APPENDIX C

BIOLOGY OF THE COVERED SPECIES

- GOLDEN-CHEEKED WARBLER
- BLACK-CAPPED VIREO
- LISTED KARST INVERTEBRATES

GOLDEN-CHEEKED WARBLER

RESOURCE ASSESSMENT

FOR THE SOUTHERN EDWARDS PLATEAU

HABITAT CONSERVATION PLAN

OCTOBER 27, 2011

1.0 INTRODUCTION

This resource assessment describes the basic biology and current status of the golden-cheeked warbler (*Setophaga chrysoparia*, GCW) in the Southern Edwards Plateau Habitat Conservation Plan (SEP-HCP) Plan Area, which includes Bexar, Medina, Bandera, Kerr, Kendall, Blanco, and Comal counties. The purpose of this assessment is to help develop the conceptual framework for the SEP-HCP and provide the basic background information for the Habitat Conservation Plan and associated Environmental Impact Statement.

Table 1 summarizes some of the important information related to the status of the golden-cheeked warbler and its habitat. Additional discussion of this information is addressed in the referenced sections.

All tables and figures are attached at the end of the report.

2.0 SPECIES DESCRIPTION

The golden-cheeked warbler is a migratory, insectivorous songbird approximately five inches long. Adult males have black on the crown, nape, back, throat, and upper breast. The wings are black with two white wing bars. The cheeks are a bright golden-yellow with a black eyeline. The underparts are white streaked with black on the flanks. Adult females are similar but duller overall and the crown and back are olive-green with some black streaking. On adult females, the chin and upper throat are yellowish with some black streaks (Ladd and Gass 1999). Figure 1 includes photographs of the golden-cheeked warbler.

3.0 LIFE HISTORY CHARACTERISTICS

3.1 RANGE AND MIGRATION PATTERNS

The golden-cheeked warbler migrates annually between wintering grounds in southern Mexico and Central America and breeding grounds on the Edwards Plateau and adjacent areas in central Texas. The species arrives in central Texas in early to mid-March to breed. Nesting activities are typically completed by the end of July, and the species begins migration south in June or July (Ladd and Gass 1999). Most warblers have left central Texas by early to mid-August (Wahl et al. 1990).

The golden-cheeked warbler is the only bird in Texas that nests exclusively within the state's boundaries (Oberholser 1974). There are currently 27 counties that are known to support golden-cheeked warblers, including Bandera, Bell, Bexar, Blanco, Bosque, Burnet, Comal, Coryell, Edwards, Gillespie, Hays, Johnson, Kendall, Kerr, Kimble, Kinney, Lampasas, Llano, Medina, Palo Pinto, Real, San Saba, Somervell, Travis, Uvalde, Williamson, and Young counties (SWCA 2007, Groce et al. 2010). Warblers have also been recently detected in Dallas, Erath, Jack, Hamilton, Hill, Hood, McLennan, and Stephens counties (SWCA 2007, Groce et al. 2010), but additional surveys are needed to determine the extent to which the species occurs in these counties. Reliable historic records of golden-cheeked warbler occurrence are known from Eastland, Hamilton, Hood, and Stephens counties; however, the current status of the species in these six counties is uncertain (Ladd and Gass 1999). Other counties that may contain potentially suitable habitat for the golden-cheeked warbler, but for which further study is needed to determine if the species is present, include Brown, Comanche, Ellis, Guadalupe, Mason, McCulloch, Menard, Mills, Parker, and Sutton counties (Ladd and Gass 1999, SWCA 2007, Groce et al. 2010).

Figure 2 shows the 35 counties identified in the 1992 Golden-cheeked Warbler Recovery Plan (USFWS 1992) as included in the breeding range of the species. This figure also notes the other 11 counties with current records of occurrence, reliable historic records of occurrence, or potentially suitable habitat.

3.2 TERRITORIAL CHARACTERISTICS

3.2.1 TERRITORY BEHAVIOR AND SIZE

Male warblers announce and defend territories partly by singing high-pitched, buzzy songs loudly from conspicuous perches near the tops of trees. Females do not sing or defend territories, and have less conspicuous behavior (Ladd and Gass 1999). Golden-cheeked warblers often occupy the same territory in subsequent breeding seasons (Campbell 2003), but limited data on GCW dispersal between years report distances of up to 62 miles for adult males and up to 1.4 miles for adult females (Groce et al. 2010). Juvenile GCWs have been documented dispersing up to approximately 6.2 miles from their natal territory (Groce et al. 2010).

Male warblers are territorial during the breeding season and defend territories that typically range from approximately four to ten acres (Ladd and Gass 1999), but territory sizes of between approximately one and 57 acres have been reported (Groce et al. 2010). Campbell (2003) states that golden-cheeked warblers forage and nest in areas of habitat encompassing approximately five to 20 acres per pair.

Unpublished data from Texas Parks and Wildlife Department (TPWD) indicate varying territory sizes in Bexar County that range from approximately two to 29 acres, but average approximately five to nine acres (Richard Heilbrun, TWPD, personal communication). Golden-cheeked warbler territory sizes reported from Hill Country State Natural Area and Guadalupe River State Natural Area range from approximately two to 10 acres and average approximately three to seven acres (Richard Heilbrun, TWPD, personal communication).

Average territory size on a property in far northwest Bexar County was estimated to be approximately 9.3 acres, based on the results of a presence/absence, spot-mapping survey completed by Loomis Partners in 2008 (unpublished data). Loomis Partners estimated an average territory size of approximately 17.5 acres on another Bexar County property in 2010, also based on the results of a presence/absence spot-mapping survey (Loomis Partners, unpublished data). Coldren (1998) found that territory size was inversely related to reproductive success, such that large territories may be an indicator of poor habitat quality (most likely due to reduced food availability and foraging opportunities).

3.2.2 TERRITORY DENSITY

Pulich (1976) estimated that 85 acres of habitat were needed to support one pair of golden-cheeked warblers in marginal habitat (1.2 pairs per 100 acres), 50 acres were needed in average habitat (2.0 pairs per 100 acres), and 20 acres were needed in excellent habitat (5.0 pairs per 100 acres). Other early studies found golden-cheeked warbler territory densities ranging between 9.5 and 20 pairs per 100 acres (USFWS 1992). Wahl et al. (1990) suggests that an approximate range-wide measure of warbler territory density in areas of suitable habitat is 6.1 territories per 100 acres (Wahl et al. 1990).

Golden-cheeked warbler territory size and territory density estimates for habitats within the SEP-HCP Plan Area are few. SWCA (2008) notes that relatively few systematic golden-cheeked warbler surveys have been conducted in the vicinity of San Antonio, which hinder attempts at developing an accurate population estimate for this area.

Wahl et al. (1990) reports golden-cheeked warbler density estimates from five sites that occur within the SEP-HCP Plan Area, based on surveys completed in 1987 and 1988 using Emlen strip census or variable circular plot survey methods. The estimated golden-cheeked warbler densities for these sites (including Guadalupe River State Park and Honey Creek State Natural Area in Comal County, Pedernales Falls State Park in Blanco County, Friedrich Park in Bexar County, and Lost Maples State Natural Area in Bandera County) range from approximately 3.2 males per 100 acres of suitable habitat to approximately 25 males per 100 acres of suitable habitat. However, the USFWS suggests estimating absolute densities of territorial birds from transect-based methods may be unreliable, as compared to spot-mapping methods (USFWS 1992).

