs + Shallow Groundwater + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 22.

17. <u>Bell's vireo (*Vireo bellii*)</u>

Bell's vireo requires dense riparian habitat to persist and breed. This species is generally monogamous and primarily insectivorous but may also consume fruit. This species can occupy dense riparian scrub or woodland, with or without water. Apparently, the mid and understory structure of vegetation is more important than the particular plant species, since the species of plants that make up the habitat vary throughout the range. Bell's vireo primarily uses native



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Abert's Towhee *(Pipilo aberti)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Figure 22

riparian woodlands and shrublands and can also use areas altered by tamarisk. This species occurs in Saguaro National Park, Organ Pipe Cactus National Monument, Buenos Aires National Wildlife Refuge, Tucson Mountain Park, Cienega Creek Park, Colossal Cave Park, and portions of the Santa Cruz River Park.

The habitat characteristics are described by vegetation, hydrology, slope, and elevation. Elevation ranges from 0 to 1600 meters, and important slope characteristics are flat areas with little to no slope. The hydrology data set is important to pinpoint riparian areas that this species depends on. Important hydrology data sets include perennial streams, intermittent streams, shallow groundwater, and springs. Based on associations with vegetation communities, land cover types that are most likely to provide habitat for Bell's vireo include cottonwood-willow, mixed broadleaf, mesquite, and riparian mixed-scrub. Land cover types that were considered in the model at a low importance value include sacaton-scrub, mixed grass-scrub, shrub-scrub disclimax, agriculture, and urban.

Habitat characteristics of Bell's vireo are scored in data layers for each variable then summed as follows:

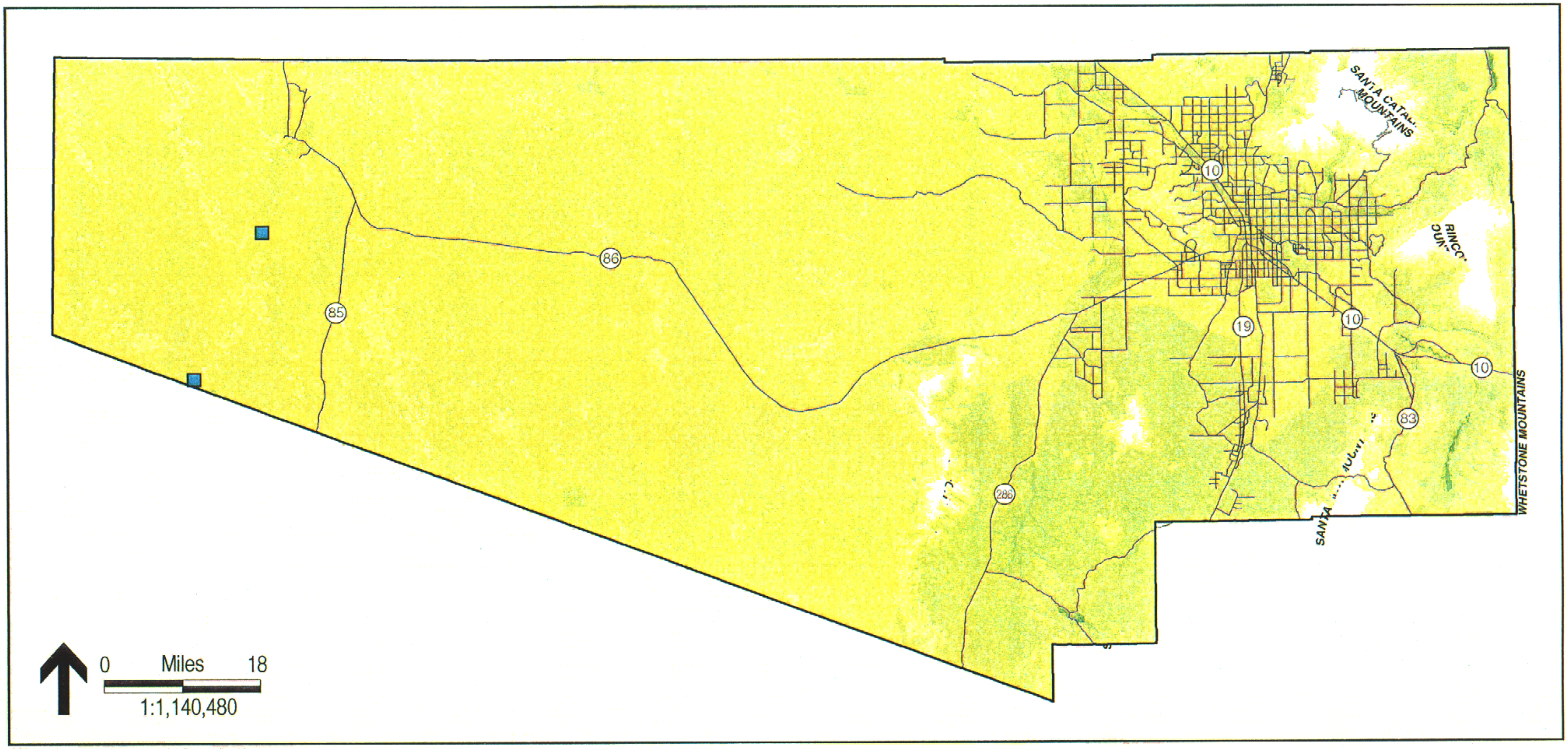
> Elevation + Slope + Perennial Streams + Intermittent Streams + Springs + Shallow Groundwater + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 23. Low to medium potential habitat is predicted throughout the county except in high elevation areas. Higher potential occurs in the mixed grass-scrub in Altar Valley and Green Valley. The highest potential is in riparian vegetation types and along watercourses.

Known locations mapped by SWCA include only two records in Organ Pipe Cactus National Monument, which fall in low to medium potential habitat. Other individuals are known to occur in certain reserve areas predicted to be medium to high potential. Agriculture and urban land cover types need to be mapped and scored for Bell's vireo. Improved riparian mapping will also help refine the habitat map for this species. Vegetation structure or density is very important for this species and is not part of the current data set. It is possible that Normalized-Difference Vegetation Index (NDVI) data could be used to identify densely vegetated areas.

18. Tucson shovel-nosed snake (*Chionactis occipitalis klauberi*)

This species could occur in the full range of low desert type communities as long as there is fine sand with few rocks. It requires deep valley fill to dig underground burrows and nests and forages for insects and larvae. This species is found in a variety of habitat types including mixed riparian scrub, creosotebush, Sonoran desert scrub, and mesquite bosque. The distribution of this species in Pima County needs to be more accurately determined, presumably by field survey efforts. The habitat characteristics are described by landform, slope, elevation, and vegetation. Elevation ranges are typically low and span from 0 to 1000 meters. Valley fill and low slope angles are critical for this species, and this is best described by the flat characteristic in the slope data set. Important vegetation associations include the land cover types mixed scrub, creosote-bursage, and paloverde-mixed cacti. Other vegetation characteristics considered in the model include mixed grass-scrub, considered at a medium level of importance, and sacaton-scrub, shrub-scrub disclimax, creosotebush-tarbush and saltbush, which were considered at a low importance level.



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Bell's Vireo *(Vireo belli)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(SWCA, 2000)

Figure 23

Habitat characteristics of Tucson shovel-nosed snake are scored in data layers for each variable then summed as follows:

Elevation + Slope + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 24. High potential habitat is predicted for most low elevation desert types in Pima County. Mixed grass-scrub types score as low potential. Available known locations for this species occur along a road in Organ Pipe Cactus National Monument, so significant associations are not apparent.

This species requires deep valley fill (fine sand with a few rocks) for burrowing/nesting. This variable does not exist in the current data layers but may be easily compiled from other sources. Little else is known about the relative value of specific environmental characteristics to the habitat distribution of the species. Known location data, if developed, may provide some insights on the critical factors that define habitat. Roadless or otherwise unfragmented habitat may also be important for the Tucson shovel-nosed snake—these can be added to the model once developed and scored for this species.

19. Organ Pipe shovel-nosed snake (*Chionactis palarostris organica*)

This species is found in a very limited portion of the Sonoran desert scrub in bajada or valley-bottom terrain where it frequents rocky soils and hillier terrain than the Tucson shovel-nosed snake. The Organ Pipe shovel-nosed snake nests in underground burrows and feeds on invertebrates, but little demographic information is available. The entire U.S. population of this species is in Pima County. The known distribution for this species is within or immediately adjacent to Organ Pipe Cactus National Monument, but other populations may occur and should be located and identified.

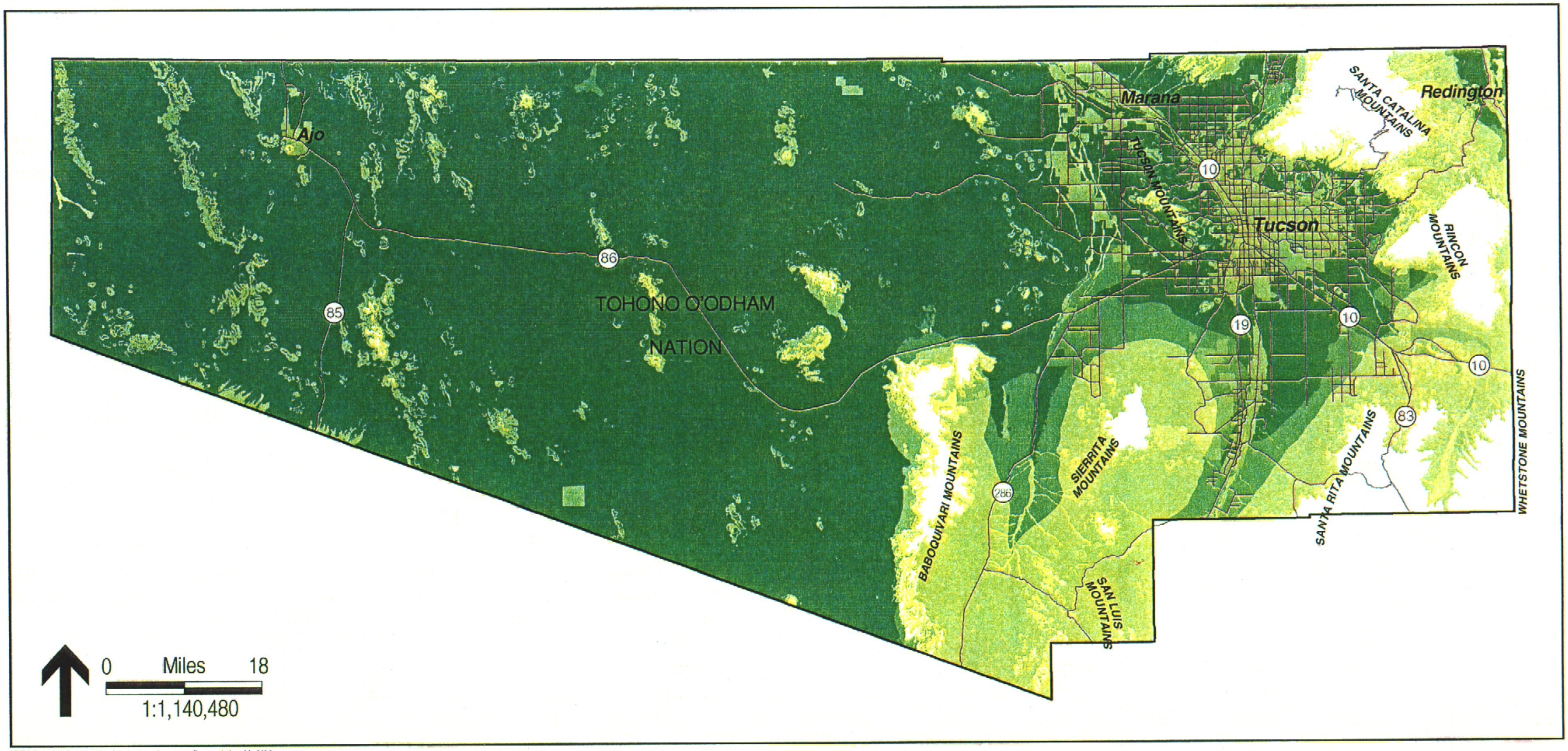
The habitat characteristics are described by landform, slope, elevation, and vegetation. Elevation ranges are typically low and span from 0 to 800 meters. Almost all of HDMS known locations are along the highway, which could be due to limited surveys in this area, and to the high visibility due to proximity to State Route 85. Potential areas for valley fill and low slope angles are best described by the low elevation and flat slope data sets. Important vegetation associations include the land cover types paloverde-mixed cacti and creosote-bursage. Land cover types considered at the medium importance level include mixed grass-scrub and shrub-scrub disclimax. Other low value land cover types include mixed grass-scrub, creosotebush-tarbush, saltbush, and shrub-scrub disclimax.

Habitat characteristics of Organ Pipe shovel-nosed snake are scored in data layers for each variable then summed as follows:

Elevation + Slope + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 25. The distribution for Organ Pipe shovel-nosed snake is similar to but more restricted than Tucson shovel-nosed snake. High potential habitat is found in valleys with Sonoran desert scrub west and northwest of Tucson, the Tohono O'odham Nation, and western Pima County.

Actual habitat potential is more narrowly restricted to bajadas and valley-bottom terrain with rocky soils. These may be feasible to incorporate into the model. Additional known location



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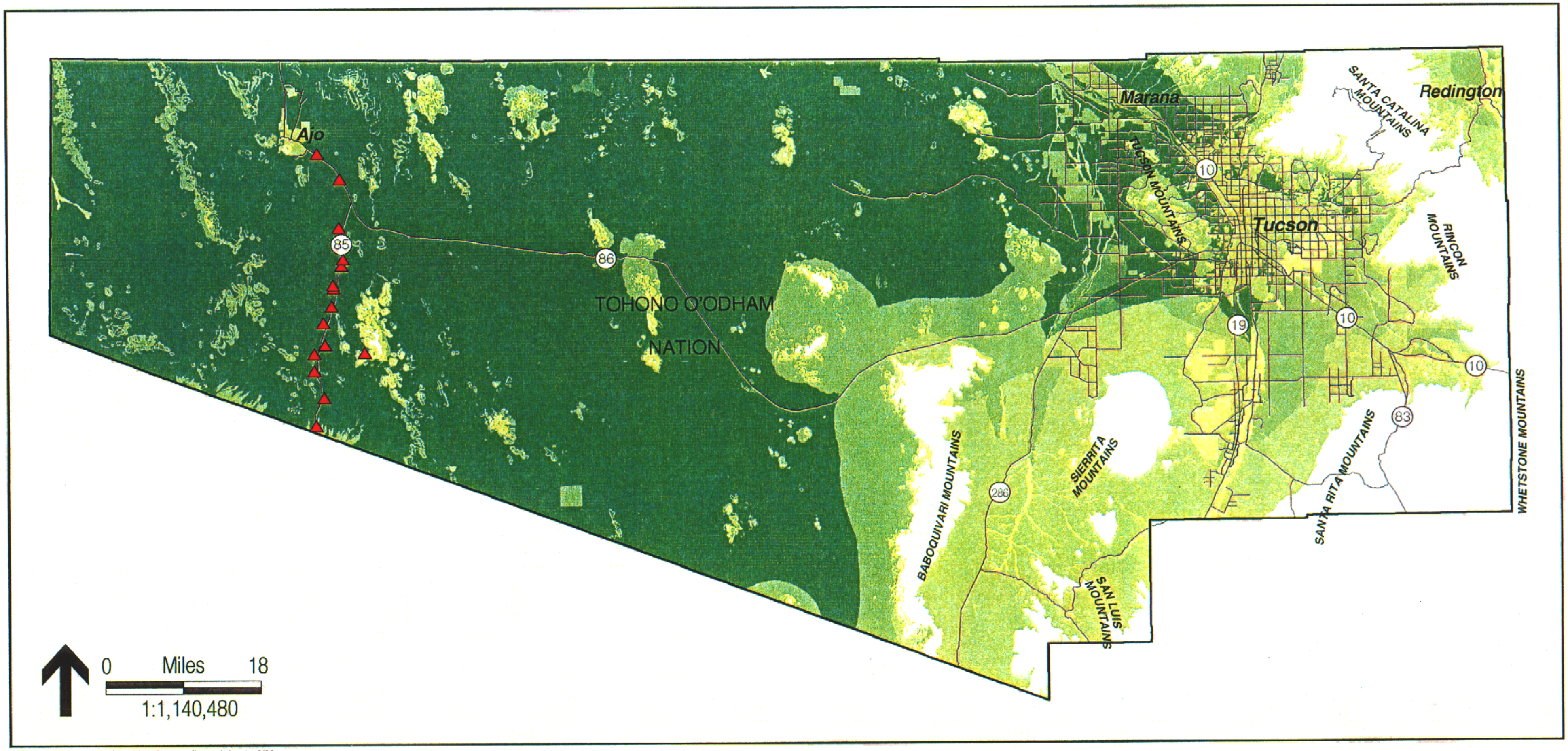
Tucson Shovel-nosed Snake *(Chionactis occipitalis klauberi)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Figure 24



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Organ Pipe Shovel-nosed Snake *(Chionactis occipitalis klauberi)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
▲ (HDMS, 2000)

Figure 25

data, especially outside of Organ Pipe, would also be helpful in more clearly defining important environmental characteristics.

20. Giant spotted whiptail (*Cnemidophorus burti stictogrammus*)

This species depends on a mosaic of open spaces and dense vegetation cover. It is typically found in lower Sonoran riparian areas in mountain canyons, arroyos, and mesas including lowland deserts along streams. This species seeks cover in dense vegetation and piles of rock and debris while foraging for arthropods. In addition to utilizing riparian communities, the giant spotted whiptail also uses adjacent habitats such as grasslands. In Pima County, this species has been recorded in the Santa Catalina, Santa Rita, and Baboquivari Mountains.

The habitat characteristics are described by landform, hydrology, slope, elevation, and vegetation. Elevation ranges can span from 0 to 1400 meters; however, most species occur in the 200- to 1200-meter range. This species prefers valley fill areas with rocky canyons which is best represented by the elevation and slope data sets. Flat slope characteristics were important in the model; however, moderate slope areas were considered since this species is known to occur in both types of slope areas. The most important hydrological data sets are perennial streams, intermittent streams, and shallow groundwater. The springs data set is considered to be somewhat important to the potential habitat for this species. Important land cover types that are most likely to provide habitat for the giant spotted whiptail include riparian mixed-scrub, cottonwood-willow, mixed broadleaf, and mesquite. Lower value types include encinal (oak), sacaton scrub, and mixed grass-scrub.

Habitat characteristics of giant spotted whiptail are scored in data layers for each variable then summed as follows:

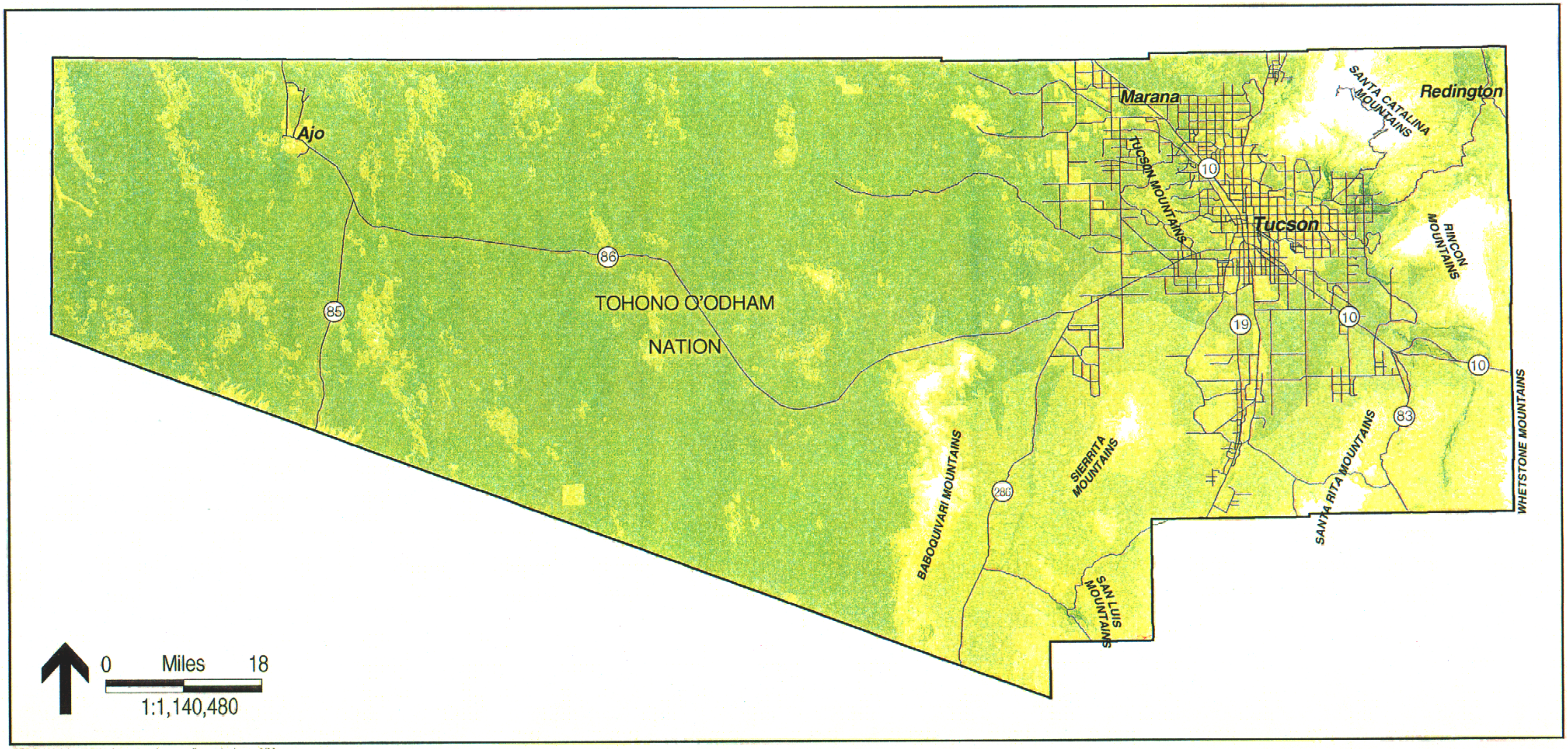
> Elevation + Slope + Perennial Streams + Intermittent Streams + Springs + Shallow Groundwater + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 26. Potential habitat is predicted across Pima County except for high elevation areas. Sonoran desert scrub types appear as medium to high potential and riparian types appear as high potential. Known location data for giant spotted whiptail is not available in GIS.

Habitat is overpredicted for this species. Vegetation density is an important component of habitat for this species that is not currently mapped. NDVI data may be used to map dense vegetation along washes. Further investigation is needed to determine whether giant spotted whiptail is restricted to stream, wash, and adjacent habitats and whether these types can be adequately mapped.

21. Red-backed whiptail (*Cnemidophorus burti xanthonotus*)

This species depends on a mosaic of open spaces and vegetation cover typically found in mesic canyons in desert mountain ranges including woodlands, riparian, and grassland desert edges with rocky slopes. It prefers to forage for arthropods in areas with rocky slopes and dense vegetation so it can seek cover. Potential habitat includes juniper-oak woodland down to the desert edge, shrubby vegetation near banks of permanent springs and arroyos, and in canyons. The known distribution for the red-backed whiptail in Pima County is limited, but it has been recorded in the Ajo, Dripping Springs, and Puerto Blanco Mountains, in Organ Pipe Cactus



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Giant Spotted Whiptail *(Cnemidopophorus burti stictogrammus)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Figure 26

National Monument. This species may occur on other isolated mountain ranges including some on the Tohono O'odham Nation, but no known records are available.

The characteristics that best describe the potential habitat for this species are rocky canyons and tertiary volcanic landforms, which are represented by the elevation and slope data sets. This species prefers moderate and steep slope areas in the 600- to 1200-meter elevation range. However, flat slope areas and slightly higher elevation range of 1200 to 1400 meters are of some importance to this species, so they are considered in this model at a lower value. Flat areas within one-half mile of moderate to steep slopes was an important characteristic considered in the model. Flat areas within two miles of moderate to steep slopes were considered at a low importance level. The most important vegetation communities that are most likely to support potential habitat include encinal (oak) and mixed evergreen sclerophyll. Other moderately important land cover types include paloverde-mixed cacti, mixed scrub, creosote-bursage, and mesquite. The potential habitat model also considered pinyon-juniper land cover, but at a low value importance level.