Long-term golden-cheeked warbler monitoring data from Camp Bullis in Bexar County between 1991 and 2008, collected from point count surveys along transects established across the property, report an average, installation-wide, annual density estimate of approximately 4.1 singing males per 100 acres of habitat, with a range of approximately 1.5 singing males per 100 acres reported in 1993 to 8.1 singing males per 100 acres reported in 2006 (Cooksey and Edwards 2008). Surveys completed between 2002 and 2008 used similar methods, and Cooksey and Edwards (2008) show a more recent average density of 5.8 singing males per 100 acres of habitat during this 7-year period. The Camp Bullis Cibolo Creek and Lewis Creek subpopulations (which represent approximately 734 acres and 1,075 acres of relatively higher quality habitat, respectively) have shown average densities of approximately 4.9 singing males per 100 acres of habitat between 1991 and 2008, with the highest reported density of approximately 10.2 singing males per 100 acres of habitat for the Cibolo Creek subpopulation in 2001 (Cooksey and Edwards 2008). The USFWS suggests that the Camp Bullis golden-cheeked warbler density estimates derived from these point count surveys may be an underestimate of the density that could be documented using territory mapping methods (USFWS 2005).

A territory mapping survey completed by Loomis Partners (formerly known as Loomis Austin, Inc.) on a ranch in northwest Bexar County in 2008 using the USFWS spot-mapping protocol for presence/absence surveys found approximately 6.9 male territories per 100 acres of suitable habitat (Loomis Austin 2008; as calculated from the sum of all territories completely within the property boundary and one-half of the territories partially within the property boundary, divided by the acres of potential habitat and multiplied by 100). A similar survey completed by Loomis Partners in 2010 on another Bexar County ranch found a density of approximately 2.9 territories per 100 acres of suitable habitat (Loomis Partners 2010a).

SWCA Environmental Consultants report that for 20 protected properties in Comal, Bexar, Medina, Blanco, and Kendall counties that include approximately 25,403 acres of suitable habitat, the average density of the known warbler population was approximately 1.1 pairs per 100 acres of suitable habitat, based on SWCA survey data and information from The Nature Conservancy, San Antonio Parks and Recreation Department, TPWD, and USFWS (SWCA 2008). The time period of these data (if reported) vary for individual properties, but generally ranges from approximately the late 1990's through the mid to late 2000's. However, the regional density estimate reported in SWCA (2008) may underestimate the true density of golden-cheeked warblers in this area since some of the data included in the estimate do not appear to have been derived from a systematic survey or represent a consistent level of survey effort (specific references for the sources of the population estimates for several properties are not reported).

Elsewhere in the range of the golden-cheeked warbler, recent studies by the U.S. Army Corps of Engineers and The Nature Conservancy on portions of Fort Hood, by the City of Austin and Travis County on the Balcones Canyonlands Preserve, and by the USFWS on the Balcones Canyonlands National Wildlife Refuge have reported territory densities for intensively studied areas in Bell, Travis, Williamson, and Burnet counties. These studies reported warbler territory densities of between approximately 2.3 and 26.3 territories per 100 acres of suitable habitat (Jette et al. 1998; Hollimon and Craft 1999; Peak 2005 and 2007a; City of Austin 2006, 2005, 2004, and 2003; Travis County 2007, 2006, 2004, and 2003; Sexton 2008).

3.3 DIET AND FORAGING BEHAVIOR

Golden-cheeked warblers eat a diet of insects, spiders, and other arthropods during the breeding season, generally taken from the upper two-thirds of the canopy (Pulich 1976). Wharton et al. (1996) notes that the golden-cheeked warbler is a generalist with a highly varied diet and that the species is capable of making use of whichever prey species is locally abundant at the time. The warbler forages in both Ashe junipers (*Juniperus ashei*) and deciduous trees present in its breeding habitat (Pulich 1976); however, deciduous trees (particularly oaks) appear to be more important as a foraging substrate in the early part of the breeding season (Wahl et al. 1990, Groce et al. 2010). Wharton et al. (1996) found that potential prey items were abundant at all canopy height levels and arthropod numbers were generally comparable across several different tree species common in golden-cheeked warbler habitat (Ashe juniper, Spanish oak (*Quercus buckleyi*), live oak (*Quercus fusiformis*), and cedar elm (*Ulmus crassifolia*)). However, Butcher et al. (2008) reported that arthropod biomass was consistently higher in Spanish oak trees, compared to Ashe juniper trees.

Golden-cheeked warblers generally forage within their territories, but are known to leave the territory to visit springs, seeps, shallow pools, creeks, or local water sources in the landscape (Pulich

1976). Coldren (1998) suggests that food availability and foraging opportunities may be an important factor limiting reproductive success.

3.4 NESTING BEHAVIOR

Soon after arrival on breeding grounds in central Texas, male and female golden-cheeked warblers form pairs. Nest building commences within several days of pairing (Ladd and Gass 1999). Both male and female golden-cheeked warblers participate in selecting suitable nesting sites, although the nest is constructed primarily by the female (Graber et al. 2006, Gass 1996, Pulich 1976). Nests are typically located in patches of dense vegetation with nearly complete canopy closure and a high density of small trees, particularly junipers (Dearborn and Sanchez 2001). Strips of Ashe juniper bark, available only from mature trees, are the primary and most essential component of golden-cheeked warbler nests (Pulich 1976). Figure 3 shows an active golden-cheeked warbler nest.

Females typically lay three or four eggs in mid-April (rarely five eggs), occasionally laying a second clutch in May (Pulich 1976). The incubation period is typically ten to 12 days (Ladd and Gass 1999). Young birds remain in the nest approximately nine to 12 days and are fed by both parents (Ladd and Gass 1999). Parents continue to feed fledglings for approximately one month, after which independent young may join mixed foraging groups that frequently utilize more open habitat (Ladd and Gass 1999).

4.0 HABITAT DESCRIPTION

In Texas, the golden-cheeked warbler is an inhabitant of old-growth or mature regrowth juniper-oak woodlands in the Edwards Plateau, Lampasas Cut-Plain, and Llano Uplift (Pulich 1976, Wahl et al. 1990, USFWS 1992). Regrowth woodlands suitable for warblers typically require 20 to 50 years to mature under favorable conditions, depending partially on soil condition and the retention of oaks after clearing (USFWS 1992, Ladd and Gass 1999, Groce et al. 2010). Golden-cheeked warblers are typically found in areas of steep slopes, canyon heads, draws, and adjacent ridgetops (Pulich 1976, Ladd 1985). However, the species is also known to utilize flat, upland terrain (Heilbrun et al. 2009), and Ladd and Gass (1999) note that "habitat is not restricted to or excluded from any particular landscape position, but may develop wherever suitable conditions and land-use practices exist for growth of mature juniper oak woodlands, though varying in habitat quality". Photos of typical golden-cheeked warbler habitat are included in Figure 4.

4.1 SPECIES COMPOSITION

Ashe juniper and various oak species are the most common tree species throughout the golden-cheeked warbler's breeding range. The peeling bark of mature Ashe juniper trees is essential for nest building, and deciduous trees (especially deciduous oaks) are important for foraging (Wahl et al. 1990).

Ashe juniper is nearly always the dominant tree in nesting habitat (Beardmore 1994, Ladd and Gass 1999, Rowell et al. 2002, Cummins 2006, and Newnam 2008), but juniper has been shown to comprise anywhere between ten and 83 percent of total trees at several sites scattered throughout the range of the species (USFWS 1992). Campbell (2003) reports that the range of juniper representation in suitable golden-cheeked warbler habitat is between ten and 90 percent of the total number of trees. Some mature Ashe juniper with peeling bark is necessary to provide material for nest construction.

Spanish oak, plateau live oak (*Quercus fusiformis*), Lacey oak (*Quercus glaucoides*), post oak (*Quercus stellata*), white shin oak (*Quercus sinuata*), cedar elm, escarpment black cherry (*Prunus serotina*), walnut (*Juglans* spp.), hackberry (*Celtis* spp.), and Texas ash (*Fraxinus texensis*) are common in golden-cheeked warbler habitat, particularly in the south-central part of the warbler's range (Pulich 1976, Beardmore 1994, Ladd and Gass 1999, SWCA 2007, Loomis Austin 2008). Some models predicting warbler use of woodland vegetation suggest that a higher density of deciduous oaks is positively associated with increased warbler density (Wahl et al. 1990).

4.2 CANOPY COVER AND HEIGHT

Golden-cheeked warblers utilize moderate to dense forest or woodland habitat with a high percent canopy cover in the middle and upper layers (Ladd and Gass 1999). Total tree cover measured at several sites across the breeding range of the warbler averaged 70 percent at 10 feet, 74 percent at 16 feet, and 70 percent above 18 feet (Ladd and Gass 1999). Others have described appropriate habitat as having as little as approximately 35 percent canopy cover (Campbell 2003, SWCA 2003, Reemts et al. 2008, Heilbrun et al. 2009).

Wahl et al. (1990) found that average canopy height of golden-cheeked warbler habitat was approximately 22 feet. Campbell (2003) reports that trees suitable for warbler nesting habitat are generally at least 15 feet tall. Higher warbler densities have been associated with greater average tree height and greater variability in average tree height (Wahl et al. 1990).

4.3 PATCH SIZE AND LANDSCAPE MATRIX

The golden-cheeked warbler is a slightly forest-interior species (Coldren 1998, DeBoer and Diamond 2006) that also utilizes woodland edges, particularly after young have fledged (Kroll 1980, Coldren 1998).

Ladd and Gass (1999) state that prime habitat is found in patches of at least 250 acres, but smaller habitat patches are also utilized by the species (USFWS 1992, Groce et al. 2010). Coldren (1998) also found that warblers selected for habitat patches larger than 250 acres, and selected against utilizing smaller patches of habitat. However, much of the available habitat for the species is within these smaller patches. DeBoer and Diamond (2006) found that approximately 32 percent of available warbler habitat range-wide was in patches of less than 250 acres. Arnold et al. (1996) reports that warblers have been observed consistently occupying and successfully reproducing in patches of at least 57 acres. Similarly, Butcher (2008) found evidence to suggest that the minimum patch size needed for warbler reproduction was between approximately 37 acres and 50 acres. However, larger patches have been shown more likely to result in higher probabilities of occupancy and better pairing and reproductive success than smaller patches (Coldren 1998, DeBoer and Diamond 2006, Morrison et al. 2010).

Magness et al. (2006) found that at least 40 percent of the landscape must have woodland cover for a site with suitable habitat to be occupied by golden-cheeked warblers (woodland cover was defined as having at least 30 percent woody canopy cover). The study further found that at least 80 percent of the landscape must have suitable woodland habitat before the probability of occupancy of a site by golden-cheeked warblers exceeds 50 percent. This relationship held at a variety of spatial scales representing approximately 1X, 4X, 6X, and 66X of a typical territory size. The authors assert that the amount of juniper-oak woodland within approximately 500 acres surrounding a site is an important predictor of occupancy and that “suitable warbler habitat is not identifiable unless considered within the context of a landscape substantially larger than an individual breeding territory…an accumulation of information collected at a fine spatial scale is not adequate for revealing the primary factors involved in habitat selection and guiding management of the species" (Magness et al. 2006).

4.4 TERRAIN

Golden-cheeked warbler habitat is frequently associated with steep canyon slopes and generally rough terrain (Ladd 1985). DeBoer and Diamond (2006) showed that occupied habitat patches generally had steeper and more variable slopes than unoccupied habitat patches. The golden-cheeked warbler Recovery Plan (USFWS 1992) provides a number of possible explanations for the association, including increased water availability favoring the growth of deciduous trees and food availability, greater protection from wild fires, and greater protection from land clearing activities due to the difficulty in accessing and working on steep slopes. However, warblers are not restricted to canyon slopes, and suitable habitat (i.e., mature juniper-oak woodlands) may also be found on adjacent ridge tops and uplands (Ladd and Gass 1999).

4.5 EDGE EFFECTS

Conditions at the edge of golden-cheeked warbler habitat patches appear to influence the occupancy, territory distribution, territory size, pairing success, and reproductive success of the species (Coldren 1998). Coldren (1998) found that reproductive success was higher in territories placed at least approximately 500 feet from a patch edge. Peak (2007b) and Reidy (2008) found that nest survival decreased as the density of forest edges in the landscape increased. Coldren (1998) suggests that the character of habitat patch boundaries (i.e., "hard" versus "soft" edges, degree of human disturbance of adjacent land uses, amount of edge) may be more important to the species than the presence of natural gaps in woodland canopy cover. Food availability, nest predation (particularly by snakes and birds, such as crows and jays), and nest parasitism by brown-headed cowbirds (*Molothrus ater*) may also contribute to edge effects, as influenced by patch size and the nature of the surrounding landscape (Engels 1995, Coldren 1998, Stake et al. 2004, USFWS 1992).

The golden-cheeked warbler appears to be less likely to occupy habitat adjacent to land uses with hard edges and high levels of human disturbance, particularly residential and commercial development (Engels 1995, Coldren 1998), and more likely to occupy habitat patches adjacent to soft edges associated with agricultural and grassland uses (Coldren 1998). Warblers also generally placed territories farther from habitat edges with adjacent high-disturbance land uses, such as residential and transportation development (Coldren 1998).

Edge effects have been shown to influence warbler breeding behavior, success, or detections at distances between approximately 330 feet to 980 feet from the edge of a habitat patch (Coldren 1998, Sperry 2007). The density of forest edge within 330 feet of a warbler nest has also been shown to influence nest survival, such that nest survival was higher in areas with less forest edge (Peak 2007b, Reidy et al. 2009).

4.6 OTHER HABITATS

Other habitats utilized by golden-cheeked warblers in central Texas, particularly by fledglings and family groups later in the breeding season, include woodlands and woodland edges with less species diversity, canopy cover, and canopy height than is typical for breeding or nesting habitat. Upland oak savannas and drier, sparser juniper woodlands may also be used later in the breeding season (Ladd and Gass 1999).

5.0 HABITAT AVAILABILITY AND POPULATION ESTIMATES

5.1 HABITAT AVAILABILITY

5.1.1 RANGE-WIDE HABITAT ESTIMATES

The golden-cheeked warbler Recovery Plan (USFWS 1992) presents several historic estimates of available habitat for the golden-cheeked warbler across its breeding range in Texas. These estimates vary between approximately 908,619 acres of “virgin juniper habitat” in 1962 (Pulich 1976) to approximately 586,043 acres of mixed evergreen-deciduous forest or woodland in 1989 (USFWS 1992).

More recent estimates of the amount of suitable golden-cheeked warbler breeding habitat are based on aerial imagery and/or spatial models that analyze satellite data. Diamond (2007) reports the results of “Model C” based on 30-meter resolution satellite data from the middle to late 1990’s that incorporated the concepts of vegetation type, landscape context, and edge effects into a model identifying potential golden-cheeked warbler habitat. Model C identified approximately 4,427,841 acres of potentially suitable habitat for the golden-cheeked warbler within the 35 counties described in USFWS (1992) as the breeding range of the species. Model C was subsequently re-run by the authors using an updated land cover classification based primarily on 2005-2007 satellite data and modified to achieve a higher resolution (10 meters). This updated Model C also treated stands of live oak as a woodland type that was not representative of potential warbler habitat (David Diamond, Missouri Resource Assessment Partnership, personal communication). The updated and re-run Model C (“Model C2”) identified approximately 3,597,747 acres of potentially suitable warbler habitat across the range of the species.