Habitat characteristics of red-backed whiptail are scored in data layers for each variable then summed as follows:

Elevation + Slope + Vegetation = Potential Habitat

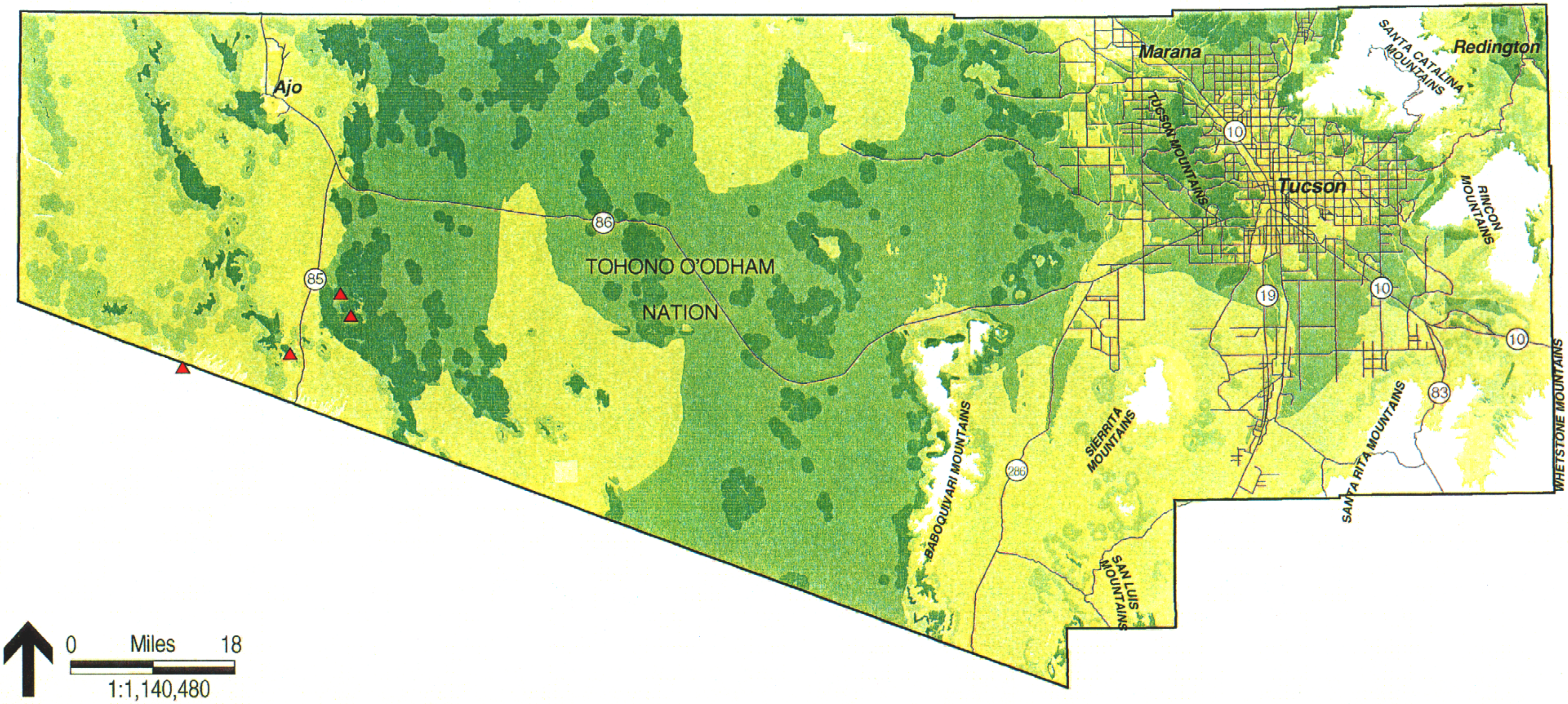
Potential habitat for this species is shown in Figure 27. A strong pattern appears in the habitat model for red-backed whiptail lizard, with medium and high potential habitat predicted for the middle third of the county and the area around Tucson in south Tucson, the Tucson Mountains, and Tortolita fan. These areas are scored higher due to the distribution of Sonoran desert scrub and the 600- to 1200-meter elevation range.

Known location data is available for Organ Pipe Cactus National Monument—species fall into high potential categories.

22. Ground snake (valley form) (*Sonora semiannulata*)

This species is known to occur in terrestrial habitats including desert grasslands, plains, valley and foothill habitats, and mountains with higher slopes. General habitat requirements can consist of loamy clay soils, lava fields, sandy areas, talus slopes, rocky outcrops, and loose and rocky soils with a southwest aspect. Subsurface moisture may be required for this species and its prey. This species requires loose soil for burrowing so it can hide in dens during the day and forage for eggs, vertebrates, and arthropods at night. This species is known to occur in Coronado National Forest and Saguaro National Park. Small populations of this species may occur on the Tohono O'odham Nation, its eastern border between Marana and Eloy, and around Tucson. Because this species is not currently being tracked by the HDMS, there is insufficient information to determine the significance of any specific populations in Pima County.

Flat areas and flat areas within one-half mile of moderate to steep slopes were considered to be important in the model. Another important characteristic to pinpoint potential habitat is an elevation range between 800 and 1600 meters. Other lower value elevation ranges that were considered in the model include a slightly lower elevation range of 600 to 800 meters and a higher elevation range of 1600 to 1800 meters. The most important vegetation land cover type for this species distribution is mixed grass-scrub. Other important land cover types include and sacaton scrub, shrub-scrub disclimax, mixed scrub, creosote-bursage, paloverde-mixed cacti, saltbush, cottonwood-willow, mixed broadleaf, and mesquite. Other lower value types of land



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Red-backed Whiptail Lizard *(Cnemidophorus burti xanthonotus)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(HDMS, 2000)

Figure 27

cover include creosotebush-tarbush, pinyon-juniper, encinal (oak), oak-pine, mesquite, manzanita, and mixed evergreen-sclerophyll.

Habitat characteristics for ground snake are scored in data layers for each variable then summed as follows:

Elevation + Slope + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 28. Medium to high potential habitat is predicted on or near steep slopes throughout the county, with the highest potential habitat occurring in mixed grass-scrub on or near slopes of eastern Pima County mountain ranges.

Some soil and geologic characteristics are thought to be associated with this species. These could be acquired/compiled and used for this analysis. Habitat requirements for this species need to be better defined.

23. Desert box turtle (*Terrapene ornata luteola*)

This is primarily a prairie turtle that inhabits semidesert grasslands with deep soil and open woodlands with herbaceous understories. Apparently, moist soil that is not compacted is required for digging burrows. The desert box turtle is omnivorous and can be found foraging on insect, arthropods, plants, and even carrion. This species seeks shelter in burrows and under rocks. The HDMS does not track this species, so the distribution in Pima County is not well known; however, this species has been recorded in the Empire-Cienega Resource Conservation Area, the Santa Cruz River near Sahuarita, and Altar Valley.

Habitat characteristics are best described by landform, slope, elevation, and vegetation variables. The elevation range for this species spans from 0 to 2200 meters; however, the mid elevations of 800 to 2000 meters seem more suitable. Valley fill is critical for this species, since it must be able to burrow, and this is best identified by the flat characteristic in the slope data set. The most important land cover types to identify potential habitat include sacaton-scrub, mixed grass-scrub, and shrub-scrub disclimax at a lower value level.

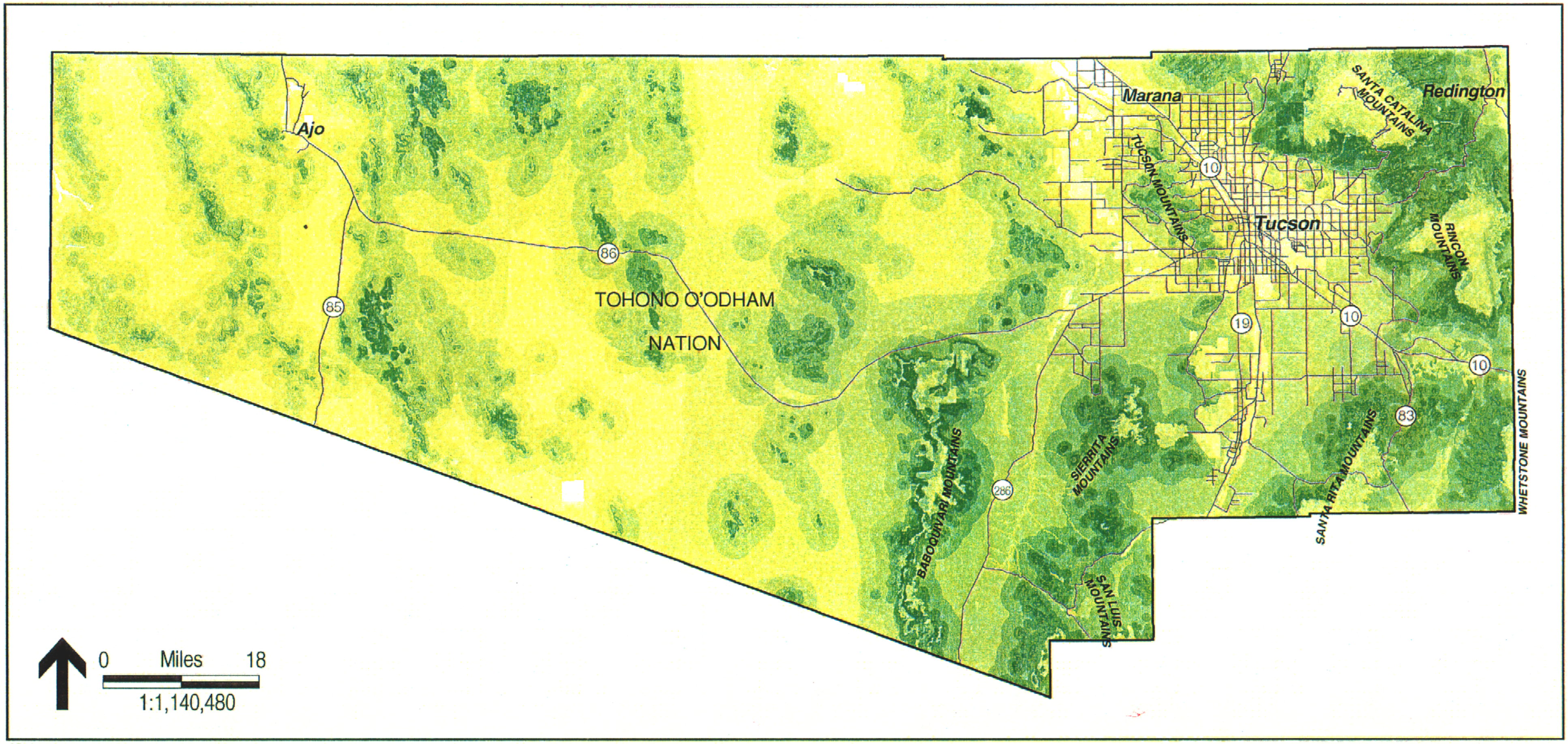
Habitat characteristics for desert box turtle are scored in data layers for each variable then summed as follows:

Elevation + Slope + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 29. High potential habitat is predicted only in mixed grass-scrub areas of eastern Pima County, which is consistent with known occurrences. Known location data are not available in GIS.

24. Mexican garter snake (*Thamnophis eques megalops*)

This is a riparian-dependent species and is most commonly known from Sonoran riparian forests and woodlands. Habitat requirements include intact riparian vegetation communities along permanent water such as streams, ponds, and cienegas. The Mexican garter snake forages for native amphibians, fishes, and small mammals around vegetated watercourses that provide shelter. Adverse predator relationships exist between this species and non-native species such as bullfrogs. Although this species is limited to riparian areas with permanent water, it has the ability to use a variety of adjacent habitats. In Pima County, there is a



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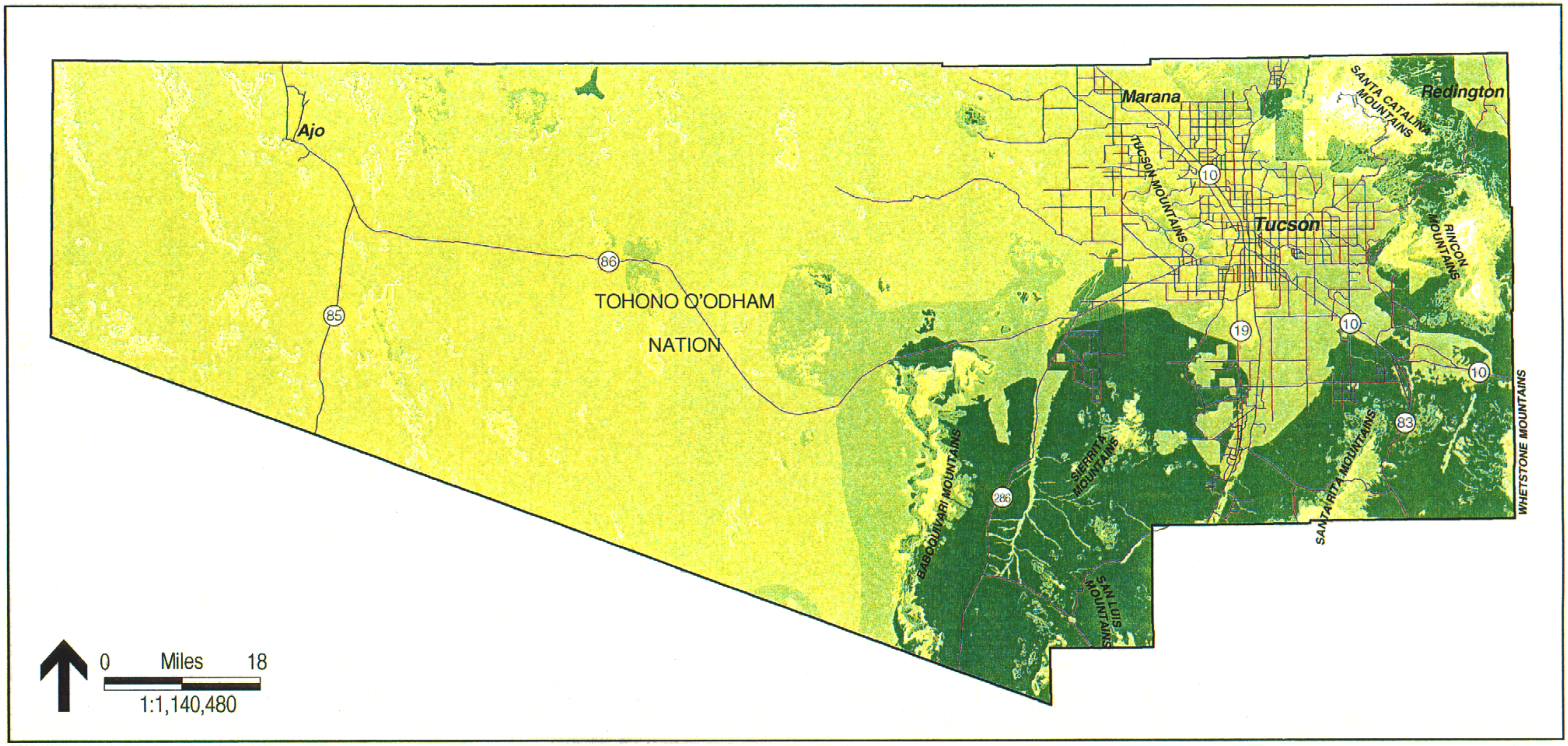
Ground Snake (Valley Form) *(Sonora semiannulata)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Figure 28



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Desert Box Turtle *(Terrapene ornata luteola)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Figure 29

significant population at Cienega Creek, but no occurrences were recorded in historic areas such as the Santa Cruz River and tributaries.

The habitat characteristics that best define the potential habitat for this species include hydrology, elevation, and vegetation. This species can occur in a wide range of elevations spanning 0 to 2000 meters but prefers elevation ranges from 600 to 2800 meters. The most critical requirement is permanent water, which is identified in the perennial stream data set. Other important hydrology characteristics include the intermittent stream, springs, and pond data sets. Vegetation is another key variable that identifies areas of potential distribution. Critical land cover types included in the model are cottonwood-willow and mixed-broadleaf. Also considered in the model, but at lower level value, was mixed scrub, the land cover type. The Mexican garter snake is restricted to riparian vegetation with permanent water; however, it has the ability to use adjacent land cover types such as mixed grass-scrub, and paloverde mixed-cacti. These land cover types were incorporated into the model and potential distribution was evaluated based on their proximity to riparian areas with permanent water.

Habitat characteristics for Mexican garter snake are scored in data layers for each variable then summed as follows:

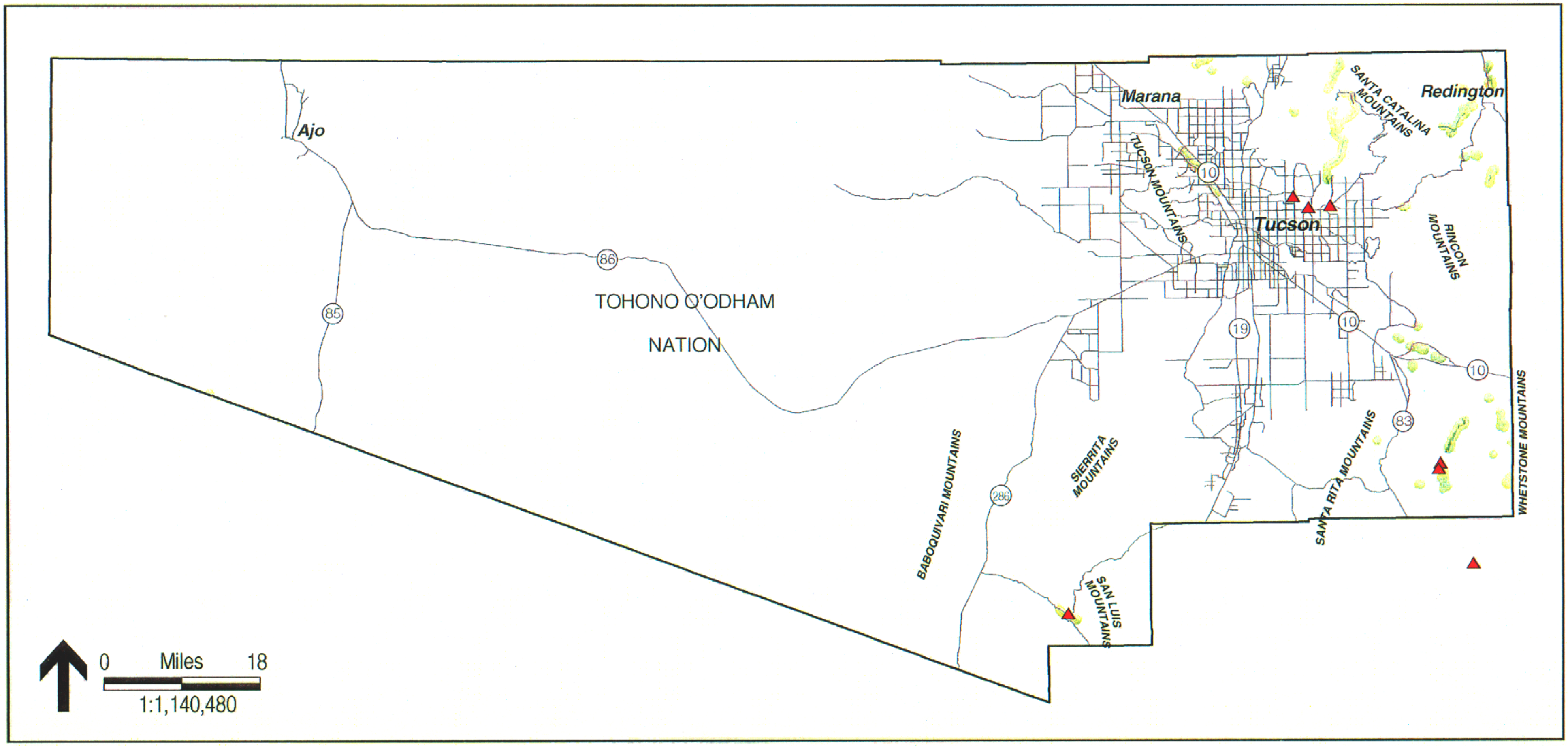
> Elevation + Slope + Perennial Streams + Intermittent Streams + Springs + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 30. Modeled potential habitat is distributed within one-half mile of perennial streams almost entirely in eastern Pima County. Within this area, additional ephemeral water sources, vegetation, slope, and elevation play a role in determining higher potential habitat. Based on these factors, highest potential habitat occurs along Cienega Creek, especially in upper Davidson Canyon, San Pedro River, the lower end of Sabino Creek near the Rillito River, and a small part of Arivaca Creek where the water flows perennially. All these areas are associated with HDMS records except San Pedro River. HDMS records also exist on Rillito River, which was considered no habitat by the model since the GIS coverage for perennial streams does not include this area.

The model does a good job of identifying the primary distribution of Mexican garter snake since its distribution is limited to perennial streams. Habitat scoring within these areas also appears to fit HDMS records moderately well. Habitat is predicted along the Santa Cruz River where the species is absent and along the San Pedro River where there are no HDMS records. An important factor in habitat distribution for this species is absence of predators such as the non-native bullfrog. The presence of this species in uninhabited perennial streams should be examined. "Potential habitat" in the current model shows where physical factors of habitat are and are not present. Perhaps it is appropriate to maintain this as the definition of potential habitat (rather than include biological factors of species distribution) and map known occupied habitat and predator distribution separately. This can be examined further during review. Other factors that should be discussed include modeling the appropriate distance from perennial streams, including ponds from the land cover data, and including areas such as Rillito River that do not appear in the GIS coverage for perennial streams.

25. Chiricahua leopard frog (*Rana chiricahuensis*)

This frog is an aquatic and riparian species that utilizes a variety of water sources including rocky streams with deep, rocky pools, overflow pools and oxbows of rivers, permanent springs, ponds, and wetlands. It may also occur in thermal springs and seeps, stock tanks, wells, and



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Mexican Garter Snake *(Thamnophis eques megalops)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(HDMS, 2000)

Figure 30

mainstream river reaches. This species forages for arachnids, crustaceans, and insects, often in adjacent upland habitats including oak and pine-oak woodlands, chaparral, grassland, and desert. An ideal habitat for this species would have permanent water for breeding, aquatic heterogeneity, abundant terrestrial and aquatic vegetation, and the absence of predatory, non-native crayfish and bullfrogs. In Pima County, this frog has been found at six sites including the Santa Rita and San Luis Mountains and at Cienega Creek and Arivaca Creek. Additional surveys are needed to determine the full extent of this species' range in Pima County.

These habitat characteristics that describe the potential distribution for this species can be described by the hydrology and elevation variables. While this species can utilize a variety of aquatic habitat, the most important aquatic features are perennial streams and springs in the hydrology data set. Ponds are also important to this species but at a lower value. The intermittent streams data set was also considered in the potential distribution model but at a low value of importance. This species can occupy elevation ranges of 200 to 2800 meters, but elevations under 1800 meters are scored higher. Important adjacent vegetation communities include riparian mixed-scrub, cottonwood-willow, mixed broadleaf, cattail, and, to a lesser extent, mesquite. Habitat characteristics for Chiricahua leopard frog are scored in data layers for each variable then summed as follows:

> Elevation + Perennial Streams + Intermittent Streams + Springs + Vegetation = Potential Habitat

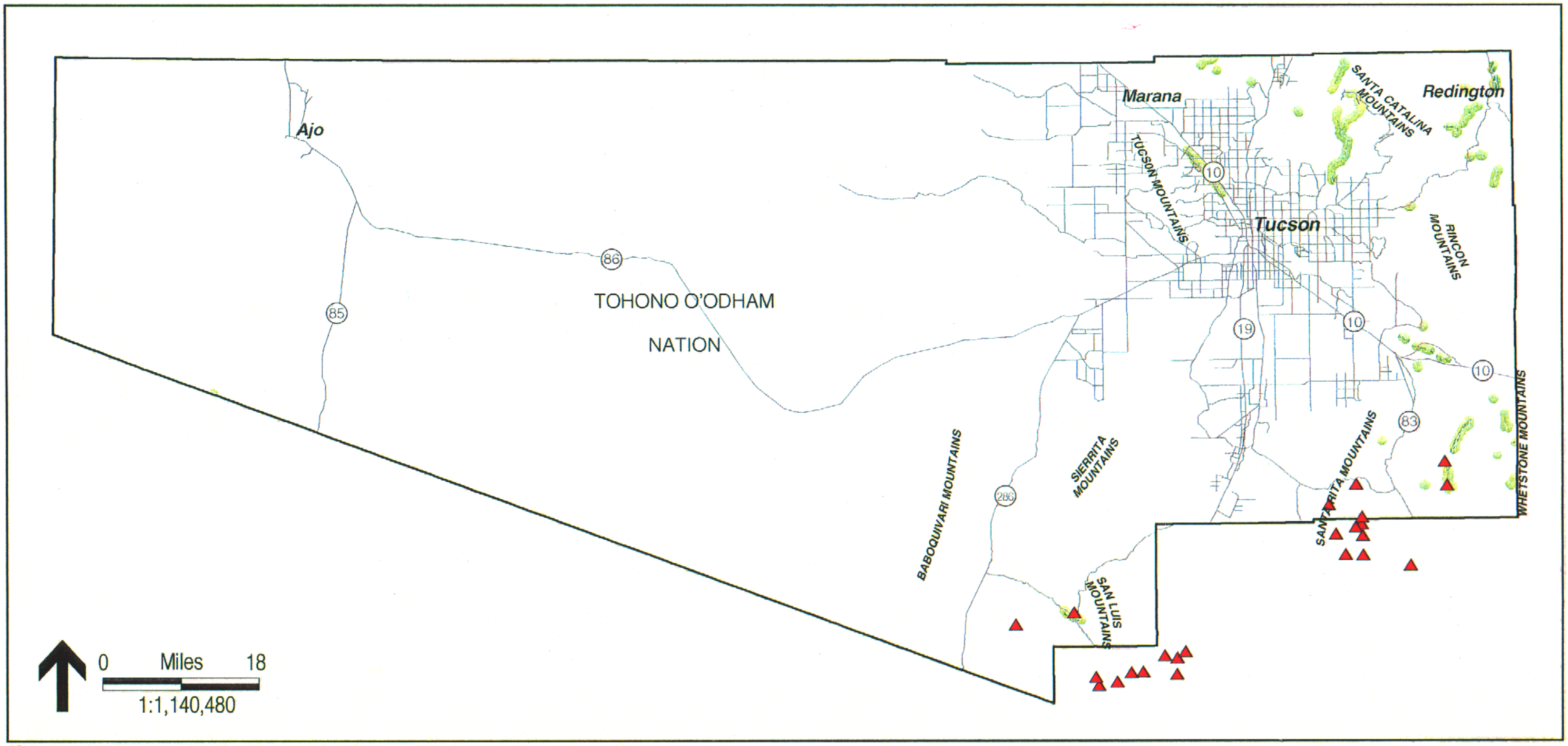
Potential habitat for this species is shown in Figure 31. All potential habitat is predicted within one-half mile of perennial streams. The largest areas of high potential habitat occur in San Pedro River, Santa Cruz River, and Cienega Creek. HDMS records exist only for the upper end of Cienega Creek, Arivaca Creek, and other water sources in the San Luis and Santa Rita Mountains, with the largest concentration of records in Santa Cruz County.

Predators prevent the Chiricahua leopard frog from inhabiting otherwise suitable habitat in Pima County, so more potential habitat appears from the model than is occupied by the species. GIS coverage for other perennial water sources, such as ponds, in the land cover data layer need to be verified and incorporated.

26. Lowland leopard frog (*Rana yavapaiensis*)

This species is restricted to permanent waters and seems to prefer small to medium streams over ponds and other aquatics habitats. Adults seem to prefer large pools for reproduction, and juveniles do well in small pools and marsh habitats. Populations typically occur in aquatic systems with surrounding Sonoran desert scrub, semidesert grassland, or Madrean evergreen woodland upland vegetation communities. Both aquatic and adjacent terrestrial habitats are necessary for this species to forage for invertebrates. The lowland leopard frog has been recorded in the Rincon Mountain District of Saguaro National Park, and a large population exists in Cienega Creek County Park.

The potential habitat distribution model for this species can be described by the hydrology, elevation, and vegetation data sets. In the hydrology data set, perennial streams and springs are the most important features due to this species' dependence on water. Intermittent streams were also considered but at a lower value level. The elevation range can span from 200 to 1800 meters, but most known occurrences for this species are in the 600- to 1600-meter range. Important adjacent vegetation land cover types that can identify potential suitable habitat include



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Chiricahua Leopard Frog *(Rana chiricuahuensis)* Modeled Potential Habitat

Figure 31

riparian mixed-scrub, cottonwood-willow, and mixed broadleaf. Also considered in the model, but at a lower importance value, were mesquite, creosote-bursage, and paloverde-mixed cacti.

Habitat characteristics for lowland leopard frog are scored in data layers for each variable then summed as follows:

> Elevation + Perennial Streams + Intermittent Streams + Springs + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 32. Predicted distribution of lowland leopard frog is very similar to Chiricahua leopard frog (occurring only within one-half mile of perennial streams) except that higher elevations appear as lower potential. HDMS records are much more widely distributed than Chiricahua leopard frog.

The current model predicts habitat in all the places where HDMS records exist. HDMS records are absent in lower Cienega Creek where the model predicts high potential habitat. The model should be modified to include other perennial water sources such as ponds. Also, distance to adjacent water and scoring of habitat characteristics near water should be examined.

27. Longfin dace (*Agosia chrysogaster*)

The requirements for this fish species include moving water with sandy or fine gravelly bottoms, preferably with little to moderate slope. Typical habitat occurs in mountain and desert streams with a variety of adjacent vegetation communities. Apparently, this species can coexist with some non-native species, but may do better where there are none. The longfin dace is omnivorous and opportunistic, feeding on whatever is available. In Pima County this species occurs primarily in Cienega Creek in Springwater Canyon and also was recorded in Buehman Canyon.

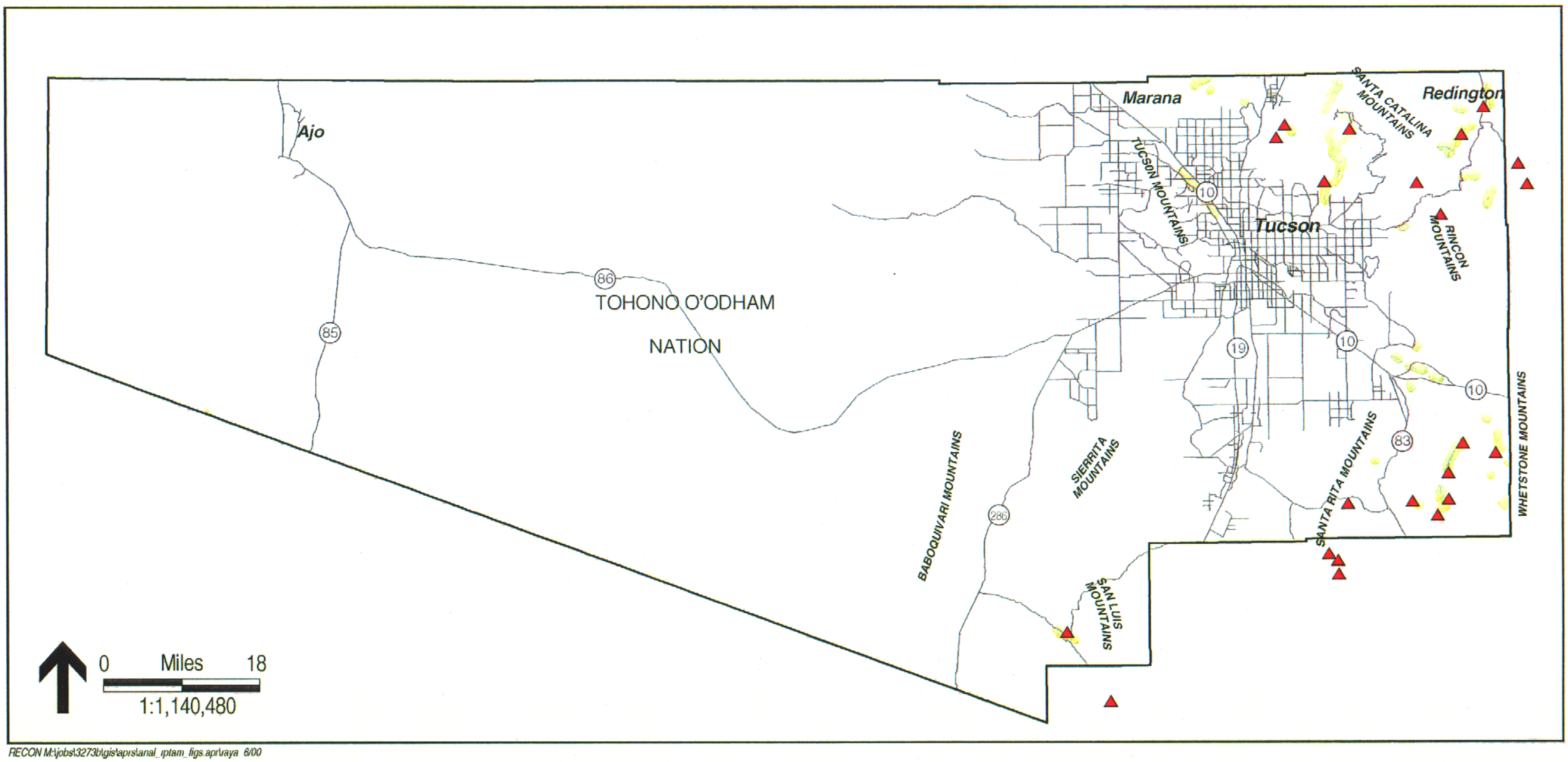
The habitat characteristics that best describe the potential distribution for this species are hydrology and elevation. This elevation range for this species spans from 0 to 1400 meters, with most known occurrences in the 400- to 1200-meter range. In the hydrology data set, the most important characteristic is perennial streams. The springs data set was also incorporated into the potential habitat distribution model for this species but at lower values of importance.

Habitat characteristics for longfin dace are scored in data layers for each variable then summed as follows:

> Elevation + Perennial Streams + Springs = Potential Habitat

Potential habitat for this species is shown in Figure 33. GIS coverages for perennial streams and springs define the extent of modeled habitat for longfin dace. Streams are valued over springs and potential habitat within each is defined by elevation.

HDMS records for this species occur only along San Pedro and Cienega Creek, although physical habitat features are probably suitable in other predicted locations. Some consideration should be given to identifying important characteristics within streams to differentiate higher and lower potential.



Lowland Leopard Frog *(Rana yavapaiensis)* Modeled Potential Habitat

Pima County Boundary

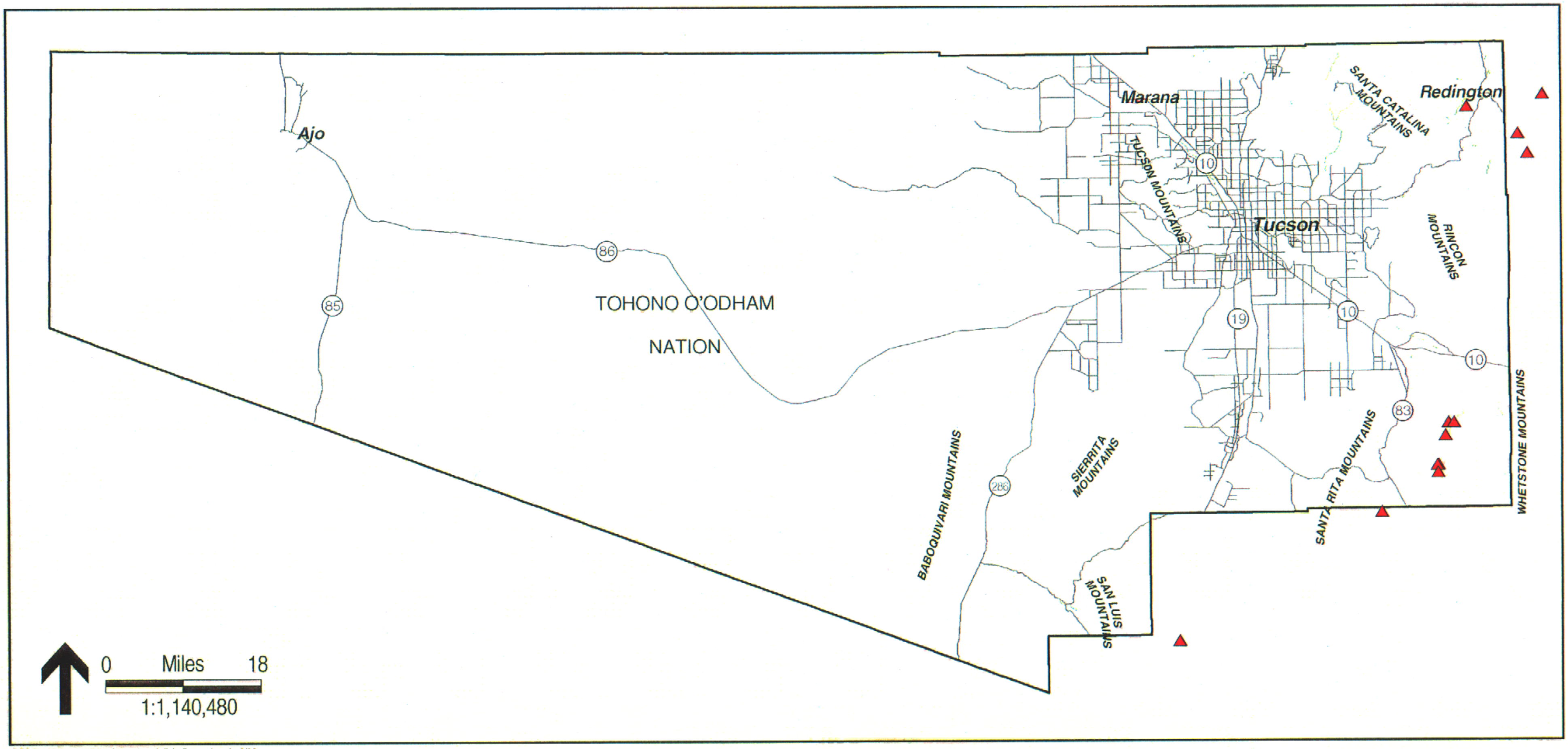
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)

- No Potential
- Low Potential
- Medium Potential
- High Potential

Known Locations
▲ (HDMS, 2000)

Figure 32



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Longfin Dace *(Agosia chrysogaster)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(HDMS, 2000)

Figure 33

28. Desert sucker (*Pantosteos clarki*)

The desert sucker is found in rapids and flowing pools of streams, mostly over bottoms of gravel-rubble with sandy silt in the interstices. This fish can tolerate a wide range of water temperature and requires a wide range of aquatic habitats. Specific habitat usage for the desert sucker is life-stage specific with larvals using backwaters, embayments, and pools while juveniles use faster-flowing rapids and adults prefer deeper pools and pool-like areas. Apparently this species does better in the absence of non-natives but may coexist with some. There are no known records of this species in Pima County.

The lack of known records of this species in Pima County seems to suggest a lack of suitable habitat; however, known HDMS records along the San Pedro River near the county line. It is still possible that this species could become established in Pima County, and the habitat characteristics that best describe potential distribution are hydrology and elevation. Potential suitable habitat for this species is indicated by the perennial stream characteristic of the hydrology data set. Other hydrology characteristics considered at low-level value include the spring and ponds data sets. Most known occurrences for this species occur in the 200- to 2200-meter elevation range; however, this species may also occur at slightly higher elevations of 2200 to 2800 meters. These elevation characteristics were incorporated into the potential distribution for this species accordingly. The critical landform characteristic for this species is valley fill.

Habitat characteristics for desert sucker are scored in data layers for each variable then summed as follows:

Elevation + Perennial Streams + Springs = Potential Habitat

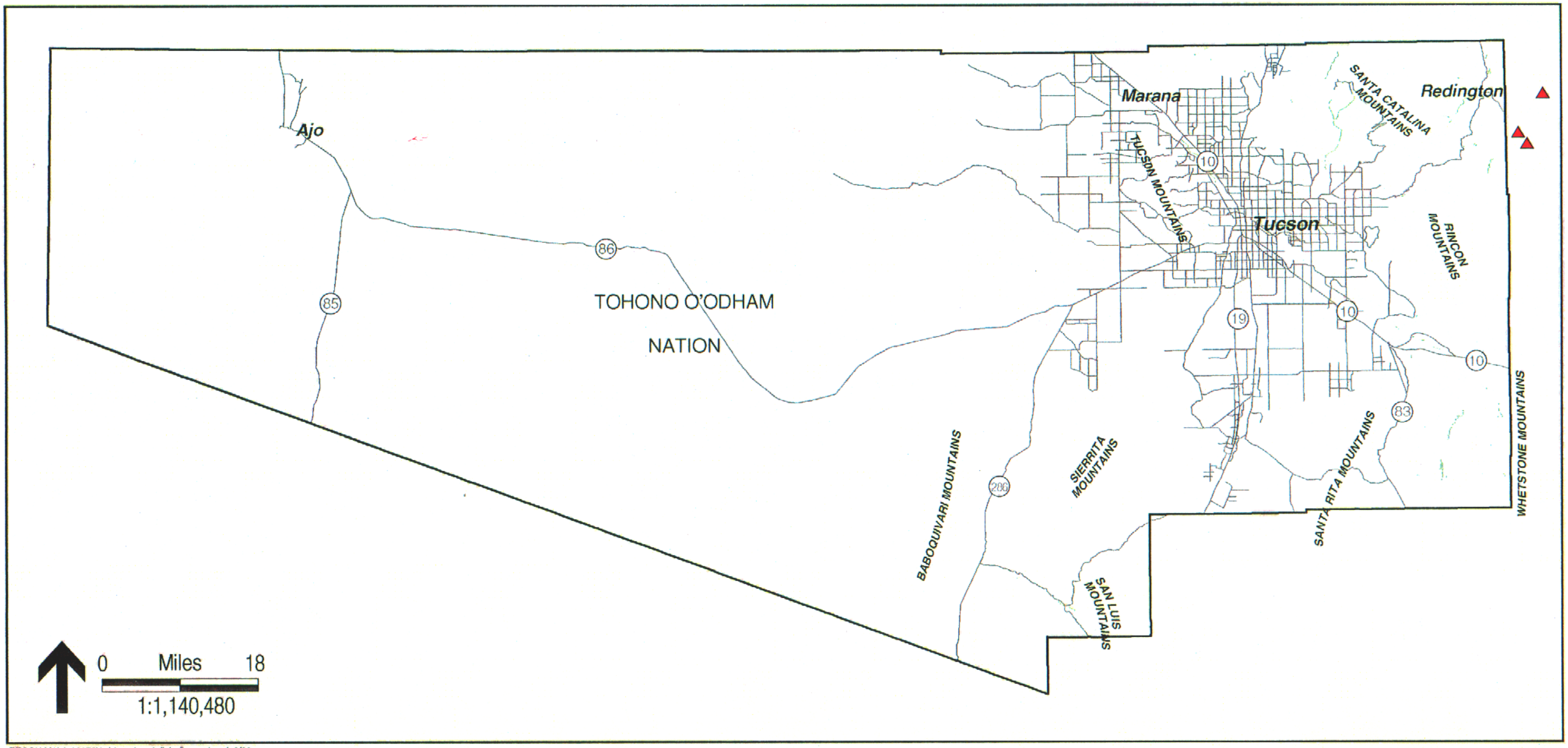
Potential habitat for this species is shown in Figure 34. GIS coverages for perennial streams and springs define the extent of modeled habitat for the desert sucker. Streams are high potential, springs are low potential, and potential habitat within each is defined by elevation.

HDMS records for this species occur in Cochise County near the San Pedro River but not in Pima County due to biological and possibly hydrologic factors. Stream bottom and stream flow may be important for this species, but these do not currently exist in the GIS data set for streams. Ponds are not currently included as potential habitat but could be incorporated.

29. Sonoran sucker (*Pantosteos insignis*)

This is a larger fish species that typically occurs in streams with pools and gravel substrate. Its preference for gravel or rocky bottoms in pools is indicated by shallow slopes. This omnivorous fish feeds on the bottoms of shallow pools and deposits its eggs into the interstices between gravel. Permanent water is crucial for this species to persist. There are no known records in Pima County, which suggest that there is no suitable habitat. Because this species requires rivers or streams with deep, quiet, gravelly pools, they are intolerant of lake or pond conditions created by dams.

With proper protection and management of the Aravaipa Creek canyon area, this species could potentially become reestablished in Pima County. The habitat characteristics that best describe the potential distribution for this species is the perennial stream data set. The spring and pond characteristics in the hydrology data set were also incorporated into the model at the low value



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Desert Sucker *(Pantosteos clarkii)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
▲ (HDMS, 2000)

Figure 34

importance level. The preferred elevation range for this species appears to be between 200 and 2200 meters. The critical landform characteristic is valley fill.

Habitat characteristics for Sonoran sucker are scored in data layers for each variable then summed as follows:

Elevation + Perennial Streams + Springs + = Potential Habitat

Potential habitat for this species is shown in Figure 35. Modeled distribution for this species is nearly identical to the desert sucker except that elevations above 2200 meters are considered no habitat for the Sonoran sucker. Perennial streams and springs are included in the model but ponds are not. There are no HDMS records for this species in Pima County, but it is known to occur in Cochise in the same area as the desert sucker. Hydrologic factors such as stream bottom and stream flow may be important for this species and could be incorporated into the model. It is likely, however, that the physical characteristics of most predicted habitat are suitable but that biological factors prevent the species from occurring there. Biogeographical factors of dispersal should be examined and incorporated into the models for all fish.

30. Desert pupfish (*Cyprinodon macularius macularius*)

This species typically occurs in rivers, streams, springs, or ponds with a broad range of water quality and temperature. It is omnivorous, consuming small invertebrates, algae, and aquatic vegetation. This species does not do well with non-native fish or other competitors. This species does not exist in Pima County, except in captivity at the International Wildlife Museum in the Tucson Mountains. Due to its ability to tolerate a broad range of water quality and temperature, this species could fair well under protection, enhancement, and reintroduction efforts. Potentially suitable habitat for reintroduction may exist in Cienega Creek Park, the Empire-Cienega Resource Conservation Area, Bingham Cienega, Arivaca Cienega and Creek, and possibly other locations.

The habitat characteristics for the potential distribution for this species are best represented by the hydrology data set. The possible elevation range for this species is 0 to 1600 meters. The most critical characteristic for the desert pupfish is the perennial streams data set. The springs data set was included in the potential distribution model, but at a low level of importance.

Habitat characteristics for desert pupfish are scored in data layers for each variable then summed as follows:

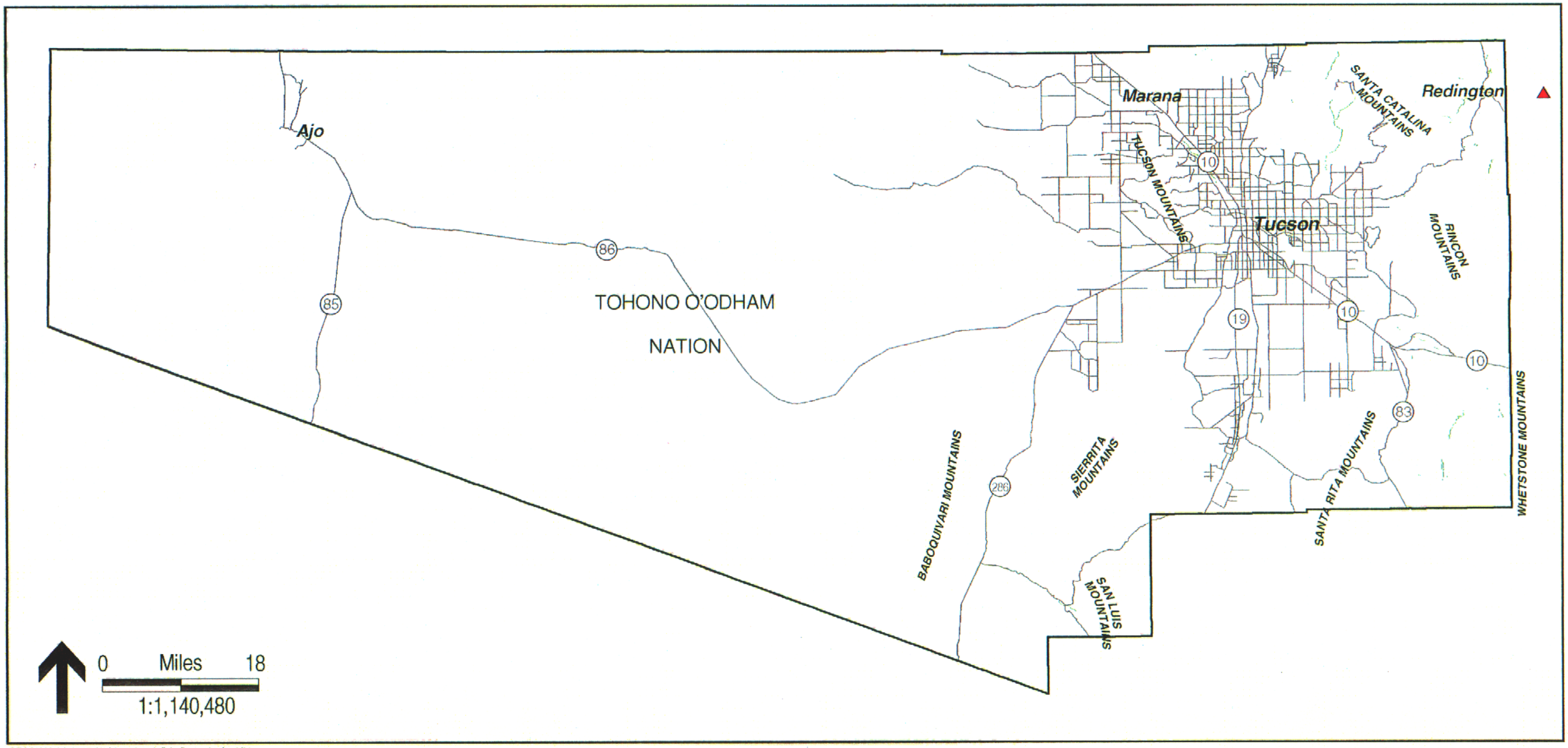
Elevation + Perennial Streams + Springs = Potential Habitat

Potential habitat for this species is shown in Figure 36. The extent of modeled potential habitat is represented by perennial streams and springs. Distribution is the same as for Sonora and desert sucker. There is one HDMS record for this species on the Santa Cruz River in Tucson.