Loomis Partners developed a GCW habitat model using the 2001 National Land Cover Dataset (NLCD) canopy cover data. The Loomis model also has a resolution of 30 meters, covers the 35 counties of occurrence described in USFWS (1992), and identifies the location, relative quality, and likelihood of occupancy of potential golden-cheeked warbler habitat based on a landscape analysis of mean tree canopy cover. The Loomis model identifies approximately 4,149,478 acres of potential golden-cheeked warbler habitat throughout the breeding range of the species, including nearly 1.6 million acres of potential high quality habitat with canopy cover that averages greater than 70 percent closure (Loomis Partners 2009).

SWCA Environmental Consultants estimated the amount of suitable golden-cheeked warbler habitat based on delineations from 2004 aerial imagery. They delineated habitat in 43 counties that are currently known or expected to harbor the species and report that approximately 1,363,807 acres of suitable warbler habitat may be available (SWCA 2007). The SWCA habitat delineation focused on identifying known habitats and areas with a reasonable potential of being utilized by the species, including mixed juniper-oak woodlands with greater than 50 percent canopy cover and generally composed of primarily larger trees. This delineation may represent a relatively conservative estimate of potential golden-cheeked warbler habitat, compared to the results of habitat models based on satellite data.

The most recent, range-wide estimate of potential golden-cheeked warbler habitat was developed by Texas A&M University (TAMU) (Morrison et al. 2010). This team used an unsupervised classification of satellite imagery dating from 2007/2008 to classify land cover across the range of the golden-cheeked warbler as either woodland (with canopy cover greater than 30 percent) or non-woodland cover. The classification was verified by aerial image interpretation of 1,000 randomly placed points across the range of the species (the aerial imagery dated to 2008). Woodland cover was assumed to be representative of potentially suitable golden-cheeked warbler habitat. The TAMU habitat model identified 4,148,138 acres of potential warbler habitat the 35-county study area, which was distributed among 63,616 individual habitat patches. Morrison et al. (2010) also predicts the probability of occupancy for patches of potential habitat (see Model III based on field surveys, patch size, landscape composition, and spatial location) and estimated that approximately 2,778,208 acres of potential habitat (67 percent of the total) had a predicted probability of occupancy of at least 50 percent.

Table 2 lists several of the historic and recent range-wide estimates of available habitat for the golden-cheeked warbler in its breeding range. However, these different habitat estimates are not directly comparable with each other due to differences in methodologies, definitions of what constitutes suitable habitat, and the geographic coverage of the analysis.

5.1.2 HABITAT ESTIMATES FOR THE SEP-HCP PLAN AREA

For the purposes of developing the SEP-HCP, this assessment evaluates the results of the 2007/2008 TAMU habitat model (Morrison et al. 2010) and an update of Model C2 prepared specifically for the SEP-HCP (Diamond et al. 2010). Diamond et al. (2010) identified forest areas that had been cleared between 2005-2007 and 2010 (except for the extreme southern and eastern extents of the species' range within the Plan Area, where changes represented the period between the middle to late 1990's and 2010). The accuracy of the forest change detection was verified by comparison to 2010 aerial imagery at 250 stratified random points. Diamond et al. (2010) re-ran the process used to create Model C2 with this updated forest cover data ("Model C2010"). These two habitat models provide the most recent estimates of potential warbler habitat for the Plan Area and are summarized in Table 3.

A liberal interpretation of the 2007/2008 TAMU model and Model C2010 indicates that between 989,000 and 1,110,000 acres of potential habitat currently exists in the Plan Area. However, both models include some areas of potential habitat that are not likely to be used by the species, as indicated by the probability of occupancy or the relative ranking of the identified habitat. Morrison et al. (2010) considered habitat patches with at least 50 percent probability of occupancy as "habitat" in their comparison of various habitat models. Ranks 3 and 4 of Model C2010 represent the interiors of habitat patches that are more likely to represent warbler habitat. Therefore, a more conservative interpretation of the amount of habitat within the Plan Area (based on TAMU habitat patches with at least 50 percent probability of occupancy and Ranks 3 and 4 from Model C2010) indicates that approximately 674,059 to 892,990 acres of this potential habitat is relatively likely to be occupied by the species. These conservative estimates of potential golden-cheeked warbler habitat represent approximately 16 to 22 percent of the total acreage of the Plan Area.

The distribution of potential golden-cheeked warbler habitat across the Plan Area is similar for both models. Bandera, Comal, and Kerr counties contain the most potential golden-cheeked warbler habitat of the seven counties in the Plan Area, while Blanco, Bexar, and Kendall counties contain the least amount of potential habitat. Figures 5 and 6 show the distribution of potential golden-cheeked warbler habitat across the Plan Area.

5.1.3 PATCH SIZE ANALYSIS

Golden-cheeked warblers are generally thought to prefer and thrive in larger patches of suitable habitat, rather than smaller patches (see Section 4.3). An analysis of habitat patch size (using the liberal estimates of potentially suitable habitat identified by the TAMU habitat model and Model C2010) indicates that between approximately 731,000 and 765,000 acres of potential golden-cheeked warbler habitat occurs in the SEP-HCP Plan Area that is part of a patch containing at least 500 acres (i.e., approximately 61 and 77 percent of all potentially available habitat in the Plan Area). The liberal estimate of potential habitat was used for the patch size analysis since this approach results in a more consistent interpretation of what constitutes a "habitat patch" between the two models.

The patch size analysis suggests that most of the currently available warbler habitat in the Plan Area, particularly in Bandera, Medina, and Bexar counties, occurs in large patches that may have long-term conservation value and demonstrates that there is a relatively high degree of habitat connectivity across the landscape.

Table 4 summarizes the patch size distribution of potential golden-cheeked warbler habitat in the SEP-HCP Plan Area. The distribution of large and small habitat patches identified by the TAMU model and Model C2010 are shown on Figures 7 and 8.

5.2 POPULATION ESTIMATES

5.2.1 RANGE-WIDE POPULATION ESTIMATES

Several estimates of golden-cheeked warbler population sizes for certain areas have been proposed. Pulich (1976) estimated a range-wide population size of approximately 18,486 pairs in 1962 and USFWS (1992) estimated that the total breeding population was approximately 13,800 pairs in the late 1970's (based on work reported in Wahl et al. 1990). SWCA Environmental Consultants preliminarily estimated that the current range-wide population of the golden-cheeked warbler is approximately 20,000 to 27,000 breeding pairs (SWCA 2007).

The most recent and rigorously assessed golden-cheeked warbler population estimate was developed by TAMU and reported in Morrison et al. (2010). TAMU estimated that the range-wide warbler population in 2009 was composed of 175,000 to 265,000 adult males, with a total estimated population of more than 370,000 adults (including females). This estimate was based on the TAMU habitat model, and considered patch size, the probability of occupancy of individual habitat patches, and patch-specific warbler density estimates based on point count data collected from across the range of the species. Morrison et al. (2010) acknowledge that this population estimate is substantially greater than prior estimates, but note that their average warbler density (approximately 5.6 adult males per 100 acres of habitat) was within the range reported by other researchers and is likely to be conservative due to an assumed detection probability of 1.0 for the analysis of bird count data (actual detection probabilities are typically less than one, resulting in an underestimate of the true number of birds that were present). The difference in the population estimates (described in Section 5.1.1) between the early 1990's and the most recent population estimate developed by TAMU (Morrison et al. 2010) is likely based on differences in the underlying habitat mapping projections, rather than a true 10-fold increase in the size of the GCW population over two decades.