Biological factors are the likely reason that physically suitable habitat is unoccupied. Ponds are not currently included as potential habitat but could be incorporated.

31. Gila chub (*Gila intermedia*)

This species is typically found in small headwater streams, cienegas, or marshes; however, it uses diverse habitat types based on the season and age of the fish. Adults prefer deep pools



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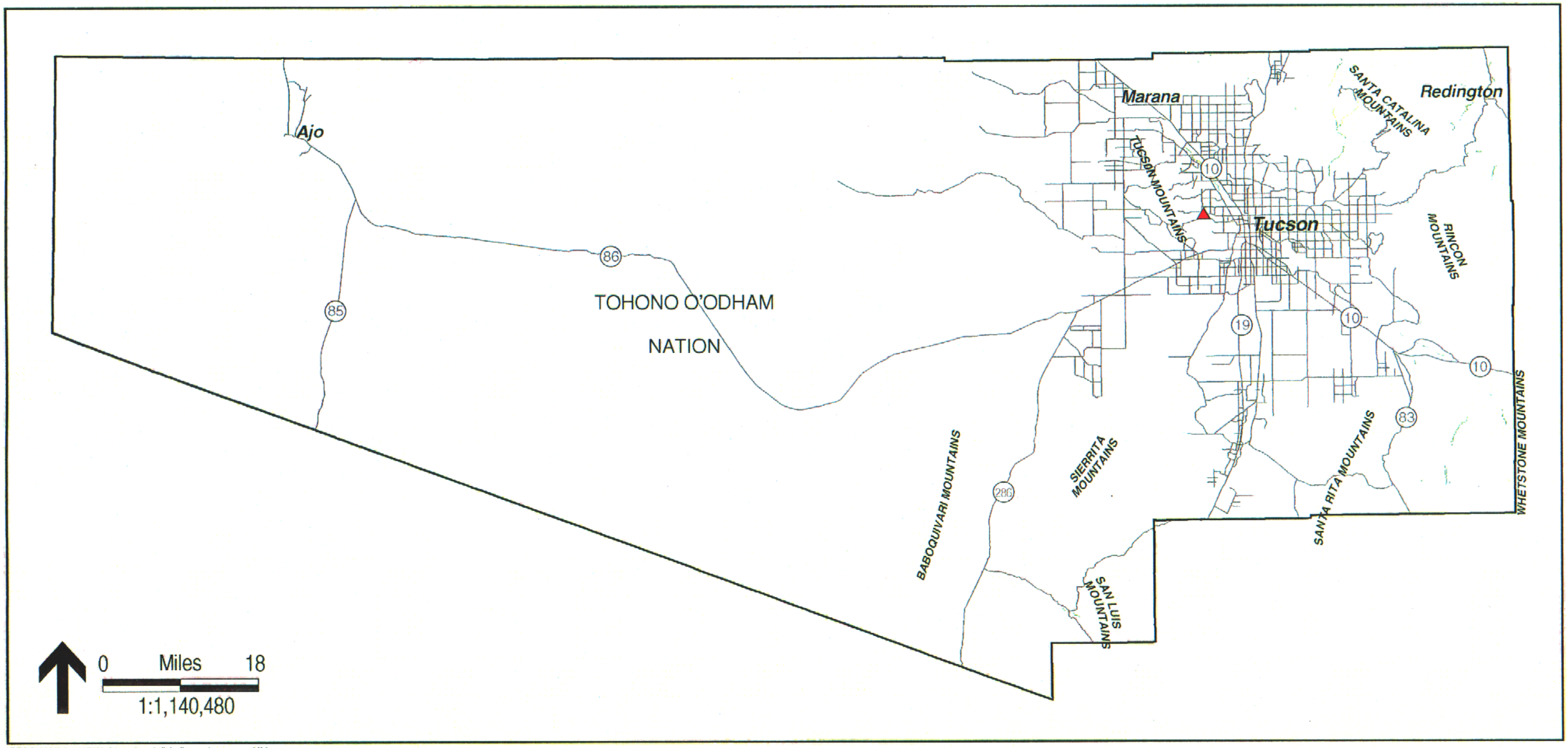
Sonoran Sucker *(Pantosteos insignus)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(HDMS, 2000)

Figure 35



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Desert Pupfish *(Cyprindodon macularius macularius)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
▲ (HDMS, 2000)

Figure 36

with heavily vegetated margins and undercut banks, while juveniles use small riffles, pools, and undercut banks of runs. This fish has an affinity for deeper pools in slow-velocity water, which is associated with cover such as undercut banks, root wads, and in-stream debris piles. This omnivorous fish feeds on insects and relies on beds of submerged aquatic vegetation for spawning. Requirements for the Gila chub include streams, cienegas, and marshes with adequate cover and food supply that is free of non-native species. There is a stable population of this species at Cienega Creek in Pima County, and there are other known occurrences at Redfield Canyon in the San Pedro drainage and at Sabino Canyon.

This species is restricted to permanent water and occupies an elevation range from 200 to 2000 meters, with most occurrences in the 800- to 1400-meter range. The critical habitat characteristic is the perennial stream data set, and at a low importance level, the springs data set was also considered in the model.

Habitat characteristics for Gila chub are scored in data layers for each variable then summed as follows:

Elevation + Perennial Streams + Springs = Potential Habitat

Potential habitat for this species is shown in Figure 37. The Gila chub modeled potential habitat appears the same as other fish except that high potential habitat appears in a more narrowly restricted elevation range. HDMS records exist along Cienega Creek and Sabino Creek with other populations a few miles east of the San Pedro in Cochise County.

Vegetation is not included in the model but may be important for discriminating preferred habitat along a stream. Dispersal limitations may explain why some streams do not have Gila chub even though the physical factors appear to make it suitable habitat. These should be investigated and incorporated into the model.

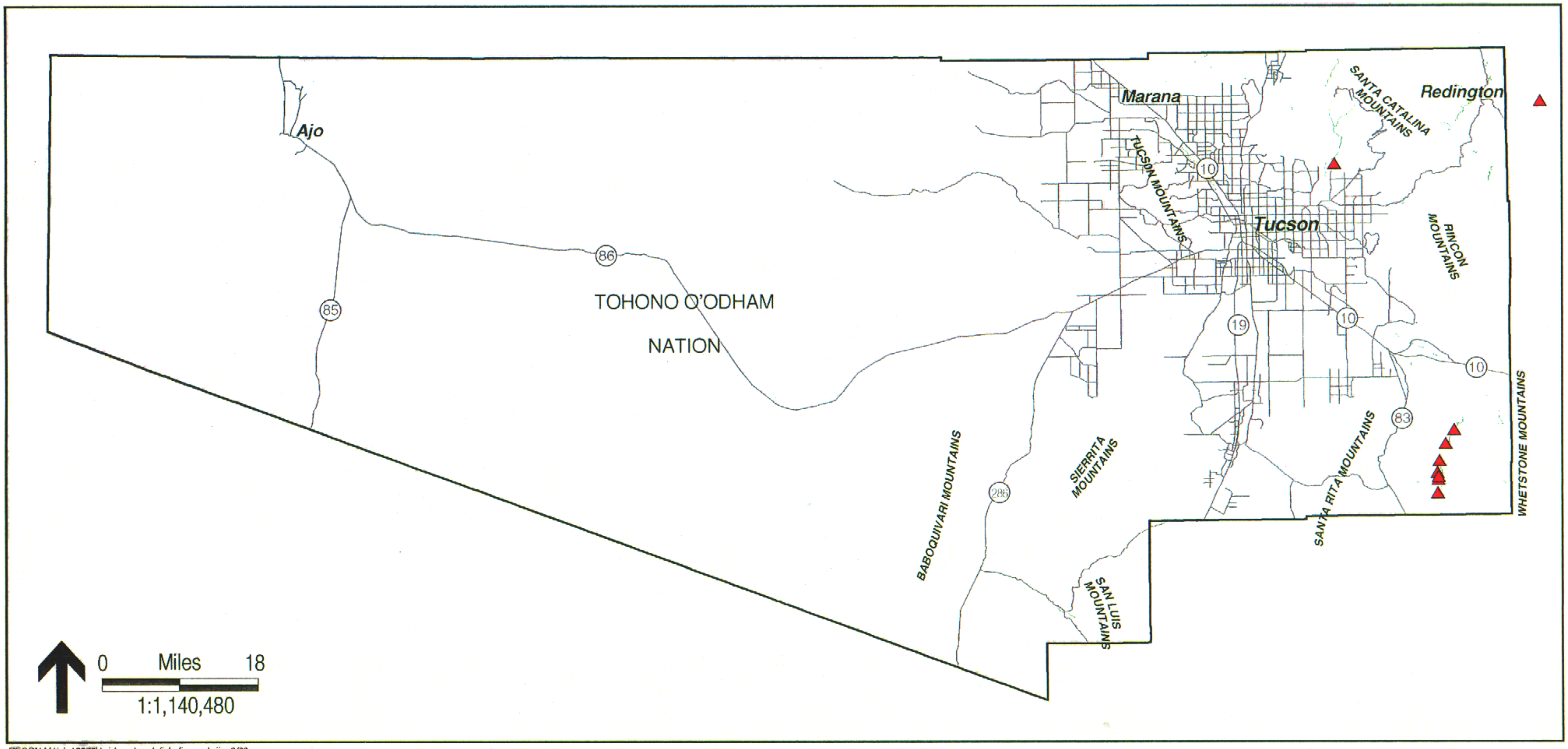
32. <u>Gila topminnow (*Poeciliopsis occidentalis occidentalis*)</u>

The basic habitat requirement for this species is permanent water that is free of non-native predators. While this species can tolerate a wide range of water temperature and quality, its preferred habitat contains dense mats of algae and debris with sandy substrates. The Gila topminnow consumes a broad spectrum of food; however, it does not do well in the presence of non-native fish. Typical aquatic habitat where this species may occur includes river, streams, cienegas, or ponds. A viable population of this species occurs in Cienega Creek on the Empire-Cienega Resource Conservation Area, and potential reintroduction sites include the Santa Cruz River, Cienega Creek drainages, and Agua Caliente Park.

The potential distribution for this species can be defined by the elevation and hydrology variables. This species can occupy an elevation range from 0 to 1600 meters, and the most important habitat characteristic is the perennial stream data set. The spring data set was considered in the model, but at a low importance value.

Habitat characteristics for Gila topminnow are scored in data layers for each variable then summed as follows:

Elevation + Perennial Streams + Springs = Potential Habitat



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Gila Chub *(Gila intermedia)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
▲ (HDMS, 2000)

Figure 37

Potential habitat for this species is shown in Figure 38. Modeled potential habitat for this species is exactly like that of the desert pupfish. HDMS records show that this fish is more broadly distributed, with most records along Cienega Creek and others in the foothills and higher elevations of the San Luis, Rincon, Santa Catalina, and Tucson Mountains.

Stream substrate may be important but does not currently exist in the GIS data. This species may occupy ponds, which should be incorporated. Some HDMS records appear where habitat is not predicted. These may be springs or perennial flow streams that are not in the GIS coverage.

33. Pseudoscorpion (*Albiorix anopthalmus*)

This small arachnid is an eyeless, cave-dwelling organism that probably is found nowhere else in the world. These creatures feed on tiny insects associated with crickets. Requirements for this species include a relatively pristine, undisturbed cave environment with limestone, high humidity, and crickets. This species is only known from Arkenstone Cave in Colossal Cave Mountain Park. It is not known whether it could potentially exist in other caves.

Habitat characteristics for pseudoscorpion are scored in data layers for each variable then summed as follows:

Carbonates = Potential Habitat

The known location for this species is shown in Figure 39. Potential habitat is not modeled for this species since it may be endemic to Arkenstone Cave. Mapping of caves and mines would show other potentially suitable locations.

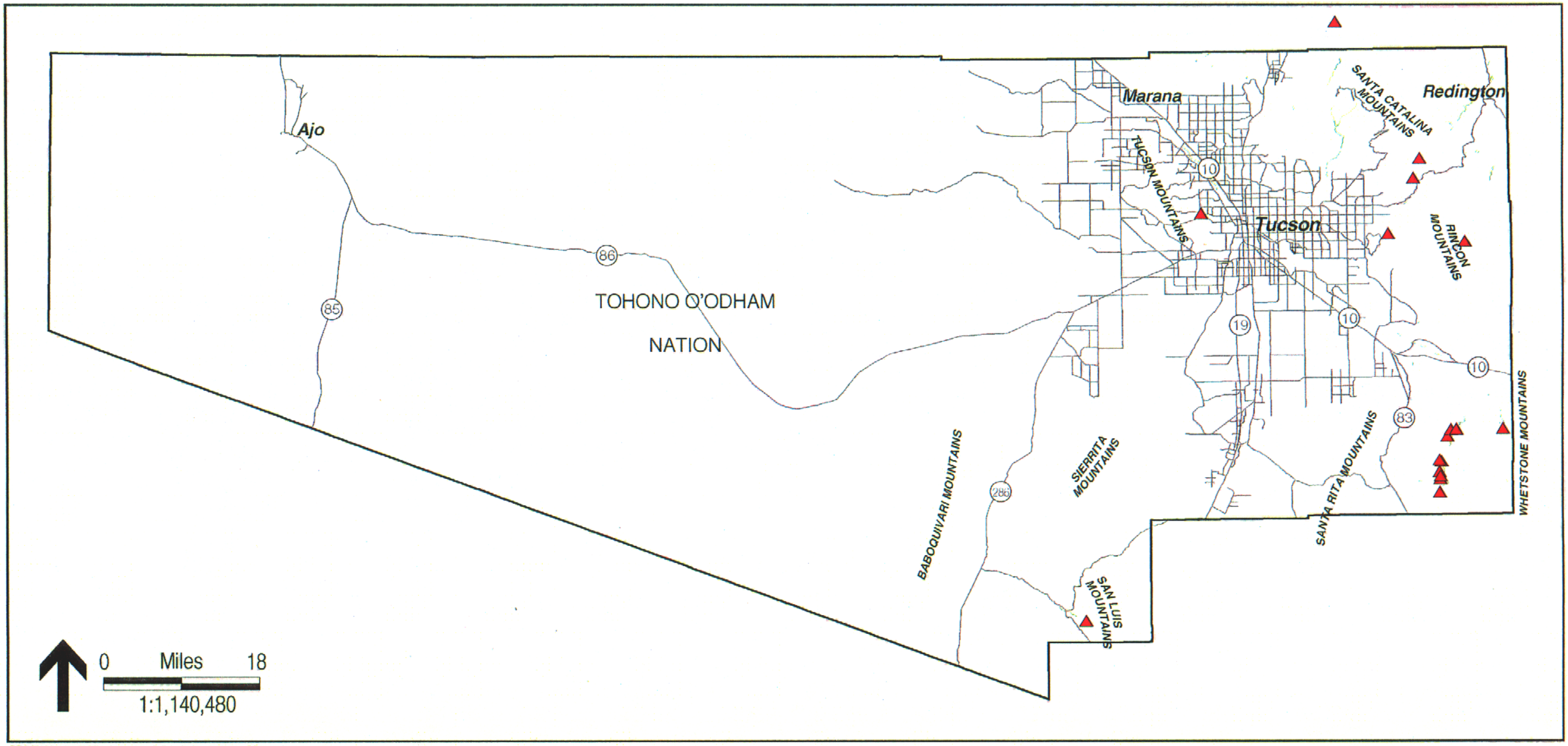
34. Talus snails (*Sonorella* spp.)

These species' only known requirement is limestone rock with cracks or talus formations. These small snails spend most of the year in dormant state in cracks and crevices between and under rocks. Apparently, all *Sonorella* species live in isolated, undisturbed areas of rocks, generally, or exclusively, limestone; mostly, if not exclusively, on north-facing or trending slopes; and usually near hilltops or in rocky canyons below 3,000 meters, although some species may live at higher elevations. Approximately 30 described species or local populations are recorded from Pima County and some of the known locations occur at Coronado National Forest, Saguaro National Park, Organ Pipe Cactus National Monument, Buenos Aires National Wildlife Refuge, and the Tohono O'odham Nation.

The habitat characteristics for the potential distribution for this species are best represented by the carbonate, slope, and elevation variables. Potential limestone outcrops and talus slopes are best represented by the carbonate and slope data sets. The important characteristics in the slope data set include steep slopes and, at a lower importance level, areas within one-half mile or two miles of a moderate to steep slope. The general elevation range occupied by these species spans from 600 to 2000 meters.

Habitat characteristics for talus snails are scored in data layers for each variable then summed as follows:

Elevation + Slope + Carbonates = Potential Habitat



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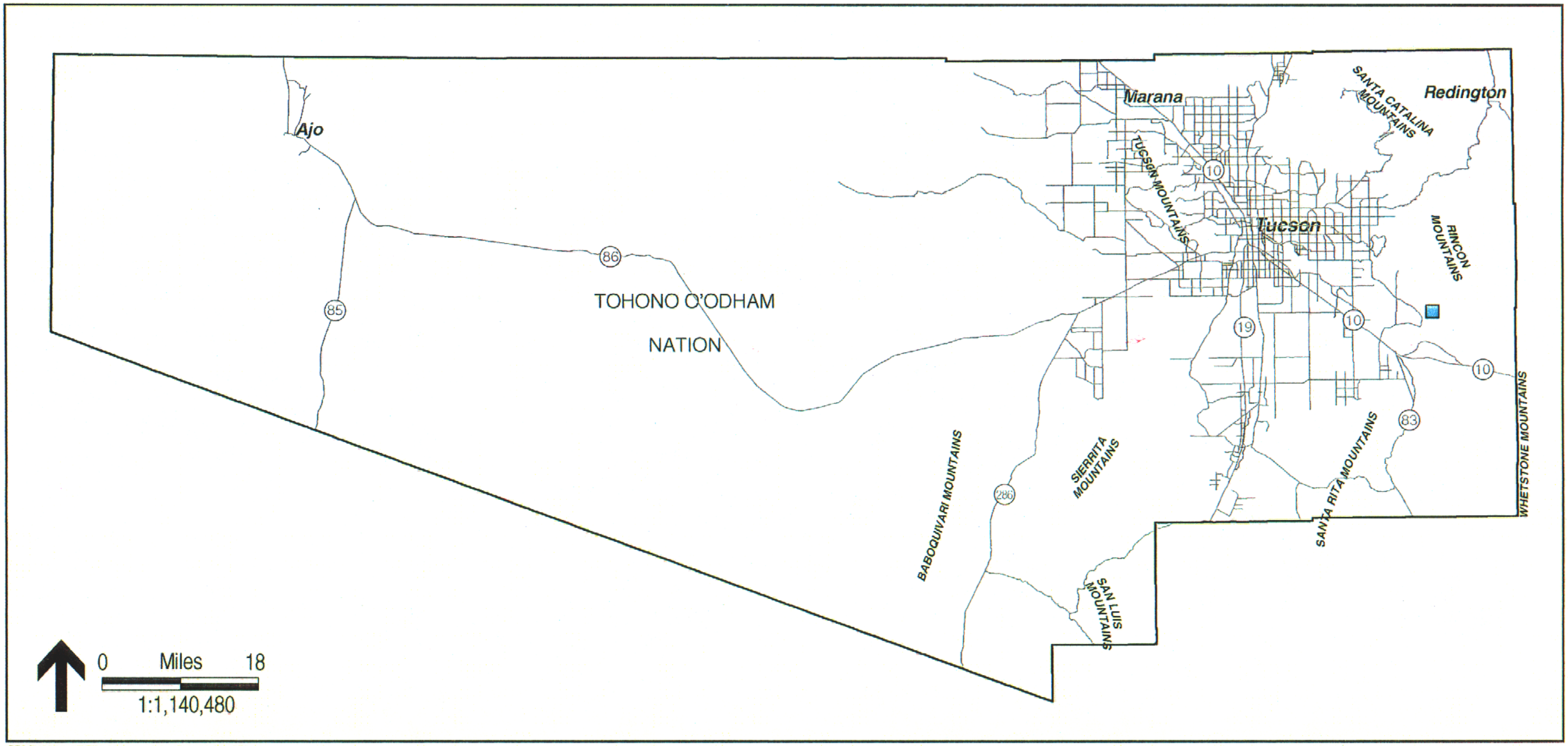
Gila Topminnow *(Poeciliopsis occidentalis occidentalis)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
▲ (HDMS, 2000)

Figure 38



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Pseudoscorpion *(Albiorix anophthalmus)* Known Location

Pima County Boundary
Major Road or Highway

Known Location
(SWCA, 2000)

Figure 39

Potential habitat for this species is shown in Figure 40. This model shows that talus snail habitat is potentially distributed throughout the county wherever there are steep slopes.

Slopes and the current carbonates coverage appear to be poor surrogates for talus slopes. Pima Association of Governments maps show only five or six talus slope areas. These could be digitized and incorporated into the model, but talus slopes will still be underrepresented. Better mapping of talus slopes is needed. Each *Sonorella* species is known from distinct geographic locations, probably because they evolved there and have limited ability to disperse. These biogeographical factors could be investigated and incorporated into separate models for each species.

35. Pima pineapple cactus (*Coryphantha scheeri robustispina*)

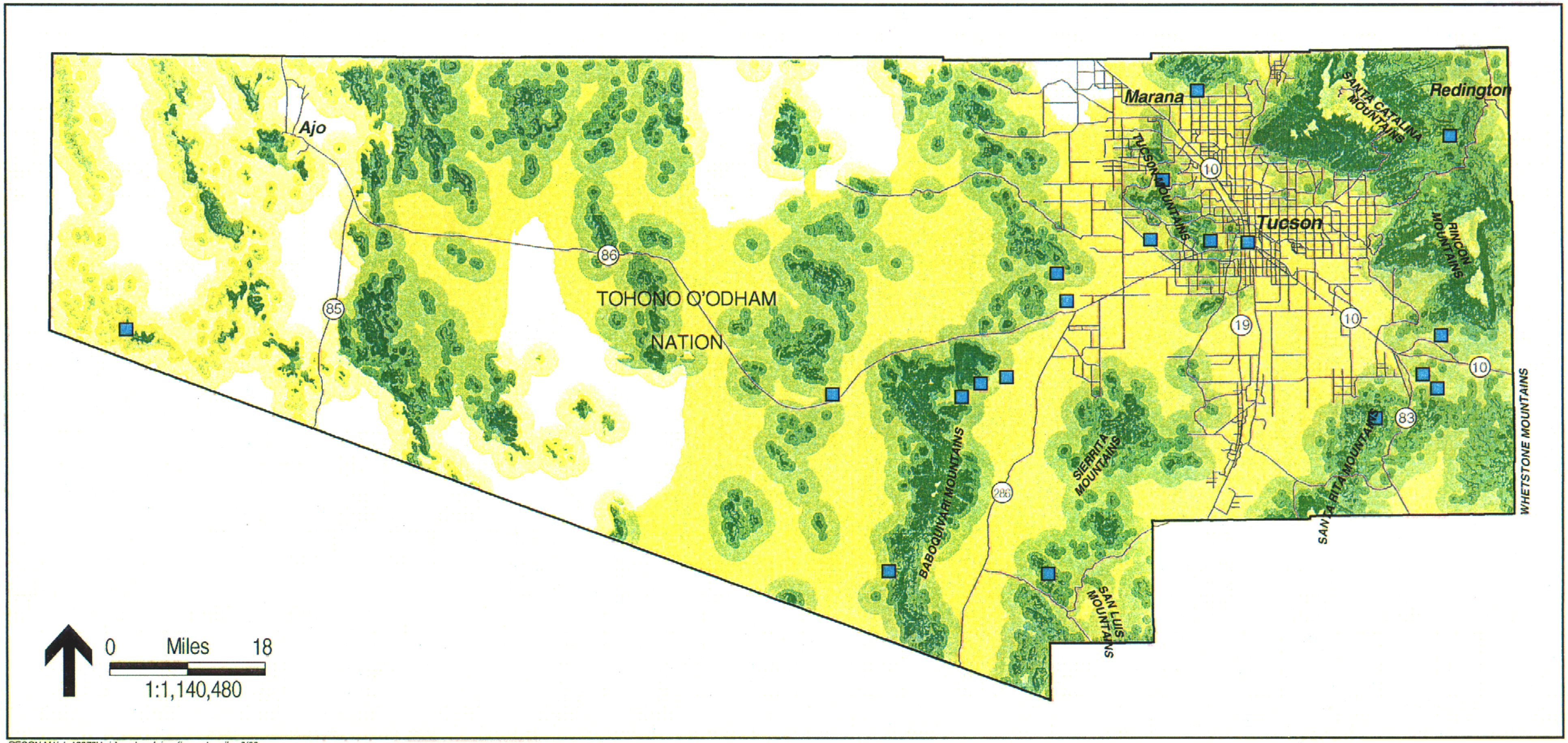
This succulent perennial cactus is found mostly along semidesert grassland and alluvial fans of Sonoran desert scrub. Usually this species occurs on flat ridgetops with little slope, in soils that are mostly rocky loams, and in open areas lacking dense grass cover. The requirements for this species are not well understood, but it appears to prefer well-drained soil. This species' limited range and sparsely distributed populations suggest specialized needs that require further research. The majority of the species' known range occurs in Pima County in Coronado National Forest, Buenos Aires National Wildlife Refuge, Tohono O'odham Nation, Bureau of Reclamation lands, Arizona State lands, and many private landowners.