5.2.2 SEP-HCP PLAN AREA POPULATION ESTIMATES

Available records from the USFWS and the TPWD of known golden-cheeked warbler localities within the SEP-HCP Plan Area are incomplete, but indicate that the species has been recorded from each of the Plan Area counties.

Golden-cheeked warbler observation data from the USFWS were received from the Austin Ecological Services office in September 2009 in GIS format (i.e., “HistoricBirdSurveys_Observations.mdb”). The data included point records with attribute fields for the observation year and source, notes regarding the quality of the data, and other comments. The data were compiled from the work of several different surveyors and were dated from between the years 1978 and 2004.

The Texas Natural Diversity Database (TXNDD) element of occurrence records were obtained in GIS polygon format from the TPWD in March 2010. The digital polygon records were adapted from point records compiled on paper maps by TPWD that were symbolized by the precision of the record (i.e., second, minute, or general observations). The precision of the original point records were incorporated into the polygon shapes of the updated digital records. Golden-cheeked warbler records in the TXNDD were dated from approximately 1988 to 2009.

Additional point observations in GIS format were provided from survey data collected by Loomis Partners between 2008 and 2010 that were not included in either the USFWS or TXNDD databases. These observations were collected with GPS equipment in the field or digitized from detailed paper maps as part of a USFWS protocol presence-absence survey.

Generalized golden-cheeked warbler localities, compiled from information provided by the USFWS, the Texas Natural Diversity Database, and from other survey records maintained by Loomis Partners, are shown on Figure 9.

A conservative estimate for golden-cheeked warbler abundance in the SEP-HCP Plan area may be derived from the 2010 habitat estimate from Model C2010 and an average density of 2.0 singing males per 100 acres of habitat (estimated by Pulich (1976) as an approximate density in “average” habitat) or 4.1 singing males per 100 acres of habitat (the long-term average density reported for Camp Bullis). Using the conservative estimate of potential habitat from Model C2010 (approximately 674,000 acres) and a warbler density of 2.0 or 4.1 males per 100 acres of habitat, approximately 13,500 to 27,600 singing males could be present within the Plan Area. Assuming a pairing rate of 70 percent (consistent with the assumptions in Morrison et al. 2010), the total population of adult golden-cheeked warblers in the Plan Area could be approximately 22,950 to 46,000 individuals.

For comparison, Morrison et al. (2010) estimated that the mean abundance of singing males in Bexar, Comal, and Kendall counties alone was approximately 21,688 in 2009 (an approximate density of 5.6 singing males per 100 acres of potential habitat).

6.0 REGULATORY STATUS AND RECOVERY GOALS

6.1 CURRENT REGULATORY STATUS

The USFWS published an emergency listing of the golden-cheeked warbler as endangered on May 4, 1990 (55 FR 18844). A proposed rule to list the warbler as endangered was also published by the USFWS on the same day. The final rule listing the species as federally endangered was published on December 27, 1990 (55 FR 53153). The USFWS has not designated critical habitat for the golden-cheeked warbler.

The golden-cheeked warbler was listed as endangered by the State of Texas on February 19, 1991 per Executive Order No. 91-001.

6.2 RECOVERY CRITERIA

The current 1992 Golden-cheeked Warbler Recovery Plan (USFWS 1992) identifies the criteria to be met for the warbler to be considered for downlisting from endangered to threatened status. These recovery criteria include the protection of sufficient breeding habitat to ensure the continued existence of at least one viable, self sustaining warbler population in each of the eight recovery regions delineated in the recovery plan, where the potential for gene flow exists across regions to ensure long-term viability of the protected populations (USFWS 1992).

The SEP-HCP Plan Area includes all of Bexar, Medina, Bandera, Kerr, Kendall, Blanco, and Comal counties. This Plan Area lies primarily within Recovery Region 6, but also includes portions of Recovery Regions 4, 5, 7 and 8 (Figure 10).

Participants at the "Population and Habitat Viability Workshop" held in August 1995 recommended protection of sufficient habitat for a carrying capacity of 3,000 breeding pairs for each golden-cheeked warbler recovery region, with habitat management measures to include prevention of habitat damage by herbivores, habitat restoration, maintenance of high percent canopy cover of trees, oak wilt prevention, predator and nest parasite control, limiting human impacts in habitat, and planning at the landscape level (USFWS 1996).

Recovery strategies for the golden-cheeked warbler include the identification and protection of "focal areas" that include a single, viable warbler population or one or more smaller populations that are interconnected (USFWS 1992). Achieving the recovery goals for the warbler also requires the protection and management of "abundant and scattered patches of habitat" outside of the focal protection areas (USFWS 1992).

While the SEP-HCP Plan Area includes portions of five different golden-cheeked warbler recovery regions, the Plan Area is primarily composed of Recovery Region 6. Conservation actions in the Plan Area that would be on par with achieving recovery of the species in Region 6 might require the permanent protection and management of approximately 75,000 acres of relatively high quality golden-cheeked warbler habitat. This broad estimate is based on achieving a protected population of 3,000 pairs at an average density of approximately 4 pairs per 100 acres of suitable habitat, which is the long-term average density of singing males recorded on Camp Bullis.

In 2009, USFWS reconvened a Recovery Team for the golden-cheeked warbler to revise the 1992 Recovery Plan for this species. However, a revised recovery plan was not released in time for consideration during the development of the SEP-HCP. A scientific evaluation of the golden-cheeked warbler was prepared by TAMU in 2010 (Groce et al. 2010) that is intended to support a 5-year status review of the species by USFWS. However, a formal status review of the species by the USFWS was not available at this time of this writing.

7.0 THREATS AND HISTORIC TRENDS

7.1 HABITAT LOSS AND FRAGMENTATION

The most significant threats to the golden-cheeked warbler are likely to be habitat loss and fragmentation in the species' breeding and wintering ranges (Wahl et al. 1990, USFWS 1992, Ladd and Gass 1999, Campbell 2003). Habitat loss may occur as the result of clearing of woodland vegetation for a broad range of land development activities (including the construction of transportation and utility infrastructure), agricultural practices, mining and quarry operations, reservoir construction, and other activities. Habitat loss also frequently leads to increased fragmentation of the remaining habitat, which may decrease the size of remaining habitat patches, increase the species' exposure to the influences of incompatible land uses along the edge of habitat patches (such as increased human activity and noise, introduction of urban-tolerant predators and competitors, and other effects), and alter the general character or context of the landscape (see Section 4.5 for a more complete description of edge effects on the species).

7.1.1 HISTORIC HABITAT LOSS ESTIMATES

Wahl et al. (1990) suggests that the rate of habitat loss for the golden-cheeked warbler in rural areas appeared to be relatively steady at approximately 2 to 3 percent per year (based on a review of aerial imagery from the 1970s and 1980s). Wahl et al. (1990) also suggests that the rate of golden-cheeked warbler habitat loss in urban areas during this same period may range from approximately 4 percent to 11.6 percent annually, based on work by Clark (1985), particularly for the San Antonio area.

7.1.2 NLCD 1992 – 2001 HABITAT LOSS ESTIMATES

The National Land Cover Dataset (NLCD) tracked changes in vegetation and land use across the U.S. between 1992 and 2001. Groce et al. (2010) summarized changes to NLCD forest cover between 1992 and 2001 within the range of the golden-cheeked warbler and limited to the extent of the Edwards Plateau and Cross Timbers ecoregions (Table 5). This dataset indicates that approximately 92,578 acres of forest cover in the SEP-HCP Plan Area that could represent potential golden-cheeked warbler habitat was converted to other types of land cover during this period. Some of this loss was mitigated by the emergence of approximately 13,923 acres of new forest cover. The NLCD indicates that there was a net decrease of forest cover in the Plan Area of approximately 6 percent between 1992 and 2001, which represents an average annual decrease of approximately 0.7 percent. Within Bexar County, there was an approximately 12 percent net loss of forest cover (approximately 16,455 acres) between 1992 and 2001, representing an average annual loss of approximately 1.4 percent. Figure 11 shows the results of the NLCD changes between 1992 and 2001.