The critical habitat characteristic for this species is valley fill, which is best represented by the slope data set. Areas having flat to little slope were most important when determining the potential distribution for this species. Areas within one-half of a mile of a moderate or steep slope were considered to be slightly important, but more important were areas within two miles of a moderate to steep slope. This species is known primarily from the 600- to 1400-meter elevation range with a few occurring at slightly higher elevations, between 1400 and 1600 meters. In the vegetation data set, the most important land cover type is mixed grass-scrub. Many land cover types were considered in the potential distribution model at a mid-importance level. These include mixed scrub, sacaton-scrub, shrub-scrub disclimax, creosote-bursage, and paloverde-mixed cacti. Other low-level value land cover types also considered in the model were encinal (oak) and mixed evergreen sclerophyll.

Habitat characteristics for Pima pineapple cactus are scored in data layers for each variable then summed as follows:

Elevation + Slope + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 41. Almost all areas in Pima County can be considered at least low potential habitat for this species, based on this model. The habitat model for the Pima pineapple cactus shows a large area of high potential habitat in central and east Pima County, corresponding with elevation ranges between 600 and 1400 meters and mixed grass-scrub vegetation. The majority of known locations are associated with medium and high potential habitat areas south of Tucson. The model for this plant species predict high potential habitat in the Cienega Creek Natural Preserve, where this species is already known to occur. Only 10 to 20 percent of the geographic range for this species is estimated to have been surveyed, and this species may occur elsewhere, possibly in portions of the Tohono O'odham Nation. The model predicts medium habitat potential in the urbanized Tucson area, which is unlikely; however, this species is known to occur in degraded grasslands and areas that were historically developed by agriculture, urban, and mining activities. The urban land cover type



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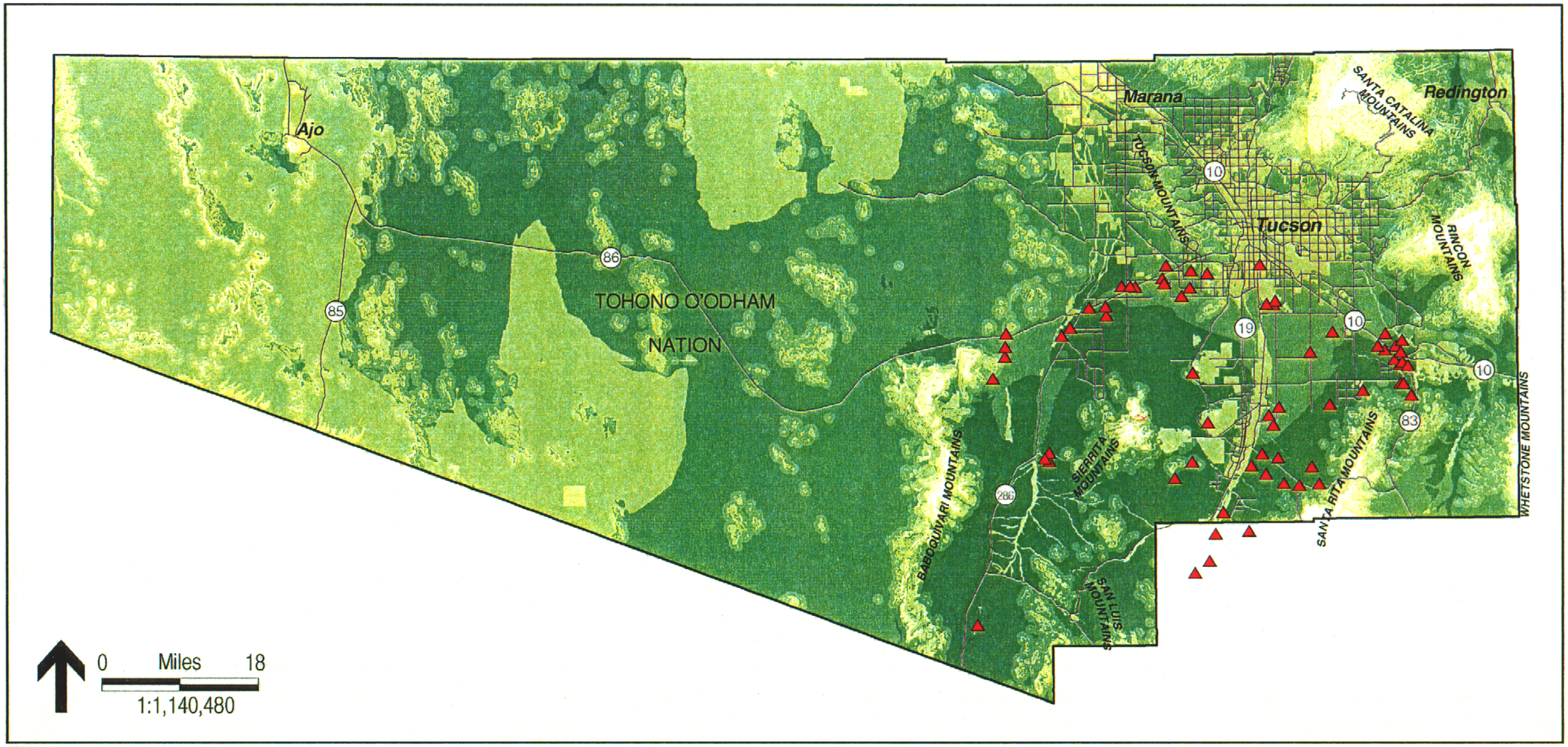
Talus Snails *(Sonorella spp.)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(SWCA, 2000)

Figure 40



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Pima Pineapple Cactus *(Coryphantha scheeri* var. *robustispina)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(HDMS, 2000)

Figure 41

should be refined, so that only appropriate land use types are included in the model for Pima pineapple cactus. This species' associations with disturbed environments and other species, such as kangaroo rats, are not clearly understood. A better understanding between the Pima pineapple cactus and its habitat requirements, including key species relationships, would improve model predictions. Improved land cover mapping, especially historic mapping in areas known to have undergone development, may lead to more accurate predictions. Also, mapping of species that are determined to have key relationships with this cactus, such as kangaroo rats, will improve the accuracy of this model.

This species is currently being investigated by the Science Technical Advisory Team (STAT) as a target, so additional information about dispersal mechanisms and key habitat relationships will likely become available.

36. Gentry indigo bush (*Dalea tentaculoides*)

This species is a shrubby, erect, perennial herb that grows from a woody root crown. It requires a substrate of sandy, gravelly loam and is often found in disturbance prone environments such as canyon bottoms subject to occasional flooding. This species typically occurs in rocky canyon bottoms with no close competition. This species can tolerate both shaded and exposed areas and typically occurs in oak-juniper woodland and Madrean evergreen woodland plant communities. Although this species is not known from Pima County, all of the potentially suitable habitat has not yet been searched, and some locations could be possible transplantation sites for this species.

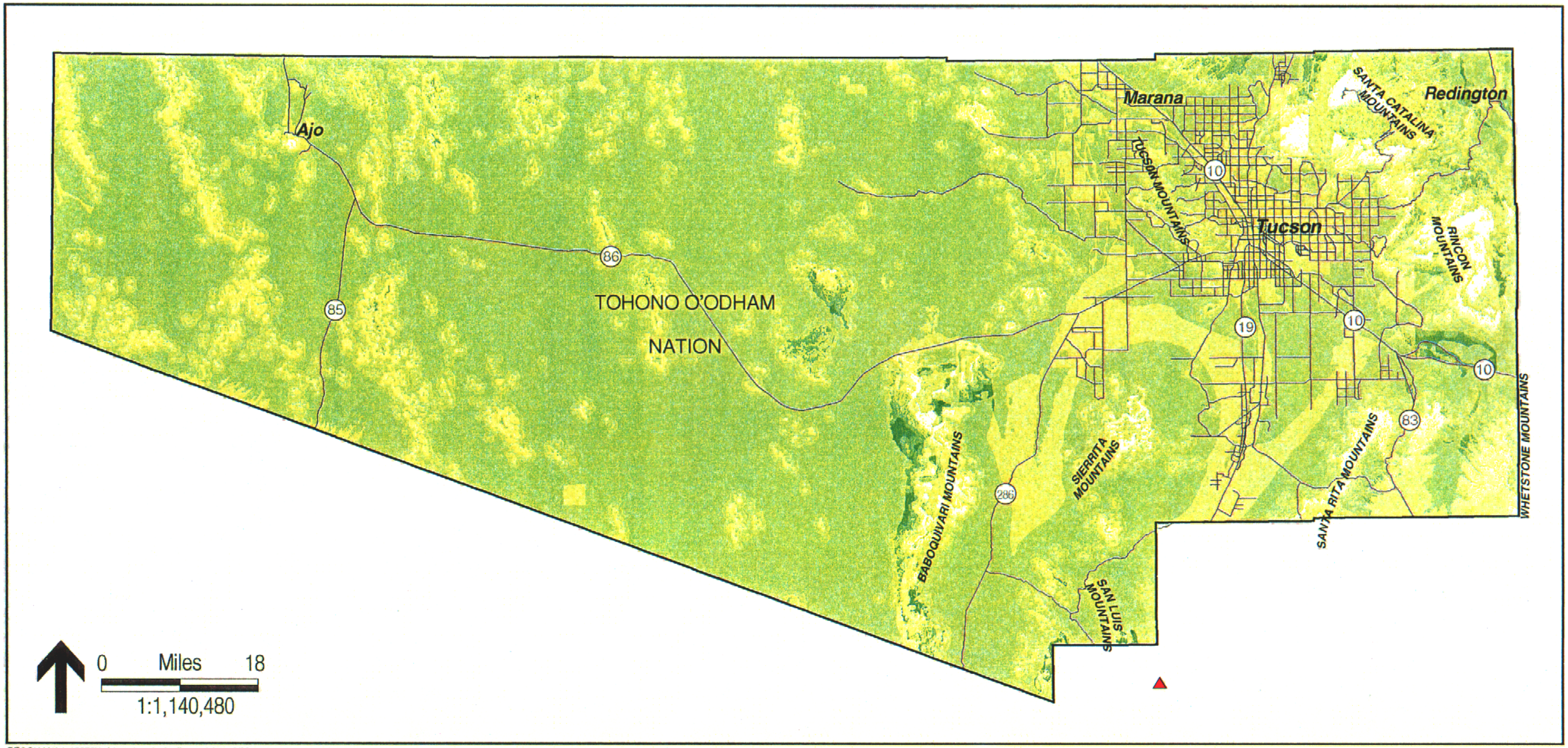
Canyon bottoms and valley fill are crucial for this species. These characteristics are best represented by the flat variable in the slope data set. The elevation range that best describes this species typical range is 1000 to 1400 meters. Land cover community types that are most important for this species include encinal (oak), oak-pine, mixed evergreen sclerophyll, and mixed broadleaf.

Habitat characteristics for Gentry indigo bush are scored in data layers for each variable then summed as follows:

Elevation + Slope + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 42. There are few areas of high potential habitat for this species: one band occurs in the Baboquivari Mountains and the other occurs in the Cienega Creek Natural Preserve Area. The model does predict high potential habitat along the south county border presumably extending into Santa Cruz County, where the largest known population of Gentry indigo bush occurs. In addition, the model predicts high potential habitat in the Baboquivari Mountains, and historic records indicate that this species was recorded there in the 1930s. Not all suitable habitat has been searched. While this species' affinity for disturbance-prone environments apparently limits the amount of high potential habitat, the medium potential habitat area covers a large portion of Pima County. Areas predicted as medium potential habitat should be further investigated to determine the accuracy of habitat assessment.

Soil data, if available, would improve the accuracy of this model. The Gentry indigo bush is associated with substrates of sandy, gravelly, loam rhyolite material, and the distribution of this soil type could potentially indicate habitat for this plant. Often, this plant occurs in disturbance-



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Gentry Indigo Bush *(Dalea tentaculoides)* Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat (RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
▲ (HDMS, 2000)

Figure 42

prone environments such as canyon bottoms that are subject to periodic flooding. Any mapped locations of these conditions would pinpoint areas where this plant is likely to occur.

37. Nichol's Turk's head cactus (*Echinocactus horizonthalonius* var. *nicholii*)

This plant is a small barrel cactus with a single stem that is restricted to limestone-derived soils. The dispersal of this plant's seeds typically occurs by birds and rainwater. This species inhabits talus slopes in Sonoran desert scrub typically on north-, west-, and south-facing slopes and is associated with paloverde-cactus shrub communities. In general, Nichol's Turk's head cactus is found in open vegetation characterized by few trees and scattered low shrubs. At lower elevations this species is found in gravely substrates, but at higher elevations it occurs in rocky areas. In the HDMS, all known occurrences of Nichol's Turk's head cactus are in Pima County. The largest population is at Waterman Peak, and other known occurrences are on lands owned by the Bureau of Land Management, Tohono O'odham Nation, Arizona State Lands Department, and private landowners.

The critical habitat characteristics for the potential distribution model of this species are landform, elevation, and vegetation. The carbonate data set is the best representation of limestone areas, which this species depends on. The important land cover type that this species is associated with is paloverde-mixed scrub, so this characteristic was considered in the model. The elevation range considered in the potential distribution model spans from 600 to 1200 meters.

Habitat characteristics for Nichol's Turk's head cactus are scored in data layers for each variable then summed as follows:

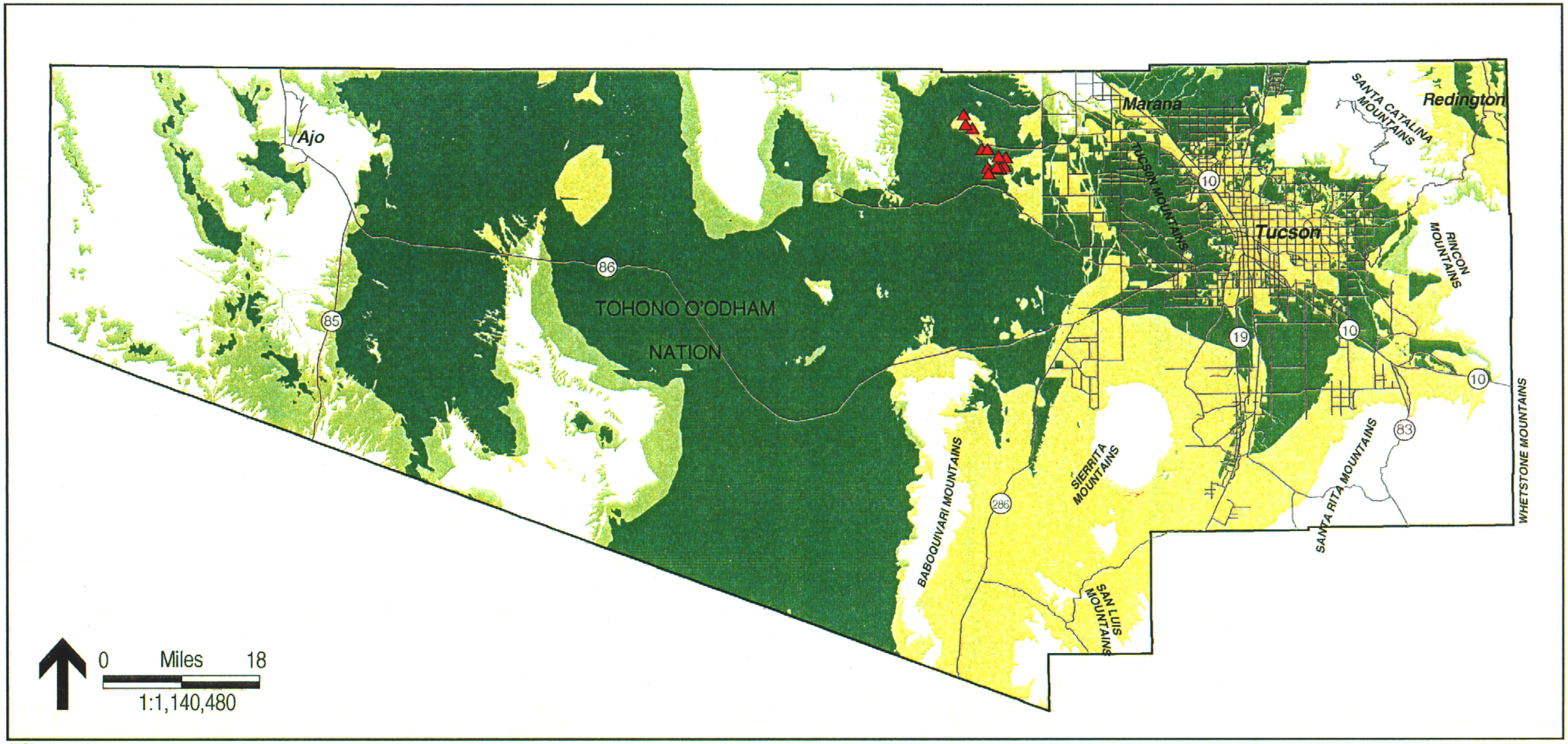
Elevation + Carbonates + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 43. This model predicts a large area of high potential habitat in central Pima County on the Tohono O'odham Nation and outside the city of Tucson, primarily based on distribution of paloverde-mixed cacti in the 600- to 1200-meter elevation range. The majority of known occurrences in Pima County, most of which are part of the Waterman Peak population, fall within the high potential habitat category, but are much more narrowly restricted.

The environmental conditions at this area should be investigated to further refine the parameters of this model. Another improvement to this model would be the inclusion of additional mapped information for carbonate, talus slopes, and soils. This plant species depends on limestone-derived soils and is likely to occur where these conditions exist.

38. Acuña cactus (*Echinomastus erectocentrus acuñensis*)

Little information is available regarding specific habitat requirements for this species; however, the rarity of this cactus may suggest specialized needs. Substrates associated with this species include granite and limestone hills and flats located in open areas. This cactus has been found in well-drained knolls and gravel ridges between major washes. Apparently this cactus is restricted to relatively pristine desert areas and does not survive substrate disturbance. Because this cactus is difficult to detect, it may be more common and widespread than is currently known. Only a very small portion of its potential range has been surveyed. Of the four known populations in the U.S., one occurs at Organ Pipe Cactus National Monument.



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Nichol's Turk's Head Cactus (*Echinocactus horizonthalonius* var. *nicholii*)
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(HDMS, 2000)

Figure 43

The critical requirement for this species is valley fill and this landform is best represented by the slope data set. Based on known location data, the most important characteristic to model the potential distribution for this species is flat areas within one-half mile of moderate or steep slopes. Flat areas within two miles of moderate or steep slopes were also important to the model, but at a low importance level. Other slope characteristics that were considered at a low importance level were flat, moderate, and steep slopes. Important elevation for this cactus ranges from 400 to 600 meters, with slightly higher and lower elevations considered at a lower importance level. The critical land cover types in the vegetation data set that considered in the model include creosote-bursage and paloverde-mixed cacti.

Habitat characteristics for Acuña cactus are scored in data layers for each variable then summed as follows:

Elevation + Slope + Vegetation = Potential Habitat

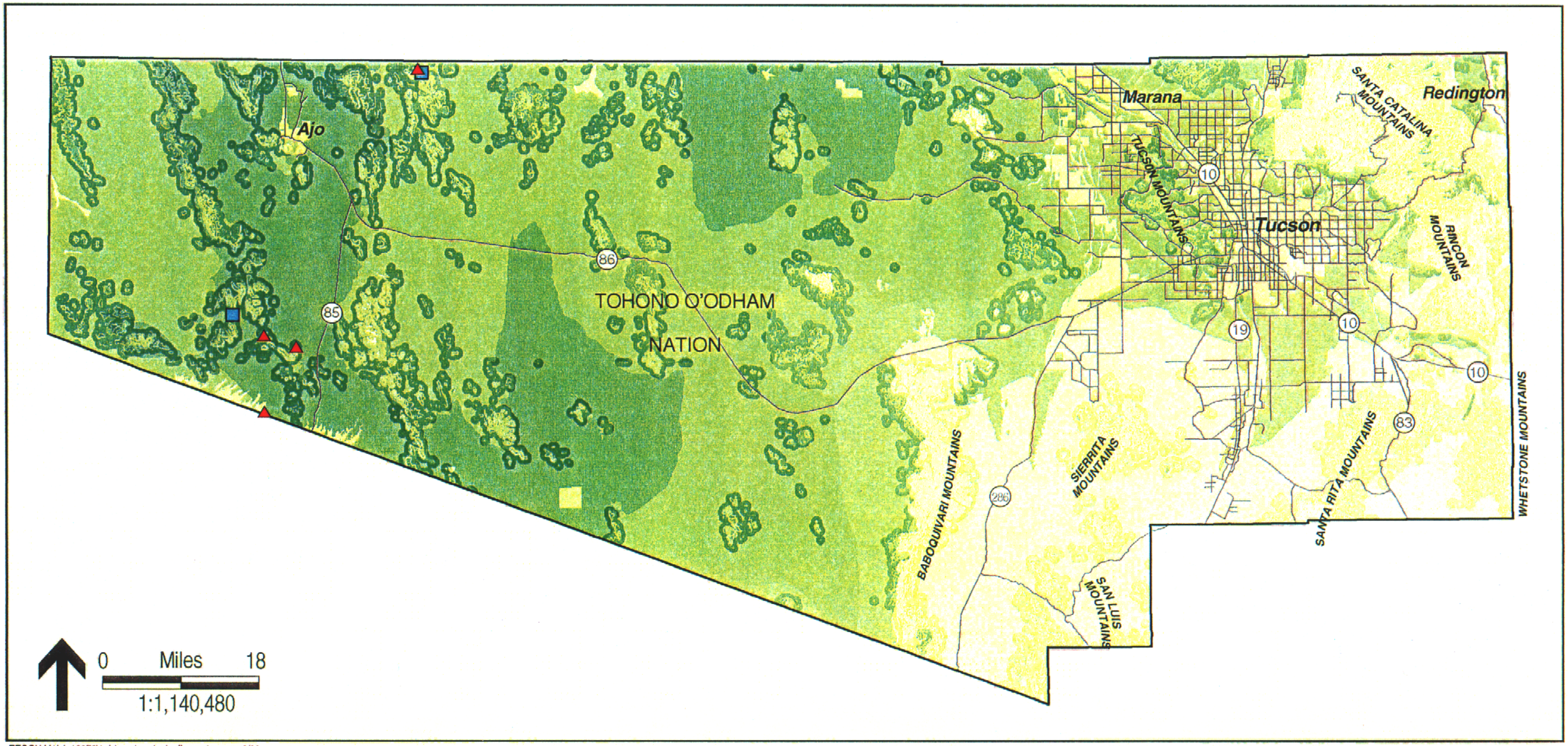
Potential habitat for this species is shown in Figure 44. The habitat model for the Acuña cactus shows narrow bands of high potential habitat surrounding steep mountain slopes. This model predicts high potential habitat well for known locations of this species. The model predicts medium potential habitat for most of central and western Pima County, which is supported by historic records of this species in Organ Pipe Cactus National Monument. There is little information regarding the habitat requirements for this species. This species may rarely occur because it may have specialized needs that are not yet understood or because only a small portion of its potential range has been surveyed. Areas of predicted high potential habitat should be investigated to determine if the species occurs here. Apparently, this species is restricted to relatively pristine desert areas and does not survive substrate disturbance. This model could be improved if areas of substrate disturbance were mapped and incorporated into the model. Population trends show that historic land use activities such as mining and livestock have contributed to the decline of this species. Inclusion of current and historic land use activity, coupled with the current composite land cover spatial data, would improve the predictions of this model.

39. Needle-spined pineapple cactus (*Echinomastus erectocentrus erectocentrus*)

This plant is a single-stemmed succulent cactus that is associated with Sonoran desert scrub and semidesert grassland. It is generally found on alluvial fans and hills on southern and western exposures. Substrates where this plant occurs consist of alluvial soils with rock and gravel over sandstone conglomerate and limestone outcrops. Pima County encompasses much of the known range of this variety, and one population is known to exist at Colossal Cave County Park. Populations of this species in Pima County appear to be scattered in a few locations and disjunct; however, large areas of potential range have never been searched adequately to find this species.

The potential distribution for this species can best be described by the elevation and vegetation variables. The elevation range for this species spans 800 to 1400 meters. Important land cover types considered in the model include mixed grass-scrub and paloverde-mixed scrub. Two other land cover types, sacaton scrub and shrub-scrub disclimax, were also included in the model but at a lower importance value.

Habitat characteristics for needle-spined pineapple cactus are scored in data layers for each variable then summed as follows:



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Acuña Cactus *(Echinomastus erectocentrus* var. *acuensis)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
(SWCA, 2000)
(HDMS, 2000)

Figure 44

Elevation + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 45. The model predicts a large area of high potential habitat in the southeastern portion of the county corresponding with mixed grass-scrub habitat. High elevation areas are excluded, as are urban areas. Known occurrences for this species are recorded around Cienega Creek Natural Preserve and slightly beyond the north and east county boundaries. This area should be further investigated to determine if model parameters should be refined. The general habitat characteristics predicted a fairly large area of potential habitat. Improving mapped features, such as limestone, carbonates, alluvial fill, and soils, that this species is associated with will increase the ability of this model to pinpoint habitat. Alluvial landforms and slope aspect could be modeled from existing DEM data and included as habitat variables.

40. Huachuca water umbel (*Lilaeopsis schaffneriana recurvata*)

The habitat requirements for this semiaquatic plant include perennial water, gentle stream gradients, and permanently wet substrate such as sand, mud, or silt for underground rhizome. This plant displays typical metapopulation dynamics, where clusters within each drainage are local populations that come and go as conditions change. Population size and density of Huachuca water umbel plants fluctuate in response to both flood cycles and changing site characteristics. This species occurs in slow-moving water, such as ponds and cienegas, within Sonoran desert scrub, grasslands, oak woodlands, or conifer forests. The only population in Pima County for which the HDMS has records is in Empire Gulch, a tributary of the Cienega Creek, which is managed by the BLM as part of the Empire-Cienega Resource Conservation Area. Given its dynamic metapopulation structure, it is possible that this species may also occur in Cienega Creek and may eventually become established within Cienega Creek County Park. Surveys of the entire Cienega Creek and its tributaries may reveal other populations.

The above habitat characteristics can be described by the hydrology, slope, and elevation variables. Because the Huachuca water umbel prefers gentle stream gradients, the important slope characteristic is flat areas. Critical hydrology characteristics that were considered in the model are the perennial and intermittent stream data sets, with more importance on the perennial stream data set. This plant typically occurs in the 1200- to 2000-meter elevation range.

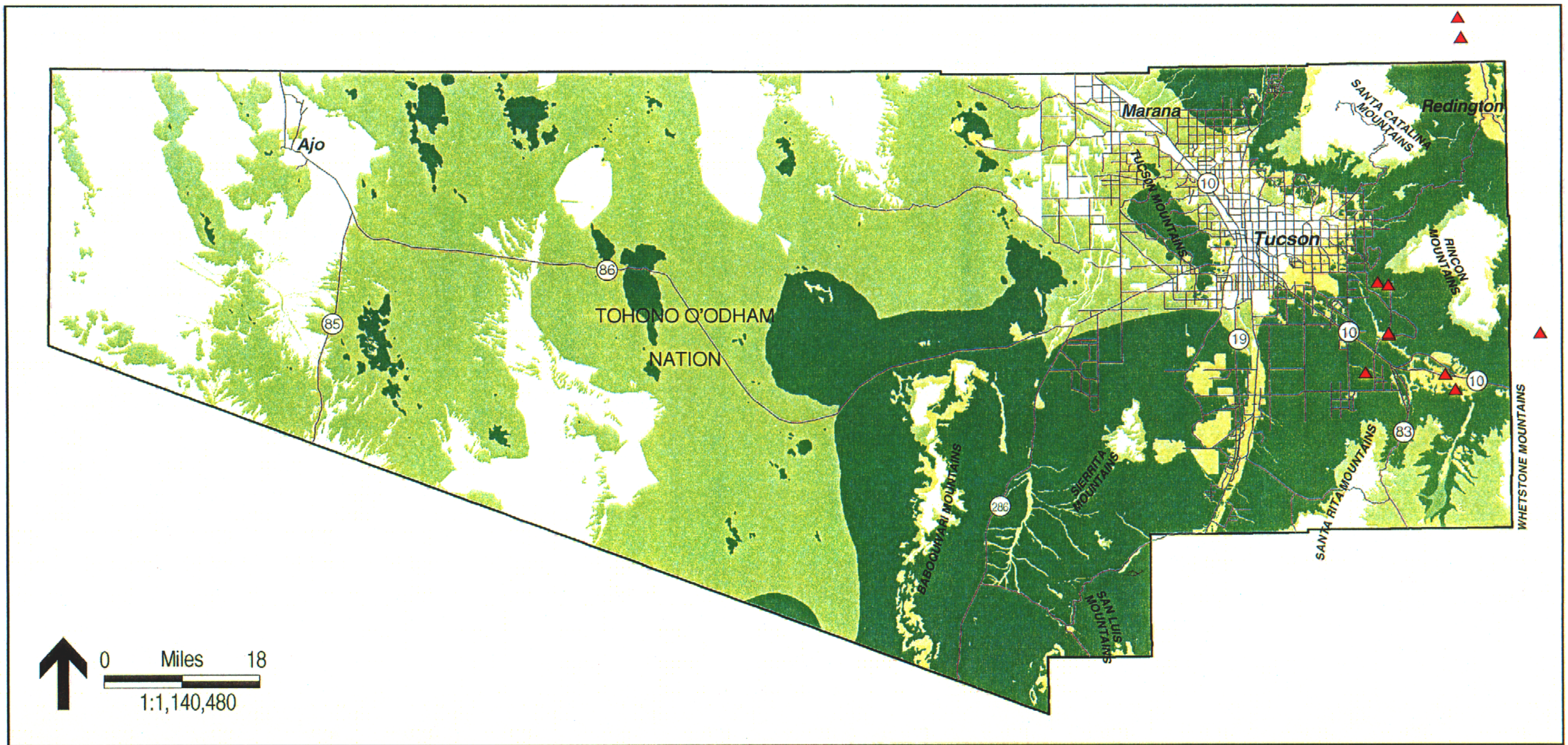
Habitat characteristics for Huachuca water umbel are scored in data layers for each variable then summed as follows:

Elevation + Perennial Streams + Intermittent Streams = Potential Habitat

Potential habitat for this species is shown in Figure 46. The extent of modeled potential habitat corresponds with perennial and intermittent streams. Ponds were not included in the model although some ponds could be habitat. Surveys to identify additional known location data would help to assess the validity of this model and possibly incorporate additional environmental factors controlling distribution.

41. Tumamoc globeberry (*Tumamoca macdougalii*)

This vine is almost always found climbing among shrubs and trees, which provide shade and support. This species is capable of occupying a wide range of habitats including coastal scrub communities, rocky loamy soils, hot and dry south-facing slopes of basalt, desert washes, and



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Needle-spined Pineapple Cactus *(Echinomastus erectocentrus* var. *erectocentrus)* Modeled Potential Habitat

Pima County Boundary

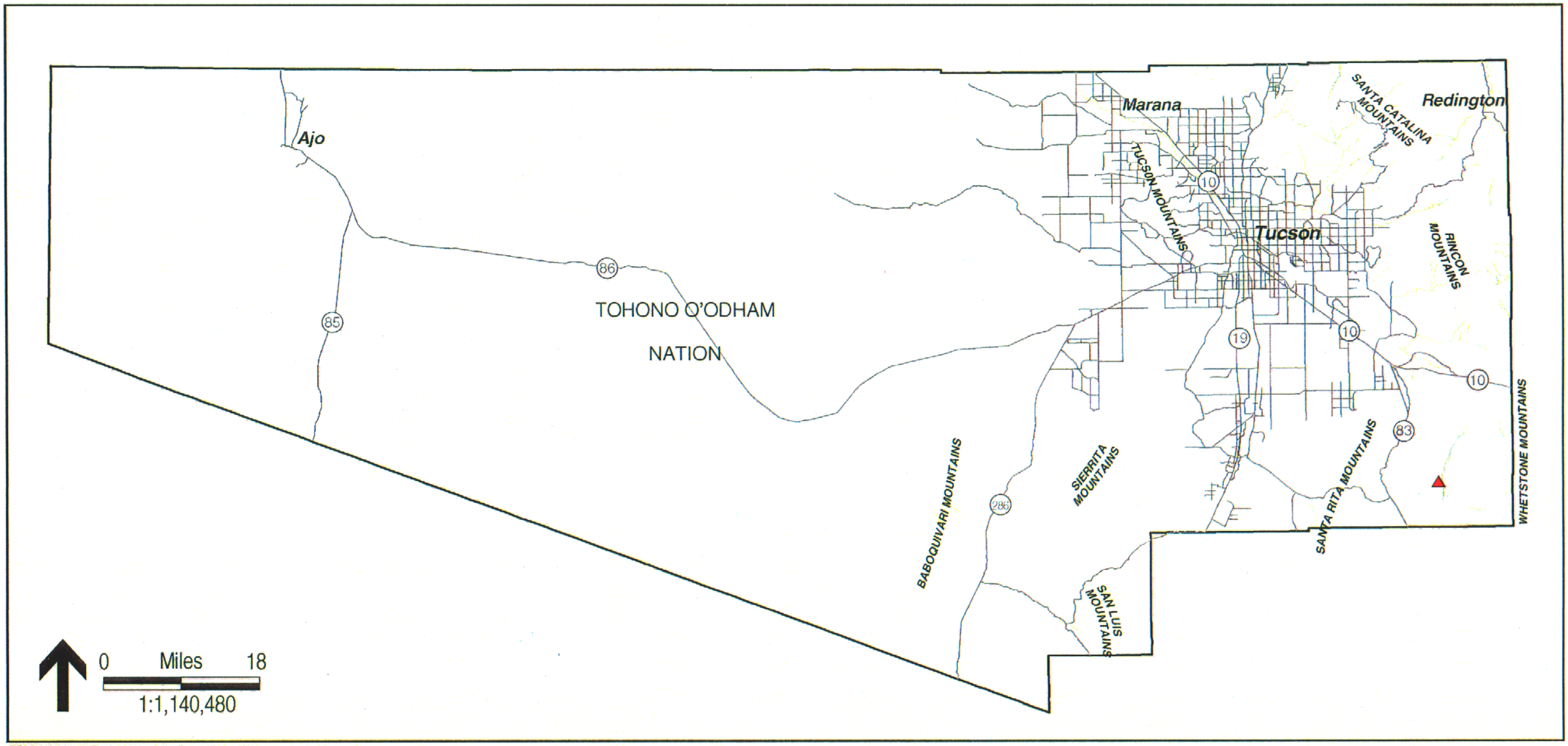
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)

- No Potential
- Low Potential
- Medium Potential
- High Potential

Known Locations
(HDMS, 2000)

Figure 45



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Huachuca Water Umbel *(Lilaeopsis schaffneriana* var. *recurva)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
▲ (HDMS, 2000)

Figure 46

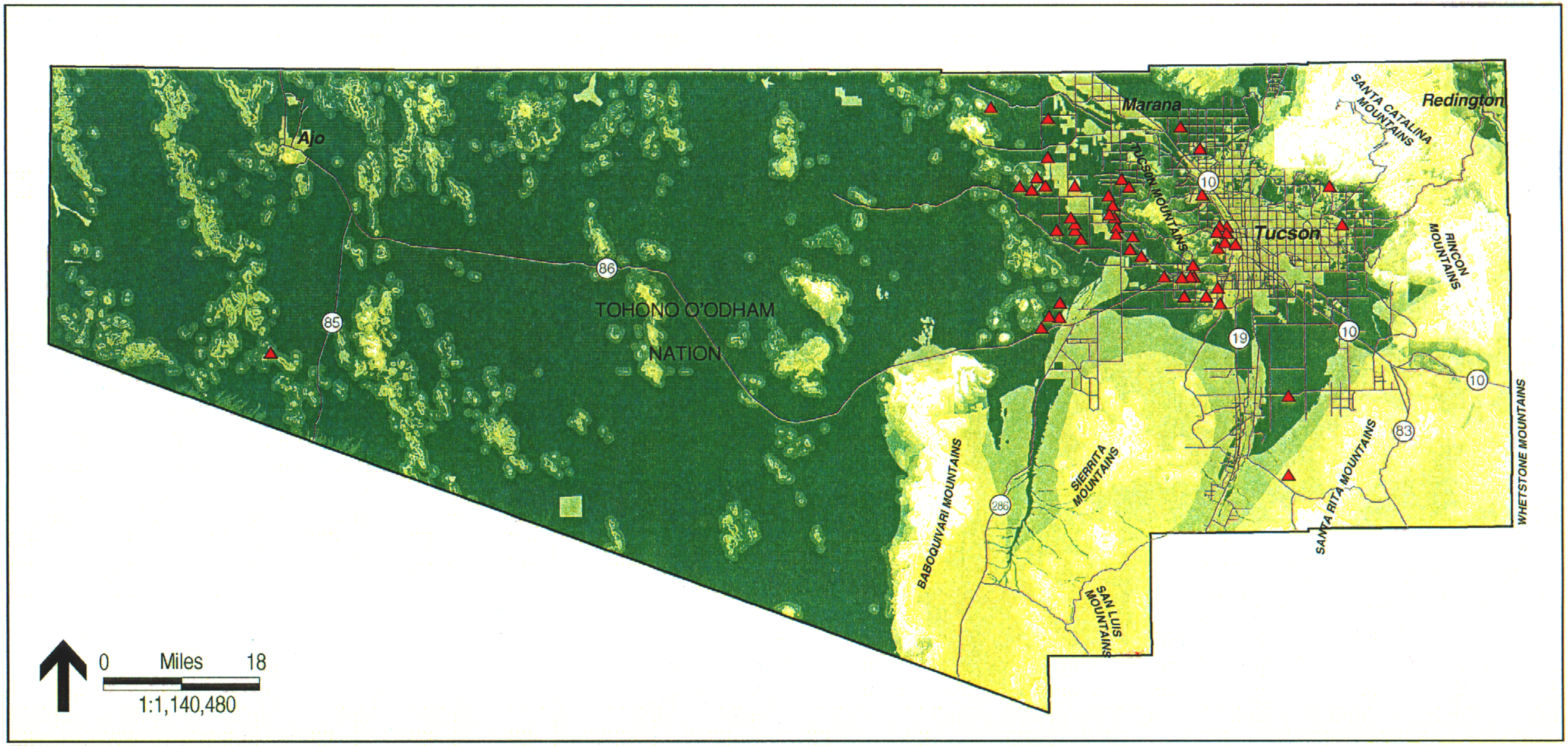
creosotebush desert scrub. Usually this species is associated with undisturbed soils. Because this plant has been found over such a wide range of conditions, precise requirements are poorly understood. In Pima County, most of the known range of this species encompasses land owned or managed by some governmental agency. Several populations in Pima County have been studied for many years and are under the management control of the CAP Canal right-of-way preserve program. One known population occurs in Sabino Canyon.

The potential distribution for this species can be described by the elevation, slope, and vegetation variables. The typical elevation range for this species spans from 195 to 1000 meters. Flat areas with valley fill are most important to the distribution this plant. In the slope data set, flat areas and flat areas within two miles of a moderate or steep slope were the most important factors when modeling potential distribution. Flat areas within one-half mile of moderate or steep slopes were also considered in the model, but at a lower importance level. In the vegetation data set, the most important land cover types for the potential distribution of this species include creosote-bursage, paloverde-mixed cacti, and mixed scrub. Other land cover types considered in the model at a lower importance value include mesquite, saltbush, and creosote-tarbush.

Habitat characteristics for Tumamoc globeberry are scored in data layers for each variable then summed as follows:

Elevation + Slope + Vegetation = Potential Habitat

Potential habitat for this species is shown in Figure 47. Large areas of high potential habitat are predicted throughout low elevation, flat slopes of Sonoran desert scrub. HDMS records fall primarily in areas predicted as high potential habitat, primarily west of Tucson in the northern portion of Altar Valley and Avra Valley. No HDMS records are available for this species in the Tohono O'odham Nation, but it may occur there. One HDMS record occurs at Organ Pipe Cactus National Monument, but the species may be more widely distributed there. Undisturbed soil may be important for this species. If so, suitable surrogates may be investigated for incorporation into the model. Additional research is needed to further refine this model.



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Tumamoc Globeberry *(Tumamoca macdougalii)*
Modeled Potential Habitat

Pima County Boundary
Major Road or Highway

Modeled Potential Habitat
(RECON, June 2000)
No Potential
Low Potential
Medium Potential
High Potential

Known Locations
▲ (HDMS, 2000)

Figure 47

V. Habitat Conservation Assessment—An Example

GIS overlay analysis provides an efficient method of assessing the status of conservation for species given that the distribution of species habitat can be adequately defined. The species habitat models illustrated in this report are preliminary; therefore, overlays of modeled potential habitat and conservation status are not presented. An example of Mexican long-tongued bat will be used to demonstrate the overlay process and the conclusions that may be drawn from this kind of analysis.

Modeled high and medium potential habitat for Mexican long-tongued bat are selected from the summary habitat potential grid, combined, and converted to a polygon coverage representing habitat areas. These habitat areas are then overlaid with a reserve coverage to assess gaps in conservation and identify opportunities for incorporating habitat into a reserve design.

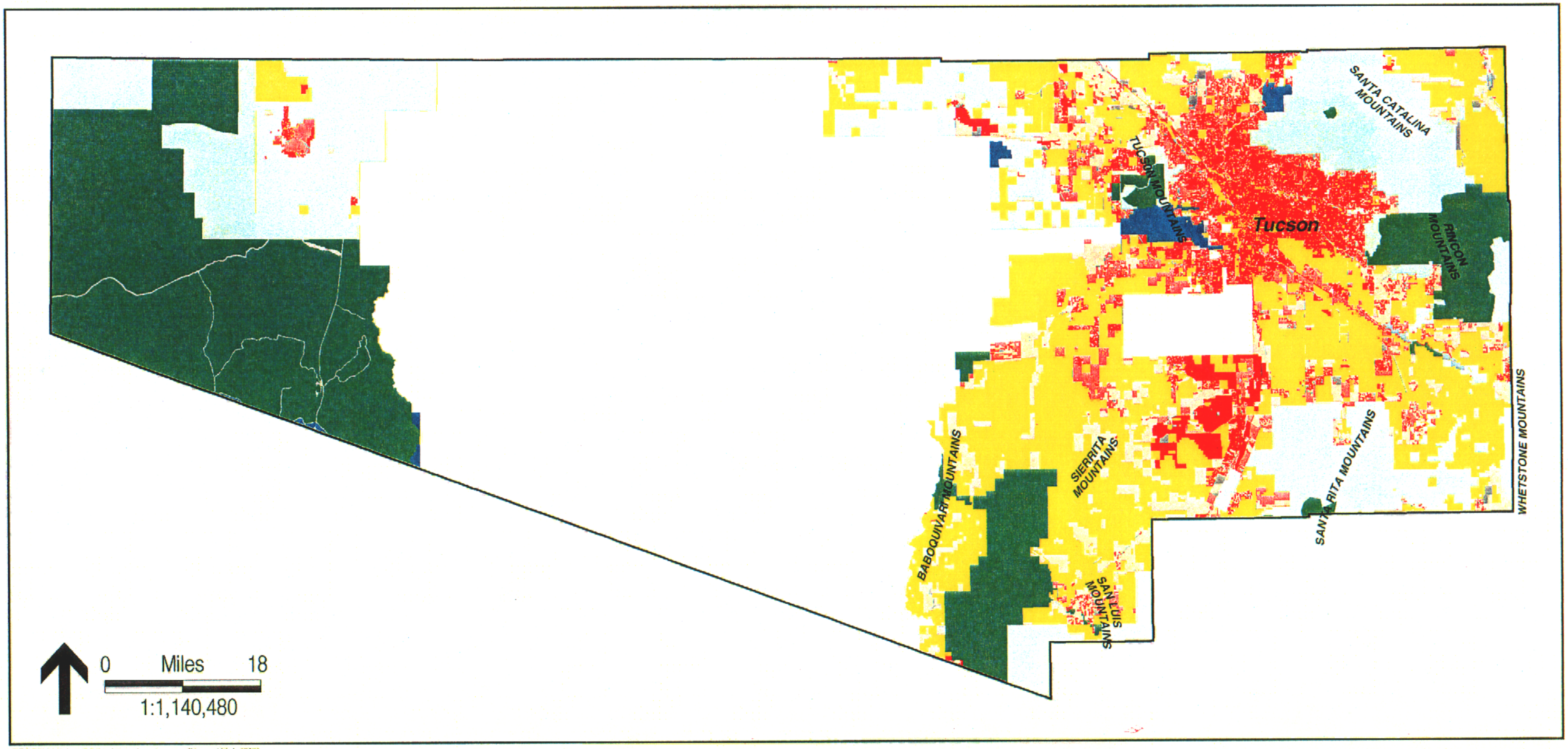
The reserve coverage used in this analysis is derived from the habitat conservation status map (Figure 48) developed for the biological stress assessment report (April 2000). GAP conservation status categories were simplified into four reserve planning categories (Table 1), which were developed for the draft reserve design guidelines report (July 2000).

TABLE 1
RELATIONSHIP BETWEEN
GAP CONSERVATION STATUS AND RESERVE PLANNING CATEGORIES

GAP Status Categories	Reserve Planning Category
1a, 1b, 2, 3a (public lands with conservation management)	Core reserve
3b, 4a (public and private lands with no management but few if any incompatible uses)	Potential for reserve expansion, addition, connection, or buffer
4b, 4c (public and private lands with some incompatible uses and potential for conversion to more intensive uses)	Potential for reserve connection or buffer
4d, 4f (public and private lands with incompatible uses)	Outside reserves

Mexican long-tongued bat habitat is then overlaid with the reserve coverage. The results are displayed in Figure 49, where potential habitat is shown as a black outline on the reserve map.

Acreages of reserve planning categories within the Mexican long-tongued bat potential habitat are summed in Table 2. Based on the model of potential habitat for this species, 18 percent of its habitat is included in core reserves and almost half is included in potential reserve expansion areas. Depending on the habitat requirements for this species, this preliminary analysis indicates that an adequate amount of habitat does not currently exist in core reserves. Adequate habitat could be reserved for Mexican long-tongued bat by adding to core reserves primarily from public lands and private lands that have no incompatible uses.