Conversion to grassland or shrubland vegetation was the most common fate of lost forest cover across the Plan Area, particularly outside of Bexar County. Conversion of forest cover to other non-urban land cover types accounted for approximately 87 percent of the forest cover loss across the Plan Area, and as much as 97 or 98 percent of the loss in Blanco, Bandera, Kendall, Kerr, and Medina counties. Approximately 44 percent of the 1992 forest cover in Bexar County was converted to urban land cover types, mostly localized to the areas in the vicinity of Loop 410, Loop 1604, and U.S. 281 in San Antonio.

7.1.3 OTHER RECENT HABITAT LOSS ESTIMATES

The Greater Edwards Aquifer Alliance (GEAA) estimated that approximately 10,544 acres of prime golden-cheeked warbler habitat in Bexar County (approximately 12.5 percent of the available habitat) was lost between mid-1990's and 2009 (Hayes 2010). This habitat loss estimate represents a rate of approximately 1.6 percent loss per year. The GEAA estimate was developed by visually comparing the results of the Diamond (2007) Model C (limited to Rank 4 habitat) and 2008 aerial photography.

Diamond et al. (2010) estimated forest cover loss by comparing the results of Model C2 (see Section 5.1.1 for model information) and a forest/non-forest classification of 2010 satellite data (Figure

12 and Table 6). This analysis estimated that approximately 23,070 acres of forest cover across the Plan Area was lost between 2005 and 2010, or 2.4 percent of the total forest cover over a 5-year period (about 0.5 percent per year). . Although, some of this reported loss (located at the extreme south end of the golden-cheeked warbler range in Bexar and Medina counties; see Figure 12) occurred over an approximately 15-year time frame. Diamond et al. (2010) estimated that approximately 5,535 acres of potential golden-cheeked warbler habitat (5.7 percent of the available habitat in Bexar County, or 1.1 percent per year) was lost between 2005 and 2010 (except for the area generally between Government Canyon State Natural Area and State Highway 281, which represented a 15 year time period).

Groce et al. (2010) report that there was no evidence to indicate that the amount of golden-cheeked warbler breeding habitat is increasing or stable, due to continued habitat loss and fragmentation from human development, shifts in land use, and construction of roads and utility transmission corridors. These threats are likely to be intensified by projected increases in human populations within the breeding range of the species.

7.1.4 WINTERING HABITAT

Warbler wintering habitat in Central America has been affected by lumbering operations (particularly in pine and pine-oak forests), mining, firewood-cutting, and land-clearing for agriculture (Lyons 1990). Conservation efforts are being undertaken in the affected areas to prevent habitat loss (Alliance for the Conservation of Pine-Oak Forests of Mesoamerica 2008).

7.2 REDUCTION OF DECIDUOUS CANOPY

Golden-cheeked breeding habitat is characterized as mature, dense woodlands composed of a mix of Ashe juniper and various deciduous trees (primarily oaks). The loss or reduction of deciduous trees from juniper-oak woodlands may be threatening the relative quality of suitable golden-cheeked warbler habitat, and could reduce the carrying capacity of available habitat over time. Changes in canopy composition have been attributed to factors such as the loss of oak trees due to the oak wilt fungus and a lack of regeneration of deciduous trees from over-browsing by livestock and wildlife (USFWS 1992). Russell and Fowler (2004) indicated that ongoing browsing pressure by deer may prevent the replacement of oaks on the Edwards Plateau. Groce et al. (2010) reports that while feral hogs (*Sus scrofa*) are known to be opportunistic omnivores (including feeding on roots and mast of trees), the foraging effects of feral hogs on oak regeneration is unknown.

The extent or overall effect of any such reduction in habitat quality or carrying capacity across the Plan Area is unknown. Groce et al. (2010) reports that mortality of mature trees from oak wilt is prevalent in the golden-cheeked warbler breeding range and that browsing pressure from ungulates also contributes to a low level of oak seedling recruitment. However, Groce et al. (2010) states that the magnitude and direction of change in this threat is difficult to predict at this time.

7.3 NEST PARASITISM AND PREDATION

Nest parasitism by brown-headed cowbirds may also have contributed to the golden-cheeked warbler's population decline (Pulich 1976, USFWS 1992). Cowbirds, which are typically associated with livestock herds, lay eggs in the nests of other songbirds, including golden-cheeked warblers, and cause the host species to either abandon their nest or to inadvertently raise cowbird chicks in addition to (or in place of) their own young.

Predation of golden-cheeked warblers (including adults, juveniles, and eggs) has been documented for a variety of wildlife species. Blue jays (*Cyanocitta cristata*) and other urban-tolerant birds were identified by the USFWS as predators on the golden-cheeked warbler (USFWS 1992) and recent studies (Stake et al. 2004, Reidy et al. 2008) have also documented predation of golden-cheeked warblers by ratsnakes (*Elaphe* spp.), western scrub-jays (*Aphelocoma californica*), American crows (*Corvus brachyrhynchos*), Cooper's hawks (*Accipter cooperii*), brown-headed cowbirds, fox squirrels (*Sciurus niger*), and red imported fire ants (*Solenopsis invicta*).

The extent or overall effect of any nest parasitism and predation on the golden-cheeked warbler is unknown; however, the exposure of golden-cheeked warblers to these adverse effects may increase with increased levels of habitat fragmentation (USFWS 1992). Groce et al. (2010) found no evidence that current predation levels or rates of cowbird parasitism are a threat to the golden-cheeked warbler population.

7.4 NATURAL DISASTERS AND CLIMATE CHANGE

Natural disasters, such as wildfire, prolonged and severe drought, floods, and tornados, are normal events that occur in the central Texas ecosystem, but nonetheless have the potential to destroy or damage large expanses of suitable golden-cheeked warbler habitat. For example, a wildfire at the Fort Hood Military Reservation in 1996 burned approximately 10,630 acres of golden-cheeked warbler habitat. Subsequently, controlled burning has been used on Fort Hood to help prevent a similar catastrophic event. The USFWS also notes that wildfires occur on Camp Bullis during most years and typically burn an average of approximately 125 acres per year (USFWS 2005).

Global climate change has the potential to alter the regional distribution of plant and animal communities by large-scale changes in average temperature, levels and frequency of precipitation, groundwater regimes, and fire regimes. Climate change could cause areas currently containing suitable habitat for the golden-cheeked warbler to increase or decrease in extent and quality. Climate change could also cause areas not currently considered to be suitable habitat for the golden-cheeked warbler, including areas currently outside of the known ranges of the species, to become suitable habitat and it is possible that the species could adapt to use such habitat.

There is currently insufficient knowledge upon which to base a reliable projection of the potential effects of global climate change on the golden-cheeked warbler. However, multiple initiatives are attempting to assess the risk of this and other wildlife species to climate change. A framework for evaluating species' vulnerabilities to climate change is under development by the U.S. Environmental Protection Agency. The golden-cheeked warbler was used as a case study for applying this proposed framework, and was categorized as "critically vulnerable" to the effects of global climate change based on anticipated impacts to its habitat (Galbraith and Price 2009). However, as reported in the "2010 State of the Birds" report, the U.S. committee of the North American Bird Conservation Initiative (a partnership lead by the USFWS and involving a number of state wildlife agencies and nongovernmental organizations) assessed sensitivity of birds to climate change based on five basic traits that demonstrate adaptability from temporal, spatial, ecological, and evolutionary perspectives. This assessment found that the golden-cheeked warbler was a conservation species of concern with a "medium" climate change vulnerability risk (North American Bird Conservation Initiative 2010).

8.0 EXISTING PROTECTIONS AND PROGRAMS

A variety of public and private lands currently receive some level of protection from future land development activities, and some of these are managed as natural areas or wildlife preserves with a focus on the protection and management of the golden-cheeked warbler. Approximately 163 conservation properties currently exist in the Plan Area, including properties under public and private ownership (not including military installations, such as Camp Bullis). These properties protect approximately 128,000 acres from the majority of future land development activities and may provide some protection for between 50,000 and 60,000 acres of potential golden-cheeked warbler habitat. See the SEP-HCP Resource Assessment for “Existing Conservation Lands” (Loomis Partners 2010b) for more detail. Groce et al. (2010) describes a variety of conservation programs and other tools that are currently available to encourage and assist landowners with actions that benefit endangered species, including habitat conservation plans, grants from the federal Cooperative Endangered Species Conservation Fund, conservation banks, the Recovery Credit system policy incentives, Safe Harbor Agreements, and a variety of other programs providing financial and/or technical assistance for land and wildlife management.

9.0 DATA GAPS AND UNCERTAINTIES

Few systematic surveys for the golden-cheeked warbler, such as a USFWS protocol presence/absence survey, have been conducted on the existing conservation properties in the SEP-HCP Plan Area. The lack of detailed, territory mapping data makes an accurate accounting of the currently protected population of golden-cheeked warblers difficult to determine. It is possible that the existing state of knowledge regarding golden-cheeked warbler occurrences on the vast acreage of currently protected properties underestimates the true conservation value of these tracts. Additionally, this lack of data complicates efforts to fine-tune estimates of territory density and habitat preferences particular to this region.

Other potential research needs include region-specific factors influencing habitat use and productivity. Research on the golden-cheeked warbler and its habitats is ongoing, and the results of future studies may be incorporated into the SEP-HCP via the adaptive management program.

10.0 SIGNATURES

This report was prepared by certified wildlife biologists covered by USFWS Threatened and Endangered Species Permit TE-841353 with authorizations for the golden-cheeked warbler at the consulting firm of Loomis Partners, Inc. in conformance with the methods and limitations described herein.

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FIGURE 1. PHOTOGRAPHS OF MALE AND FEMALE GCWS.

Photo 1. Male GCW in Bexar County (May 2010). Photo by J. Blair, Loomis Partners.

Photo 2. Female GCW. Photo by J. Blair, Loomis Partners.

FIGURE 2. GCW BREEDING RANGE AND COUNTIES OF KNOWN OR POTENTIAL OCCURRENCE.

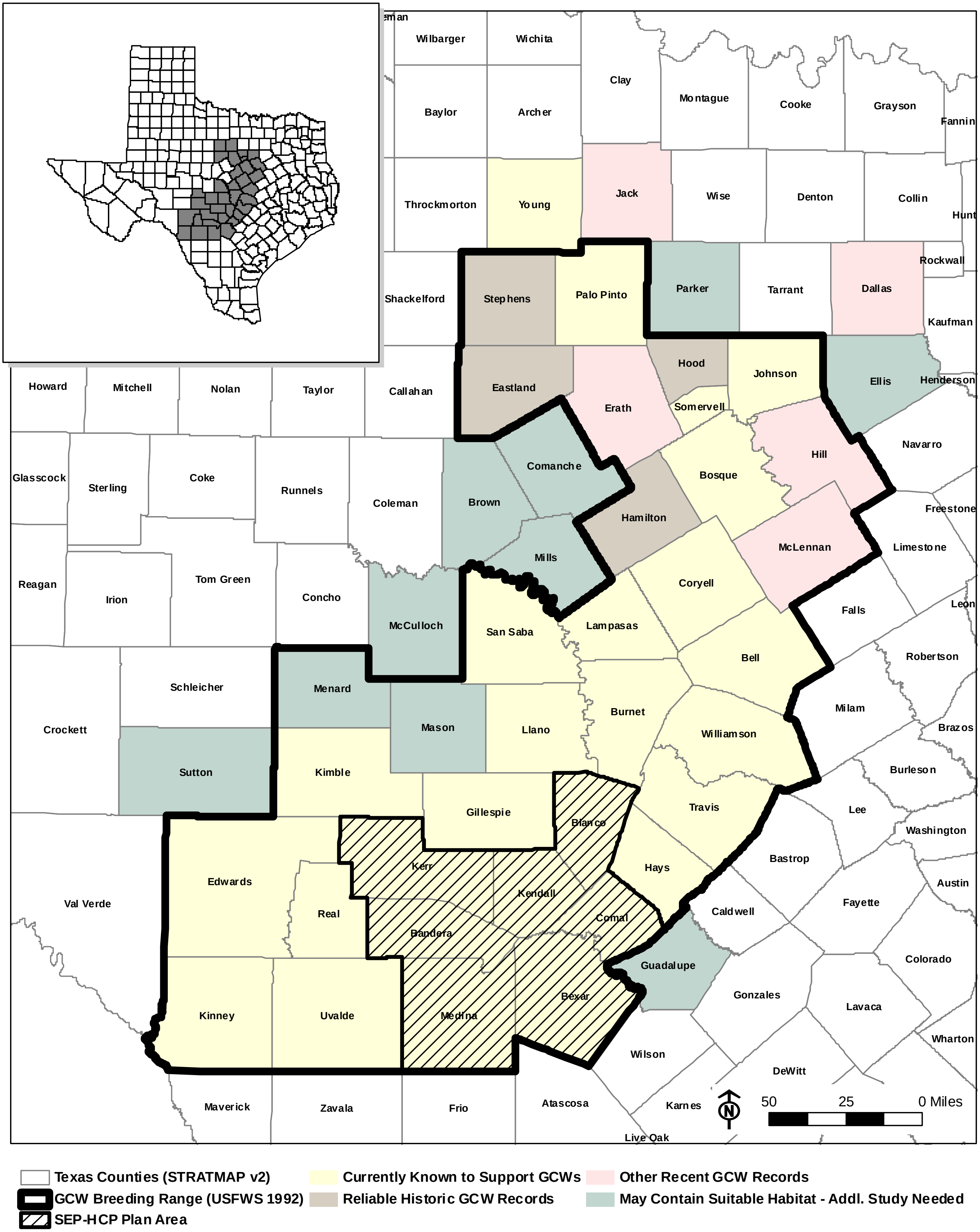


FIGURE 3. GCW NEST CONSTRUCTED FROM ASHE JUNIPER BARK.

Photo 1. Active GCW nest positioned in Ashe juniper in Palo Pinto County (April 2006). Photo by A. Aurora, Loomis Partners.

FIGURE 4. LANDSCAPE VIEWS OF TYPICAL GCW HABITAT.

Photo 1. Typical GCW Habitat in Bexar County April 2010). Photo by A. Aurora, Loomis Partners.

Photo 2. Typical GCW habitat in Bexar County (May 2008). Photo by J. Blair, Loomis Partners.

Photo 3. Typical GCW Habitat in Bandera County May 2009). Photo by J. Blair, Loomis Partners.

Photo 4. Typical GCW habitat in Bandera County (May 2009). Photo by J. Blair, Loomis Partners.

FIGURE 5. POTENTIAL GCW HABITAT AS IDENTIFIED BY THE 2007/2008 TAMU HABITAT MODEL.