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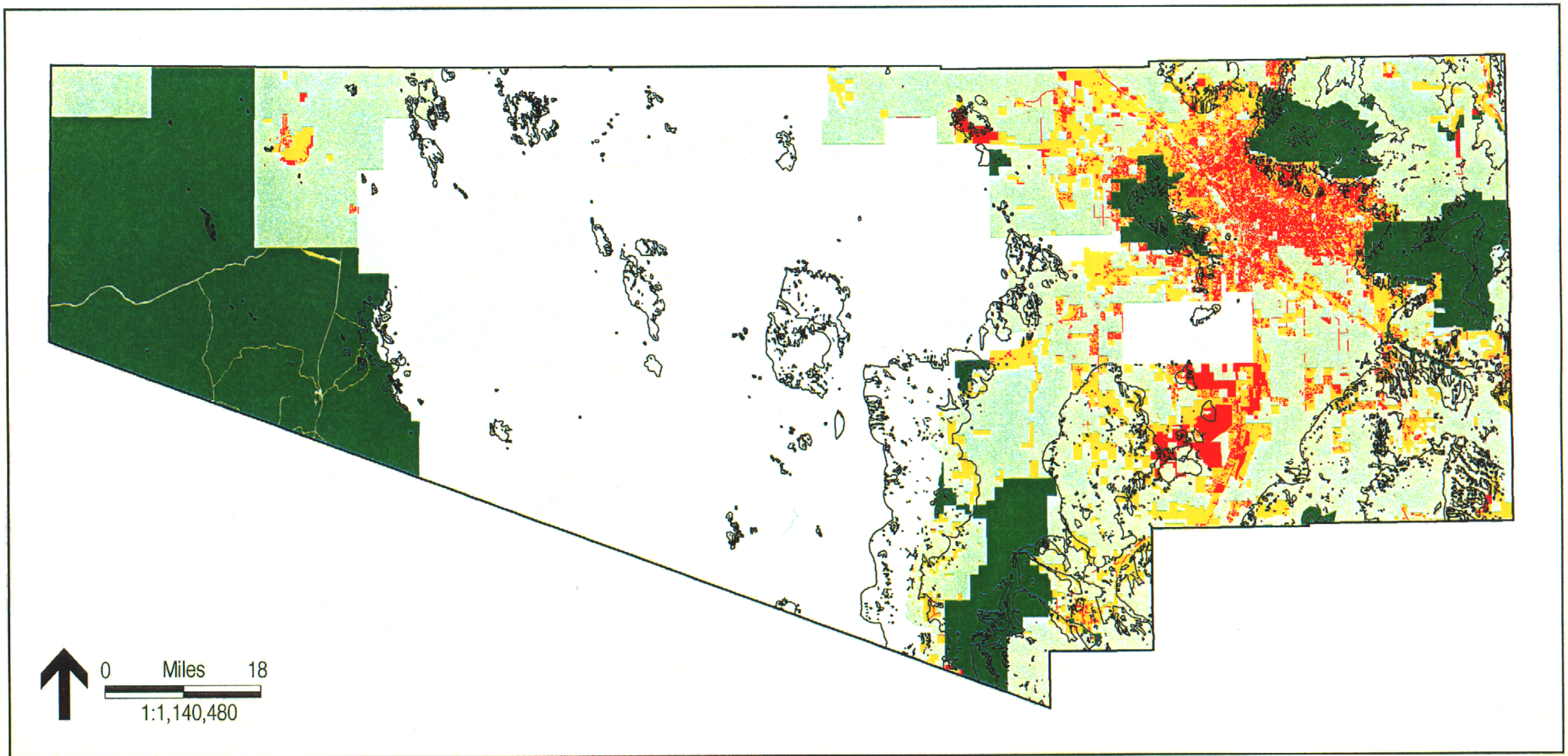
Summary of Conservation Status for Pima County

Pima County Boundary

Level of Threat	Conservation Status		
Low	1a	Most Protected	(Public lands with permanent protection.)
	1b		(Public lands with permanent protection, but may contain uses that detract from quality of biological resources.)
	2		(Public lands with permanent protection, but includes uses that degrade quality of biological resources.)
	3a		(Public lands managed to maintain biodiversity, but not subject to permanent protection.)
	3b		(Public lands with permanent protection, but subject to extractive uses.)
	4a		(Unprotected private or public lands without existing land uses which limit the value for conservation.)
	4b		(Unprotected private or public lands with no existing development, but with existing land uses which limit the value for conservation.)
	4c		(Unprotected private or public lands with existing land use designations for increased intensity of land uses.)
	4e		(Unprotected private or public lands with entitlements to increased intensity of land uses)
	4f		(Native American lands)
High	4x	Least Protected	(Private or public lands with existing development.)

Figure 48



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Reserve Planning Status for Mexican Long-Tongued Bat

Pima County Boundary

Modeled Medium and High Potential Habitat
(RECON, June 2000)

Reserve Planning Status
- Core Reserves
- Potential Reserve Expansion/Addition/Connection/Buffer
- Potential Reserve Connection/Buffer
- Outside Reserve
- Tohono O'Odham Nation

Figure 49

TABLE 2
RESERVE PLANNING STATUS FOR
MEXICAN LONG-TONGUED BAT POTENTIAL HABITAT

Reserve Planning Status	Medium/High Potential Habitat (Acres)	Percent Habitat
Core reserves (conservation status 1a, 1b, 2, 3a)	214,671	18
Potential reserve expansion/addition/connection/buffer (conservation status 3b, 4a)	601,720	49
Potential reserve connection/buffer (conservation status 4b, 4c)	126,480	10
Outside reserve (conservation status 4f)	27,810	2
Tohono O'odham Nation	252,655	21
GRAND TOTAL	1,223,338	100

This kind of reserve planning analysis can be conducted for each species to help identify priority areas for conservation and assess the feasibility of reserving adequate habitat for vulnerable species. By examining the overlap in conservation gaps for all vulnerable species, one is also able to develop priorities for reserve expansion.

VI. Summary of Data Gaps

Potential habitat models can be improved in part by identifying and incorporating additional data into the GIS. Data gaps are described more specifically in each species' discussion, but an attempt will be made to summarize these here. Specific data gaps for each species will be prioritized following review and discussion of draft species habitat models with STAT.

- Improve mapping of caves and mines: The existing carbonates layer does not appear to be an adequate surrogate for this important bat habitat requirement based on the poor association between bat known locations and the carbonates layer.

- Insure that all water sources are adequately and accurately mapped: Many species require water, which is probably underrepresented by the existing land cover and springs coverages.

- Better define habitat requirements for species: Behaviors that influence geographic distribution (i.e., foraging, nesting, dispersal) for many vulnerable species is poorly known, which limits the ability to accurately map habitat.

- Improve mapping of riparian areas: Many of the vulnerable species are riparian-dependent and will benefit from the current effort to improve the delineation of riparian areas. For a large proportion of these, classification of riparian types (i.e., cottonwood-willow vs. mesquite) is also important.

- Acquire/compile mapping for discrete features: Some species require certain topographic features (canyon bottoms), geology/soil types (talus slopes), or plant species (agaves, saguaros) that are not currently mapped.

- Differentiate urban and agricultural subclasses: Some species can use certain urban and agricultural types (i.e., low density residential, orchards) but avoid others (i.e., commercial, row crops). By differentiating and scoring these types in revised habitat models, we will get a better picture of how species make use of areas that will remain outside reserves.

- Improve land cover mapping: Errors and inadequacies have been identified in the composite land cover map that lead to errors in habitat mapping. Many of these can be corrected as outlined in the land cover data assessment report.

- Incorporate habitat quality variable in habitat models: Some species are sensitive to human influence and disturbance near urban areas and roads. These areas could be identified and incorporated into habitat models as negative influences on potential habitat. A habitat quality variable may also include presence or absence of pest species. Pest species mapping could be developed and used as additional layers in the habitat model.

- Research and compile additional known location data: Known location data help to define habitat characteristics for species and validate model results, but relatively little known location data is currently available in GIS.

VII. GIS Model Feasibility

It is important to identify and map potential habitat for species in order to adequately plan for their conservation in a reserve design. In order to do this, we must take into consideration areas where a species is known to occur and environmental characteristics that comprise a species' habitat. Environmental characteristics defining habitat for any one species is complex and requires an examination of many layers of information. Due to the complexity of this analysis and its inherent spatial nature, GIS is the most feasible starting point for habitat mapping.

One of the greatest advantages of using GIS for habitat models is the ability of the GIS to synthesize detailed information that would be impossible for a person to manually accomplish. We use only 9 layers of environmental information in these models—many more could be used. Each layer has between 2 and 26 possible characteristics. This means that any particular place can have over 1 million combinations of environmental characteristics that describe the landscape. Across 5.9 million acres, even at the fairly coarse scale resolution used (23-acre cells), there are over 250,000 places (cells) to be evaluated. These are awesome computations!

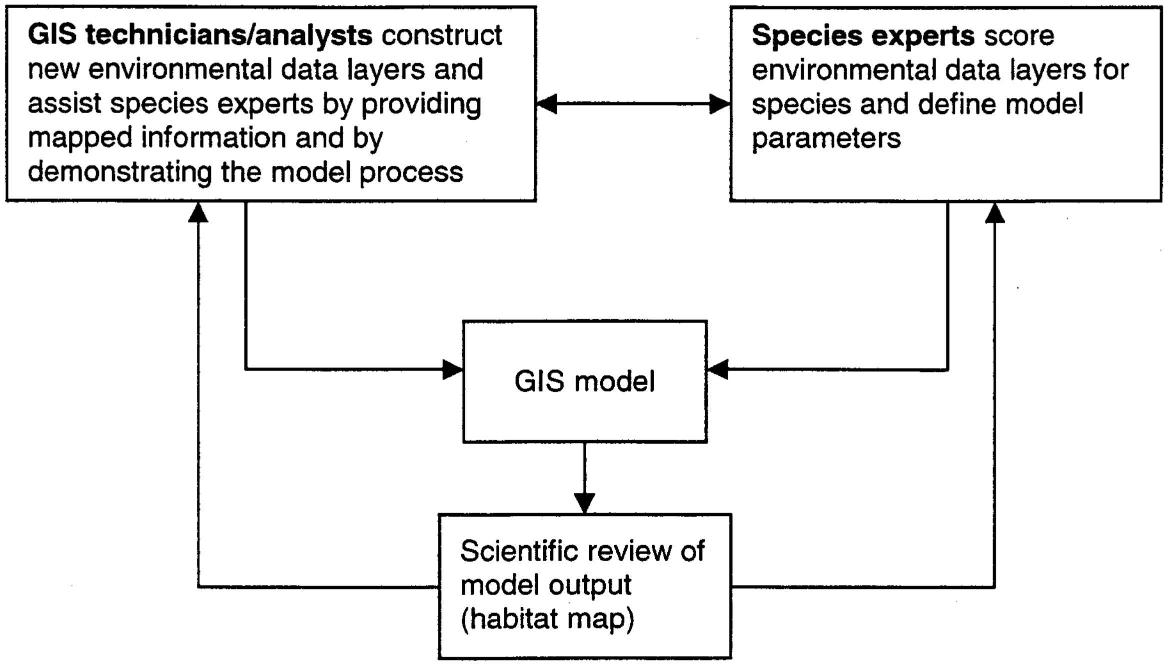
Another advantage of GIS models is that the assumptions used to produce GIS maps are accessible so that map reviewers and users understand how and why a map looks the way it does. These assumptions can be easily modified and input into the model so that map alternatives can be quickly compiled. A GIS can also be used to help determine model parameters by evaluating the association of known location data with habitat characteristics.

GIS maps of habitat may point out areas of constraints and opportunities that had been missed using manual methods of habitat mapping. Good habitat models are also able to extend hypotheses about habitat potential into areas where little scientific information is available across political boundaries—this is very important to regional conservation planning.

GIS maps provide discrete, quantifiable boundaries. This is advantageous only if used appropriately. If the model is good, quantifying habitat areas helps planners understand issues of how much and where (and therefore what cost) more precisely. But discrete boundaries can also be problematic, especially if they are not correct. The draft habitat models are based on environmental data that are probably 80 percent correct and 60 percent complete. Then we have made scientifically based assumptions about the meaning of these data for species. The resulting maps do a remarkable job of describing habitat for some species, but even for these species, habitat boundaries are not real lines on the ground. They are "fuzzy" and should be interpreted as places where the probability of encountering species habitat changes.

Ultimately, we want to improve our confidence in these fuzzy boundaries as much as possible. Depending on the knowledge about species' habitat requirements, the availability of GIS data for representing habitat characteristics, and the manner in which habitat data are incorporated into the model, GIS models may not accurately or adequately represent species habitat. It is essential to combine the GIS modeling process with expert review by scientists who know the species in an iterative process illustrated in the flow model below.

Incorporating knowledge of scientists is important for identifying and prioritizing additional data needs, representing new layers on maps, revising model parameters, and building the model. Through this process we can improve habitat maps as well as identify model deficiencies that we may not be able to correct. Understanding model limitations will then help us to correctly interpret and use the resulting habitat maps.


GIS technicians/analysts construct new environmental data layers and assist species experts by providing mapped information and by demonstrating the model process
Species experts score environmental data layers for species and define model parameters
GIS model
Scientific review of model output (habitat map)

VIII. <u>Conclusions and Recommendations</u>

Species habitat boundaries need to be defined on maps since these provide an important component of reserve design. Because of the scale of the planning area and the complexity of species habitat, using GIS is the most feasible approach to accomplishing habitat mapping—provided that it is conducted in cooperation with scientists who know the species and that the resulting maps are appropriately interpreted and used.

Preliminary GIS models have been constructed and assessed for the habitat data analysis task. In order to move forward, model assumptions and maps should be reviewed and revised by the STAT, and data gaps for each species should be identified and prioritized. As data gaps are filled and alternative parameters established, new models should be constructed in an iterative, cooperative process between STAT and GIS personnel.

Final models should be assessed and validated if possible. Model validation usually requires the acquisition of field data, which may not be feasible in the short term. Qualitative habitat map assessments can be made through expert review and description of maps. Areas where scientists are unsure about model parameters can also be mapped and quantified using the same GIS modeling tool used to build habitat models. (In a separate matrix, habitat characteristics that reviewers are unsure about could be scored –1, others could be scored 1. When grids are summed using the habitat model for species, a new surface is generated representing certainty about model parameters. Positive numbers in this new grid would represent some degree of certainty; negative numbers would represent some degree of uncertainty.) Measures of certainty about mapped habitat can then be carried through subsequent analyses of reserve design.

Models of potential habitat should not be confused with maps of known occupied habitat. The latter should be contained within areas of high potential habitat and should be drawn on maps by species experts, using GIS habitat maps, ancillary data, and personal knowledge. These maps, together with potential habitat maps, will be used in reserve design planning.

While we are still in an exploratory phase of habitat modeling, resulting in the preliminary habitat maps presented in this report, this approach has great potential. Together with STAT and other expert input, GIS habitat mapping has the ability to synthesize large amounts of information, over a large area within the time constraints of this planning effort, to produce new layers of information critical to the development of a successful reserve design.

APPENDIX A

APPENDIX A
SPECIES-ENVIRONMENT MATRIX

SDCP 56 Priority Vulnerable Species - Cave & Mine Potential

Scientific Name	Common Name	Taxon	Carbonates	Area within 1 mile of Carbonates
Choeronycteris mexicana	Mexican long-tongued bat	1	2	1
Idionycteris phyllotis	Allen's big-eared bat (Lappet-eared bat)	1	2	1
Lasiuris blossevillii	Western Red Bat	1	*	*
Lasiuris xanthinus	Southern Yellow Bat	1	*	*
Leptonycteris curasoae yerbabuenae	Lesser Long-nosed Bat	1	2	1
Macrotis californicus	California leaf-nosed bat	1	*	*
Peromyscus merriami	Merriam's Mouse (Mesquite Mouse)	1	*	*
Plecotus townsendii pallescens	Pale Townsend's Big-eared Bat	1	2	1
Sorex arizonae	Arizona Shrew	1	*	*
Aimophila carpalis	Rufous-winged Sparrow	2	*	*
Athene cunicularia	Burrowing Owl	2	*	*
Buteo swainsoni	Swainson's Hawk	2	*	*
Coccyzus americanus occidentalis	Western Yellow-billed Cuckoo	2	*	*
Empidonax traillii extimus	Southwestern Willow Flycatcher	2	*	*
Glaucidium brasilianum cactorum	Cactus Ferruginous Pygmy-Owl	2	*	*
Pipilo aberti	Abert's Towhee	2	*	*
Vireo bellii	Bell's Vireo	2	*	*
Chionactis occipitalis klauberi	Tucson Shovel-nosed Snake	3	*	*
Chionactis palarostris organica	Organ Pipe Shovel-nosed Snake	3	*	*
Cnemidophorus burti stictogrammus	Giant Spotted Whiptail	3	*	*
Cnemidophorus burti xanthonotus	Red-backed Whiptail Lizard	3	*	*
Sonora semiannulata	Ground Snake (ground form)	3	*	*
Terrapene ornata luteola	Desert Box Turtle	3	*	*
Thamnophis eques megalops	Mexican Garter Snake	3	*	*
Rana chiricahuensis	Chiricahua Leopard Frog	4	*	*
Rana yavapaiensis	Lowland Leopard Frog	4	*	*
Agosia chrysogaster	Longfin dace	5	*	*
Catostomus clarkii	Desert Sucker	5	*	*
Catostomus insignus	Sonoran Sucker	5	*	*
Cyprinidon macularius macularius	Desert Pupfish	5	*	*
Gila intermedia	Gila Chub	5	*	*
Poeciliopsis occidentalis occidentalis	Gila Topminnow	5	*	*
Albiorix anophthalmus	Pseudoscorpion (subspecies)	6	*	*
Sonorella spp.	Talussnail	6	*	*
Coryphantha scheeri var. robustispina	Pima Pineapple Cactus	7	*	*
Dalea tentaculoides	Gentry Indigobush	7	*	*
Echinocactus horizonthalonius var. nicholii	Nichol's Turk's Head Cactus	7	*	*
Echinomastus erectocentrus acunensis	Acuna Cactus	7	*	*
Echinomastus erectocentrus var. erectocen	Needle-spined Pineapple Cactus	7	*	*
Lilaeopsis schaffneriana ssp. Recurva	Huachuca Water Umbrel	7	*	*
Tumamoca macdougalii	Tumamoc Globeberry	7	*	*

APPENDIX A
SPECIES-ENVIRONMENT MATRIX

SDCP 56 Priority Vulnerable Species - Hydrology

Common Name	taxon	Intermittent Stream	Adjacent Habitat within 1/2 mile of Intermittent stream	Adjacent Habitat within 1 mile of Intermittent stream	Perennial Stream	Adjacent Habitat within 1/2 mile of Perennial stream	Adjacent Habitat within 1 mile of Perennial stream	Adjacent Habitat within 5 miles of Perennial stream	Area >5 miles from Perennial Stream	Shallow Groundwater	Spring	Adjacent Habitat within 1/2 mile of Spring
Mexican long-tongued bat	1	*	*	*	*	*	*	*	*	*	*	*
Allen's big-eared bat (Lappet-eared ba	1	1	1	0	3	3	2	1	MASK	*	1	1
Western Red Bat	1	1	1	0	3	3	0	0	MASK	2	1	0
Southern Yellow Bat	1	1	1	0	2	2	0	0	MASK	1	1	1
Lesser Long-nosed Bat	1	*	*	*	*	*	*	*	*	*	*	*
California leaf-nosed bat	1	1	1	0	2	2	1	1	0	*	1	0
Merriam's Mouse (Mesquite Mouse)	1	*	*	*	2	2	0	0	0	2	*	*
Pale Townsend's Big-eared Bat	1	1	0	0	1	0	0	0	0	*	1	0
Arizona Shrew	1	*	*	*	2	2	0	0	0	*	1	1
Rufous-winged Sparrow	2	*	*	*	*	*	*	*	*	*	*	*
Burrowing Owl	2	*	*	*	*	*	*	*	*	*	*	*
Swainson's Hawk	2	*	*	*	*	*	*	*	*	*	*	*
Western Yellow-billed Cuckoo	2	1	0	0	2	2	0	0	0	2	*	*
Southwestern Willow Flycatcher	2	2	0	0	2	2	0	0	0	2	1	0
Cactus Ferruginous Pygmy-Owl	2	*	*	*	*	*	*	*	*	*	*	*
Abert's Towhee	2	2	0	0	2	2	0	0	0	2	2	0
Bell's Vireo	2	2	0	0	2	2	0	0	0	2	2	0
Tucson Shovel-nosed Snake	3	*	*	*	*	*	*	*	*	*	*	*
Organ Pipe Shovel-nosed Snake	3	*	*	*	*	*	*	*	*	*	*	*
Giant Spotted Whiptail	3	2	0	0	2	1	0	0	0	2	1	0
Red-backed Whiptail Lizard	3	*	*	*	*	*	*	*	*	*	*	*
Ground Snake (valley form)	3	*	*	*	*	*	*	*	*	*	*	*
Desert Box Turtle	3	*	*	*	*	*	*	*	*	*	*	*
Mexican Garter Snake	3	1	1	0	3	2	0	0	0	0	1	0
Chiricahua Leopard Frog	4	1	0	0	3	0	0	0	0	0	3	0
Lowland Leopard Frog	4	1	0	0	3	0	0	0	0	0	3	0
Longfin dace	5	*	*	*	3	MASK	MASK	MASK	MASK	*	2	MASK
Desert Sucker	5	*	*	*	3	MASK	MASK	MASK	MASK	*	1	MASK
Sonoran Sucker	5	*	*	*	3	MASK	MASK	MASK	MASK	*	1	MASK
Desert Pupfish	5	*	*	*	3	MASK	MASK	MASK	MASK	*	1	MASK
Gila Chub	5	*	*	*	3	MASK	MASK	MASK	MASK	*	1	MASK
Gila Topminnow	5	*	*	*	3	MASK	MASK	MASK	MASK	*	1	MASK
Pseudoscorpion (subspecies)	6	*	*	*	*	*	*	*	*	*	*	*
Talussnail	6	*	*	*	*	*	*	*	*	*	*	*
Pima Pineapple Cactus	7	*	*	*	*	*	*	*	*	*	*	*
Gentry Indigobush	7	*	*	*	*	*	*	*	*	*	*	*
Nichol's Turk's Head Cactus	7	*	*	*	*	*	*	*	*	*	*	*
Acuna Cactus	7	*	*	*	*	*	*	*	*	*	*	*
Needle-spined Pineapple Cactus	7	*	*	*	*	*	*	*	*	*	*	*
Huachuca Water Umbel	7	2	MASK	MASK	3	MASK	MASK	MASK	MASK	*	*	*
Tumamoc Globeberry	7	*	*	*	*	*	*	*	*	*	*	*

APPENDIX A
SPECIES-ENVIRONMENT MATRIX

SDCP 56 Priority Vulnerable Species - Vegetation/Land cover

			1	2	3	4	5	6	7	8	9	10	11	12	13
			Pinyon-Juniper	Douglas-Fir-Mixed Conifer	Pine	Encinal (Oak)	Oak-Pine	Mesquite	Manzanita	Mixed Evergreen Sclerophyll	Sacaton-Scrub	Mixed Grass-Scrub	Shrub-Scrub Disclimax	Creosotebush-Tarbush	Mixed Scrub
Scientific Name	**Common Name**	**Taxon**	**122.41**	**122.61**	**122.62**	**123.31**	**123.32**	**124.71**	**133.32**	**133.36**	**143.14**	**143.15**	**143.16**	**153.21**	**153.26**
Choeronycteris mexicana	Mexican long-tongued bat	1	1	0	1	2	2	0	1	1	1	1	0	0	0
Idionycteris phyllotis	Allen's big-eared bat (Lappet-eared	1	2	0	2	2	2	1	0	1	0	0	0	0	0
Lasiuris blossevillii	Western Red Bat	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lasiuris xanthinus	Southern Yellow Bat	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptonycteris curasoae yerbabuenae	Lesser Long-nosed Bat	1	1	0	1	1	1	0	1	1	0	1	1	0	0
Macrotis californicus	California leaf-nosed bat	1	1	0	0	1	0	0	0	1	0	0	1	1	1
Peromyscus merriami	Merriam's Mouse (Mesquite Mouse	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Plecotus townsendii pallescens	Pale Townsend's Big-eared Bat	1	2	2	2	2	2	1	1	1	1	1	1	1	1
Sorex arizonae	Arizona Shrew	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Aimophila carpalis	Rufous-winged Sparrow	2	0	0	0	0	0	0	0	0	2	3	1	0	1
Athene cunicularia	Burrowing Owl	2	0	0	0	0	0	0	0	0	1	1	1	0	1
Buteo swainsoni	Swainson's Hawk	2	0	0	0	0	0	0	0	0	2	3	1	0	0
Coccyzus americanus occidentalis	Western Yellow-billed Cuckoo	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Empidonax traillii extimus	Southwestern Willow Flycatcher	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Glaucidium brasilianum cactorum	Cactus Ferruginous Pygmy-Owl	2	0	0	0	0	0	1	0	0	0	2	0	0	0
Pipilo aberti	Abert's Towhee	2	0	0	0	0	0	3	0	0	1	1	1	0	1
Vireo bellii	Bell's Vireo	2	0	0	0	0	0	0	0	0	1	1	1	0	0
Chionactis occipitalis klauberi	Tucson Shovel-nosed Snake	3	0	0	0	0	0	0	0	0	1	2	1	1	3
Chionactis palarostris organica	Organ Pipe Shovel-nosed Snake	3	0	0	0	0	0	0	0	0	0	2	2	1	1
Cnemidophorus burti stictogrammus	Giant Spotted Whiptail	3	0	0	0	1	1	1	1	0	1	1	0	0	0
Cnemidophorus burti xanthonotus	Red-backed Whiptail Lizard	3	1	0	0	3	0	2	0	3	0	0	0	0	2
Sonora semiannulata	Ground Snake (ground form)	3	1	0	0	1	1	1	1	1	2	3	2	1	2
Terrapene ornata luteola	Desert Box Turtle	3	0	0	0	0	0	0	0	0	3	3	2	0	0
Thamnophis eques megalops	Mexican Garter Snake	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Rana chiricahuensis	Chiricahua Leopard Frog	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Rana yavapaiensis	Lowland Leopard Frog	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Agosia chrysogaster	Longfin dace	5	*	*	*	*	*	*	*	*	*	*	*	*	*
Catostomus clarkii	Desert Sucker	5	*	*	*	*	*	*	*	*	*	*	*	*	*
Catostomus insignus	Sonoran Sucker	5	*	*	*	*	*	*	*	*	*	*	*	*	*
Cyprinidon macularius macularius	Desert Pupfish	5	*	*	*	*	*	*	*	*	*	*	*	*	*
Gila intermedia	Gila Chub	5	*	*	*	*	*	*	*	*	*	*	*	*	*
Poeciliopsis occidentalis occidentalis	Gila Topminnow	5	*	*	*	*	*	*	*	*	*	*	*	*	*
Albiorix anophthalmus	Pseudoscorpion (subspecies)	6	*	*	*	*	*	*	*	*	*	*	*	*	*
Sonorella spp.	Talussnail	6	*	*	*	*	*	*	*	*	*	*	*	*	*
Coryphantha scheeri var. robustispina	Pima Pineapple Cactus	7	0	0	0	1	0	0	0	1	2	3	2	0	2
Dalea tentaculoides	Gentry Indigobush	7	0	0	0	3	3	0	0	3	0	0	0	0	0
Echinocactus horizonthalonius var. nicholii	Nichol's Turk's Head Cactus	7	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinomastus erectocentrus acunensis	Acuna Cactus	7	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinomastus erectocentrus var. erectocentrus	Needle-spined Pineapple Cactus	7	0	0	0	0	0	0	0	0	2	3	2	0	0
Lilaeopsis schaffneriana ssp. Recurva	Huachuca Water Umbel	7	*	*	*	*	*	*	*	*	*	*	*	*	*
Tumamoca macdougalii	Tumamoc Globeberry	7	0	0	0	0	0	2	0	0	0	0	0	0	0

APPENDIX A
SPECIES-ENVIRONMENT MATRIX

SDCP 56 Priority Vulnerable Species - Vegetation/Land cover

		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
		Creosote-Bursage	Paloverde-Mixed Cacti	Saltbush	Creosote-Tarbush	Cottonwood-Willow	Mixed Broadleaf	Mesquite	Cottonwood-Willow	Mixed Scrub	Cattail	Saltgrass	Unclassified	Agriculture	Urban	Water	Bare Ground
Scientific Name	**Common Name**	**154.11**	**154.12**	**154.17**	**154.21**	**223.21**	**223.22**	**224.52**	**224.53**	**234.71**	**244.71**	**244.75**	**999**	**999.1**	**999.2**	**999.3**	**999.4**
Choeronycteris mexicana	Mexican long-tongued bat	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Idionycteris phyllotis	Allen's big-eared bat (Lappet-eared	0	0	0	0	2	2	1	1	0	0	0	0	0	0	0	0
Lasiuris blossevillii	Western Red Bat	0	0	0	0	3	3	1	3	0	0	0	0	1	0	0	0
Lasiuris xanthinus	Southern Yellow Bat	0	0	0	0	1	1	0	1	0	0	0	0	1	3	0	0
Leptonycteris curasoae yerbabuenae	Lesser Long-nosed Bat	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Macrotis californicus	California leaf-nosed bat	1	2	0	1	0	0	1	0	2	0	0	0	0	0	0	0
Peromyscus merriami	Merriam's Mouse (Mesquite Mouse	0	0	0	0	0	0	3	0	2	0	0	0	0	0	0	0
Plecotus townsendii pallescens	Pale Townsend's Big-eared Bat	2	2	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Sorex arizonae	Arizona Shrew	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aimophila carpalis	Rufous-winged Sparrow	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Athene cunicularia	Burrowing Owl	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Buteo swainsoni	Swainson's Hawk	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Coccyzus americanus occidentalis	Western Yellow-billed Cuckoo	0	0	0	0	3	3	3	3	0	0	0	0	2	0	0	0
Empidonax traillii extimus	Southwestern Willow Flycatcher	0	0	0	0	3	3	0	3	0	0	0	0	0	0	0	0
Glaucidium brasilianum cactorum	Cactus Ferruginous Pygmy-Owl	1	3	0	0	0	0	1	1	1	0	0	0	1	2	0	0
Pipilo aberti	Abert's Towhee	0	1	1	0	3	3	3	3	3	2	0	0	1	1	0	0
Vireo bellii	Bell's Vireo	0	0	0	0	2	2	2	2	2	0	0	0	1	1	0	0
Chionactis occipitalis klauberi	Tucson Shovel-nosed Snake	3	3	1	1	0	0	0	0	0	0	0	0	1	1	0	0
Chionactis palarostris organica	Organ Pipe Shovel-nosed Snake	3	3	1	1	0	0	0	0	0	0	0	0	1	0	0	0
Cnemidophorus burti stictogrammus	Giant Spotted Whiptail	0	0	0	0	2	2	2	2	2	0	0	0	0	0	0	0
Cnemidophorus burti xanthonotus	Red-backed Whiptail Lizard	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sonora semiannulata	Ground Snake (ground form)	2	2	2	1	2	2	2	2	2	0	0	0	0	0	0	0
Terrapene ornata luteola	Desert Box Turtle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thamnophis eques megalops	Mexican Garter Snake	0	0	0	0	3	3	0	3	2	0	0	0	0	0	0	0
Rana chiricahuensis	Chiricahua Leopard Frog	0	0	0	0	2	2	1	2	2	2	0	0	1	0	0	0
Rana yavapaiensis	Lowland Leopard Frog	0	0	0	0	2	2	1	2	2	2	0	0	1	0	0	0
Agosia chrysogaster	Longfin dace	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Catostomus clarkii	Desert Sucker	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Catostomus insignus	Sonoran Sucker	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Cyprinidon macularius macularius	Desert Pupfish	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Gila intermedia	Gila Chub	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Poeciliopsis occidentalis occidentalis	Gila Topminnow	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Albiorix anophthalmus	Pseudoscorpion (subspecies)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Sonorella spp.	Talussnail	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Coryphantha scheeri var. robustispina	Pima Pineapple Cactus	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dalea tentaculoides	Gentry Indigobush	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Echinocactus horizonthalonius var. nicholii	Nichol's Turk's Head Cactus	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinomastus erectocentrus acunensis	Acuna Cactus	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Echinomastus erectocentrus var. erectocentrus	Needle-spined Pineapple Cactus	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lilaeopsis schaffneriana ssp. Recurva	Huachuca Water Umbel	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Tumamoca macdougalii	Tumamoc Globeberry	3	3	2	2	0	0	2	0	3	0	0	0	0	0	0	0

APPENDIX A
SPECIES-ENVIRONMENT MATRIX

SDCP 56 Priority Vulnerable Species - Topography (Aspect)

			Aspect - Degrees							
			North	Northeast	East	Southeast	South	Southwest	West	Northwest
Scientific Name	**Common Name**	**Taxon**	**0-22.5, 337.5-360**	**22.5-67.5**	**67.5-112.5**	**112.5-157.5**	**157.5-202.5**	**202.5-247.5**	**247.5-292.5**	**292.5-337.5**
Choeronycteris mexicana	Mexican long-tongued bat	1	0	0	0	0	1	2	2	1
Idionycteris phyllotis	Allen's big-eared bat (Lappet-eared ba	1	*	*	*	*	*	*	*	*
Lasiuris blossevillii	Western Red Bat	1	*	*	*	*	*	*	*	*
Lasiuris xanthinus	Southern Yellow Bat	1	*	*	*	*	*	*	*	*
Leptonycteris curasoae yerbabuenae	Lesser Long-nosed Bat	1	*	*	*	*	*	*	*	*
Macrotis californicus	California leaf-nosed bat	1	*	*	*	*	*	*	*	*
Peromyscus merriami	Merriam's Mouse (Mesquite Mouse)	1	*	*	*	*	*	*	*	*
Plecotus townsendii pallescens	Pale Townsend's Big-eared Bat	1	0	0	0	0	1	2	2	1
Sorex arizonae	Arizona Shrew	1	*	*	*	*	*	*	*	*
Aimophila carpalis	Rufous-winged Sparrow	2	*	*	*	*	*	*	*	*
Athene cunicularia	Burrowing Owl	2	*	*	*	*	*	*	*	*
Buteo swainsoni	Swainson's Hawk	2	*	*	*	*	*	*	*	*
Coccyzus americanus occidentalis	Western Yellow-billed Cuckoo	2	*	*	*	*	*	*	*	*
Empidonax traillii extimus	Southwestern Willow Flycatcher	2	*	*	*	*	*	*	*	*
Glaucidium brasilianum cactorum	Cactus Ferruginous Pygmy-Owl	2	*	*	*	*	*	*	*	*
Pipilo aberti	Abert's Towhee	2	*	*	*	*	*	*	*	*
Vireo bellii	Bell's Vireo	2	*	*	*	*	*	*	*	*
Chionactis occipitalis klauberi	Tucson Shovel-nosed Snake	3	*	*	*	*	*	*	*	*
Chionactis palarostris organica	Organ Pipe Shovel-nosed Snake	3	*	*	*	*	*	*	*	*
Cnemidophorus burti stictogrammus	Giant Spotted Whiptail	3	*	*	*	*	*	*	*	*
Cnemidophorus burti xanthonotus	Red-backed Whiptail Lizard	3	*	*	*	*	*	*	*	*
Sonora semiannulata	Ground Snake (ground form)	3	*	*	*	*	*	*	*	*
Terrapene ornata luteola	Desert Box Turtle	3	*	*	*	*	*	*	*	*
Thamnophis eques megalops	Mexican Garter Snake	3	*	*	*	*	*	*	*	*
Rana chiricahuensis	Chiricahua Leopard Frog	4	*	*	*	*	*	*	*	*
Rana yavapaiensis	Lowland Leopard Frog	4	*	*	*	*	*	*	*	*
Agosia chrysogaster	Longfin dace	5	*	*	*	*	*	*	*	*
Catostomus clarkii	Desert Sucker	5	*	*	*	*	*	*	*	*
Catostomus insignus	Sonoran Sucker	5	*	*	*	*	*	*	*	*
Cyprinidon macularius macularius	Desert Pupfish	5	*	*	*	*	*	*	*	*
Gila intermedia	Gila Chub	5	*	*	*	*	*	*	*	*
Poeciliopsis occidentalis occidentalis	Gila Topminnow.	5	*	*	*	*	*	*	*	*
Albiorix anophthalmus	Pseudoscorpion (subspecies)	6	*	*	*	*	*	*	*	*
Sonorella spp.	Talussnail	6	*	*	*	*	*	*	*	*
Coryphantha scheeri var. robustispina	Pima Pineapple Cactus	7	*	*	*	*	*	*	*	*
Dalea tentaculoides	Gentry Indigobush	7	*	*	*	*	*	*	*	*
Echinocactus horizonthalonius var. nicholii	Nichol's Turk's Head Cactus	7	*	*	*	*	*	*	*	*
Echinomastus erectocentrus acunensis	Acuna Cactus	7	*	*	*	*	*	*	*	*
Echinomastus erectocentrus var. erectocentrus	Needle-spined Pineapple Cactus	7	*	*	*	*	*	*	*	*
Lilaeopsis schaffneriana ssp. Recurva	Huachuca Water Umbrel	7	*	*	*	*	*	*	*	*
Tumamoca macdougalii	Tumamoc Globeberry	7	*	*	*	*	*	*	*	*

SDCP 56 Priority Vulnerable Species - Topography (Slope)

Scientific Name	Common Name	Taxon	flat	moderate	steep	Flat within 1/2 mile of Moderate to Steep Slopes	Flat within 2 miles of Moderate to Steep Slopes
Choeronycteris mexicana	Mexican long-tongued bat	1	0	3	3	2	1
Idionycteris phyllotis	Allen's big-eared bat (Lappet-eared bat)	1	0	3	3	2	1
Lasiuris blossevillii	Western Red Bat	1	2	0	0	0	0
Lasiuris xanthinus	Southern Yellow Bat	1	2	MASK	MASK	MASK	MASK
Leptonycteris curasoae yerbabuenae	Lesser Long-nosed Bat	1	0	3	3	2	1
Macrotis californicus	California leaf-nosed bat	1	0	3	2	3	1
Peromyscus merriami	Merriam's Mouse (Mesquite Mouse)	1	3	0	0	0	0
Plecotus townsendii pallescens	Pale Townsend's Big-eared Bat	1	0	3	3	2	1
Sorex arizonae	Arizona Shrew	1	2	0	0	0	0
Aimophila carpalis	Rufous-winged Sparrow	2	2	0	0	0	0
Athene cunicularia	Burrowing Owl	2	3	0	0	0	0
Buteo swainsoni	Swainson's Hawk	2	2	0	0	0	0
Coccyzus americanus occidentalis	Western Yellow-billed Cuckoo	2	2	0	0	0	0
Empidonax traillii extimus	Southwestern Willow Flycatcher	2	3	0	0	0	0
Glaucidium brasilianum cactorum	Cactus Ferruginous Pygmy-Owl	2	*	*	*	*	*
Pipilo aberti	Abert's Towhee	2	2	0	0	0	0
Vireo bellii	Bell's Vireo	2	2	0	0	0	0
Chionactis occipitalis klauberi	Tucson Shovel-nosed Snake	3	2	0	0	0	0
Chionactis palarostris organica	Organ Pipe Shovel-nosed Snake	3	2	0	0	0	0
Cnemidophorus burti stictogrammus	Giant Spotted Whiptail	3	2	0	0	0	0
Cnemidophorus burti xanthonotus	Red-backed Whiptail Lizard	3	1	2	2	2	1
Sonorella ambigua ambigua	Ground Snake (ground form)	3	0	3	3	2	0
Terrapene ornata luteola	Desert Box Turtle	3	2	0	0	0	0
Thamnophis eques megalops	Mexican Garter Snake	3	2	0	0	0	0
Rana chiricahuensis	Chiricahua Leopard Frog	4	*	*	*	*	*
Rana yavapaiensis	Lowland Leopard Frog	4	*	*	*	*	*
Agosia chrysogaster	Longfin dace	5	*	*	*	*	*
Catostomus clarkii	Desert Sucker	5	*	*	*	*	*
Catostomus insignus	Sonoran Sucker	5	*	*	*	*	*
Cyprinidon macularius macularius	Desert Pupfish	5	*	*	*	*	*
Gila intermedia	Gila Chub	5	*	*	*	*	*
Poeciliopsis occidentalis occidentalis	Gila Topminnow	5	*	*	*	*	*
Albiorix anophthalmus	Pseudoscorpion (subspecies)	6	*	*	*	*	*
Sonora Spp.	Talussnail	6	0	3	3	2	1
Coryphantha scheeri var. robustispina	Pima Pineapple Cactus	7	3	0	0	1	3
Dalea tentaculoides	Gentry Indigobush	7	2	0	0	0	0
Echinocactus horizonthalonius var. nicholii	Nichol's Turk's Head Cactus	7	*	*	*	*	*
Echinomastus erectocentrus acunensis	Acuna Cactus	7	1	1	1	3	1
Echinomastus erectocentrus var. erectocentrus	Needle-spined Pineapple Cactus	7	*	*	*	*	*
Lilaeopsis schaffneriana ssp. Recurva	Huachuca Water Umbrel	7	3	0	0	0	0
Tumamoca macdougalii	Tumamoc Globeberry	7	3	0	0	1	3

APPENDIX A
SPECIES-ENVIRONMENT MATRIX

SDCP 56 Priority Vulnerable Species - Topography (Elevation)

Scientific Name	Common Name	Taxon	195-400	401-600	601-800	801-1000	1001-1200	1201-1400	1401-1600	1601-1800	1801-2000	2001-2200	2201-2400	2401-2600	2601-2800
Choeronycteris mexicana	Mexican long-tongued bat	1	MASK	MASK	MASK	2	3	3	2	2	2	MASK	MASK	MASK	MASK
Idionycteris phyllotis	Allen's big-eared bat (Lappet-eared ba	1	MASK	MASK	MASK	1	2	2	2	2	2	2	1	1	1
Lasiuris blossevillii	Western Red Bat	1	MASK	MASK	2	2	2	2	2	2	2	2	0	MASK	MASK
Lasiuris xanthinus	Southern Yellow Bat	1	2	2	2	2	MASK	MASK	MASK	MASK	MASK	MASK	MASK	MASK	MASK
Leptonycteris curasoae yerbabuenae	Lesser Long-nosed Bat	1	2	2	2	2	2	2	2	2	2	MASK	MASK	MASK	MASK
Macrotis californicus	California leaf-nosed bat	1	2	2	2	2	1	1	0	MASK	MASK	MASK	MASK	MASK	MASK
Peromyscus merriami	Merriam's Mouse (Mesquite Mouse)	1	1	1	1	3	3	1	0	MASK	MASK	MASK	MASK	MASK	MASK
Plecotus townsendii pallescens	Pale Townsend's Big-eared Bat	1	1	1	1	1	2	2	2	2	2	2	2	2	2
Sorex arizonae	Arizona Shrew	1	0	0	0	0	0	0	0	0	0	0	0	3	3
Aimophila carpalis	Rufous-winged Sparrow	2	1	2	2	2	2	2	2	1	0	0	0	0	0
Athene cunicularia	Burrowing Owl	2	2	2	2	2	0	0	0	0	0	0	0	0	0
Buteo swainsoni	Swainson's Hawk	2	1	1	1	1	2	2	2	2	0	0	0	0	0
Coccyzus americanus occidentalis	Western Yellow-billed Cuckoo	2	1	1	1	2	2	2	1	1	0	0	0	0	0
Empidonax traillii extimus	Southwestern Willow Flycatcher	2	1	2	2	2	1	1	1	1	1	1	1	1	1
Glaucidium brasilianum cactorum	Cactus Ferruginous Pygmy-Owl	2	1	2	2	2	2	0	0	0	0	0	0	0	0
Pipilo aberti	Abert's Towhee	2	1	2	2	2	1	MASK	MASK	MASK	MASK	MASK	MASK	MASK	MASK
Vireo bellii	Bell's Vireo	2	2	2	2	2	2	2	1	MASK	MASK	MASK	MASK	MASK	MASK
Chionactis occipitalis klauberi	Tucson Shovel-nosed Snake	3	2	2	2	2	0	0	MASK	MASK	MASK	MASK	MASK	MASK	MASK
Chionactis palarostris organica	Organ Pipe Shovel-nosed Snake	3	2	2	2	0	0	MASK	MASK	MASK	MASK	MASK	MASK	MASK	MASK
Cnemidophorus burti stictogrammus	Giant Spotted Whiptail	3	2	2	2	2	2	1	0	MASK	MASK	MASK	MASK	MASK	MASK
Cnemidophorus burti xanthonotus	Red-backed Whiptail Lizard	3	0	0	2	2	2	1	0	0	0	0	0	0	0
Sonora semiannulata	Ground Snake (ground form)	3	0	0	1	2	2	2	2	1	0	0	0	0	0
Terrapene ornata luteola	Desert Box Turtle	3	1	1	1	2	2	2	2	2	2	1	0	0	0
Thamnophis eques megalops	Mexican Garter Snake	3	0	1	2	2	2	2	2	2	1	1	1	1	1
Rana chiricahuensis	Chiricahua Leopard Frog	4	2	2	2	2	2	2	2	2	1	1	1	1	1
Rana yavapaiensis	Lowland Leopard Frog	4	1	1	1	2	2	2	2	1	0	0	0	0	0
Agosia chrysogaster	Longfin dace	5	1	2	2	2	2	1	1	1	0	0	0	0	0
Catostomus clarkii	Desert Sucker	5	2	2	2	2	2	2	2	2	2	2	1	1	1
Catostomus insignus	Sonoran Sucker	5	2	2	2	2	2	2	2	2	2	2	0	0	0
Cyprinidon macularius macularius	Desert Pupfish	5	2	2	2	2	2	2	2	0	0	0	0	0	0
Gila intermedia	Gila Chub	5	1	1	1	2	2	2	1	1	1	0	0	0	0
Poeciliopsis occidentalis occidentalis	Gila Topminnow	5	2	2	2	2	2	2	2	0	0	0	0	0	0
Albiorix anophthalmus	Pseudoscorpion (subspecies)	6	*	*	*	*	*	*	*	*	*	*	*	*	*
Sonorella spp.	Talussnail	6	0	0	2	2	2	2	2	2	2	0	0	0	0
Coryphantha scheeri var. robustispina	Pima Pineapple Cactus	7	0	0	2	2	2	2	1	0	0	0	0	0	0
Dalea tentaculoides	Gentry Indigobush	7	0	0	0	0	2	2	0	0	0	0	0	0	0
Echinocactus horizonthalonius var. nicholii	Nichol's Turk's Head Cactus	7	0	0	2	2	2	0	0	0	0	0	0	0	0
Echinomastus erectocentrus acunensis	Acuna Cactus	7	1	2	1	0	0	0	0	0	0	0	0	0	0
Echinomastus erectocentrus var. erectocentrus	Needle-spined Pineapple Cactus	7	0	0	0	2	2	2	0	0	0	0	0	0	0
Lilaeopsis schaffneriana ssp. Recurva	Huachuca Water Umbel	7	0	0	0	0	0	2	2	2	2	0	0	0	0
Tumamoca macdougalii	Tumamoc Globeberry	7	2	2	2	2	0	0	0	0	0	0	0	0	0

APPENDIX A
SPECIES-ENVIRONMENT MATRIX

SDCP 56 Priority Vulnerable Species - Summary

Scientific Name	Common Name	Taxon	hydrology	vegetation	topo-slope	topo-elev	topo-aspect	cave & mine potential
Choeronycteris mexicana	Mexican long-tongued bat	1	*	1	1	1	1	1
Idionycteris phyllotis	Allen's big-eared bat (Lappet-eared bat)	1	1	1	1	1	*	1
Lasiuris blossevillii	Western Red Bat	1	1	1	1	1	*	*
Lasiuris xanthinus	Southern Yellow Bat	1	1	1	1	1	*	*
Leptonycteris curasoae yerbabuenae	Lesser Long-nosed Bat	1	*	1	1	1	*	1
Macrotis californicus	California leaf-nosed bat	1	1	1	1	1	*	*
Peromyscus merriami	Merriam's Mouse (Mesquite Mouse)	1	1	1	1	1	*	*
Plecotus townsendii pallescens	Pale Townsend's Big-eared Bat	1	1	1	1	1	1	1
Sorex arizonae	Arizona Shrew	1	1	1	1	1	*	*
Aimophila carpalis	Rufous-winged Sparrow	2	*	1	1	1	*	*
Athene cunicularia	Burrowing Owl	2	*	1	1	1	*	*
Buteo swainsoni	Swainson's Hawk	2	*	1	1	1	*	*
Coccyzus americanus occidentalis	Western Yellow-billed Cuckoo	2	1	1	1	1	*	*
Empidonax traillii extimus	Southwestern Willow Flycatcher	2	1	1	1	1	*	*
Glaucidium brasilianum cactorum	Cactus Ferruginous Pygmy-Owl	2	*	1	*	1	*	*
Pipilo aberti	Abert's Towhee	2	1	1	1	1	*	*
Vireo bellii	Bell's Vireo	2	1	1	1	1	*	*
Chionactis occipitalis klauberi	Tucson Shovel-nosed Snake	3	*	1	1	1	*	*
Chionactis palarostris organica	Organ Pipe Shovel-nosed Snake	3	*	1	1	1	*	*
Cnemidophorus burti stictogrammus	Giant Spotted Whiptail	3	1	1	1	1	*	*
Cnemidophorus burti xanthonotus	Red-backed Whiptail Lizard	3	*	1	1	1	*	*
Sonora semiannulata	Ground Snake (ground form)	3	*	1	1	1	*	*
Terrapene ornata luteola	Desert Box Turtle	3	*	1	1	1	*	*
Thamnophis eques megalops	Mexican Garter Snake	3	1	1	1	1	*	*
Rana chiricahuensis	Chiricahua Leopard Frog	4	1	1	*	1	*	*
Rana yavapaiensis	Lowland Leopard Frog	4	1	1	*	1	*	*
Agosia chrysogaster	Longfin dace	5	1	*	*	1	*	*
Catostomus clarkii	Desert Sucker	5	1	*	*	1	*	*
Catostomus insignus	Sonoran Sucker	5	1	*	*	1	*	*
Cyprinidon macularius macularius	Desert Pupfish	5	1	*	*	1	*	*
Gila intermedia	Gila Chub	5	1	*	*	1	*	*
Poeciliopsis occidentalis occidentalis	Gila Topminnow	5	1	*	*	1	*	*
Albiorix anophthalmus	Pseudoscorpion (subspecies)	6	*	*	*	1	*	*
Sonorella spp.	Talussnail	6	*	*	1	1	*	*
Coryphantha scheeri var. robustispina	Pima Pineapple Cactus	7	*	1	1	1	*	*
Dalea tentaculoides	Gentry Indigobush	7	*	1	1	1	*	*
Echinocactus horizonthalonius var. nicholii	Nichol's Turk's Head Cactus	7	*	1	*	1	*	*
Echinomastus erectocentrus acunensis	Acuna Cactus	7	*	1	1	1	*	*
Echinomastus erectocentrus var. erectocen	Needle-spined Pineapple Cactus	7	*	1	*	1	*	*
Lilaeopsis schaffneriana ssp. Recurva	Huachuca Water Umbrel	7	1	*	1	1	*	*
Tumamoca macdougalii	Tumamoc Globeberry	7	*	1	1	1	*	*