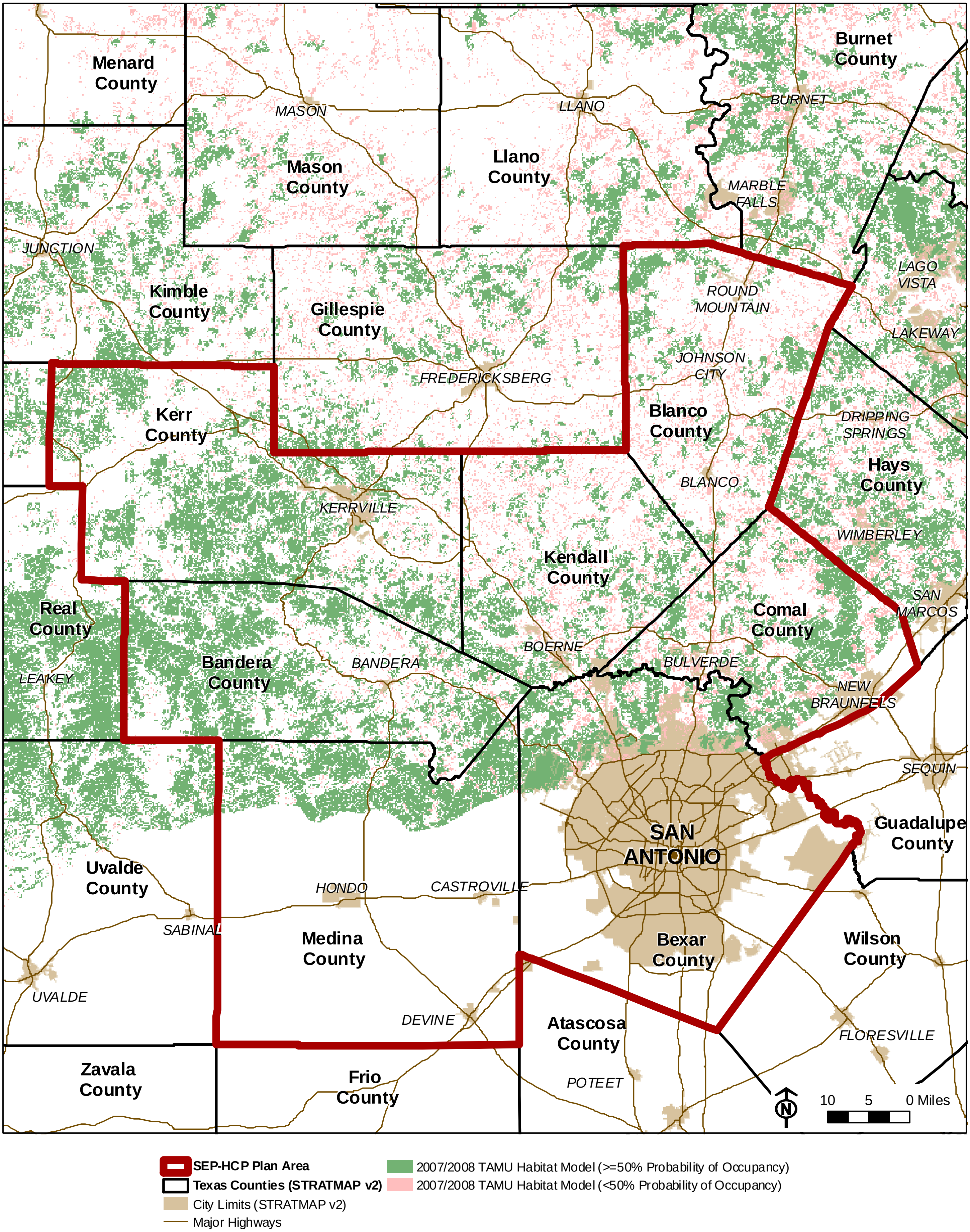
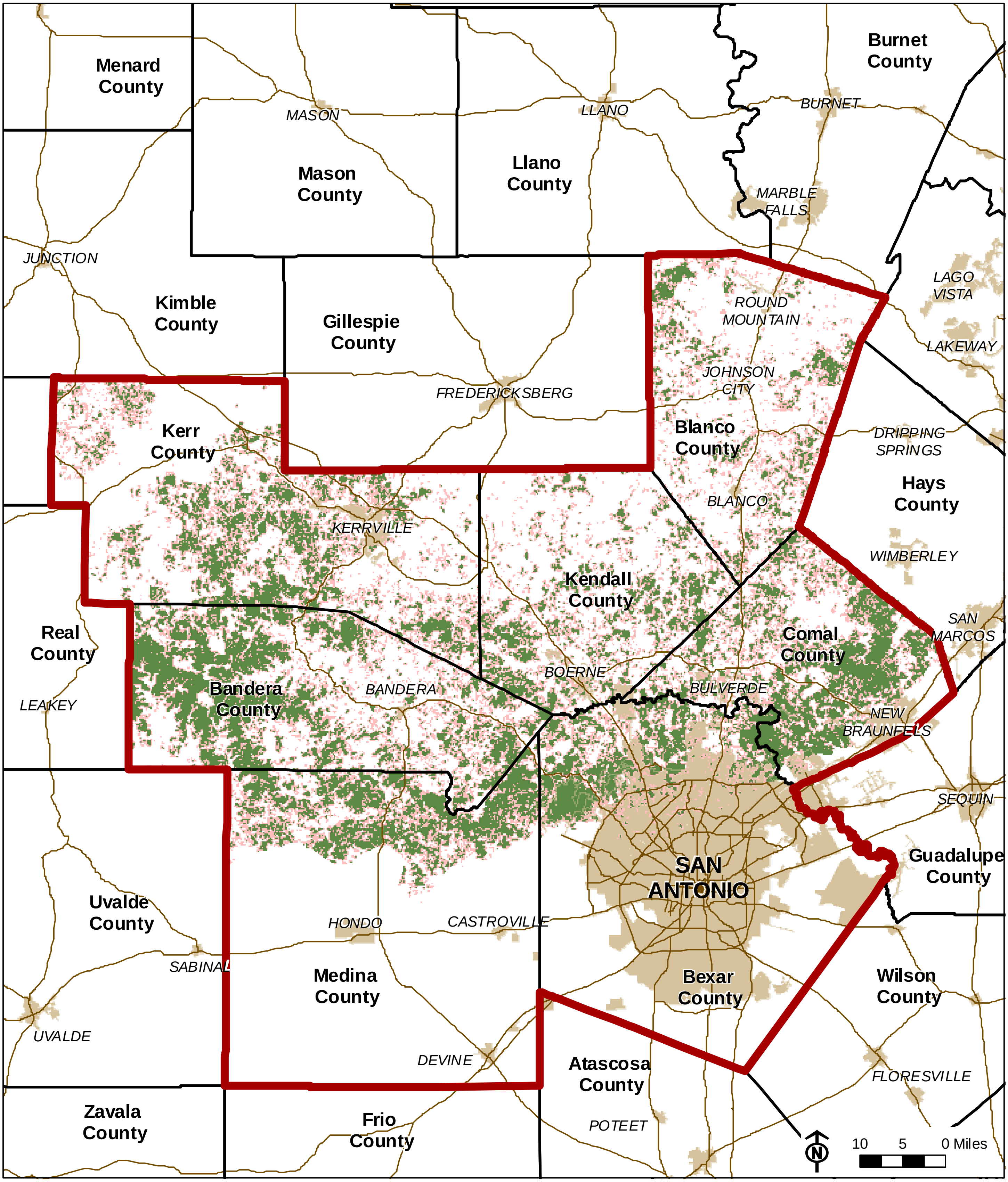


FIGURE 6. POTENTIAL GCW HABITAT AS IDENTIFIED BY THE DIAMOND ET AL. (2010) MODEL C2010.



SEP-HCP Plan Area
Texas Counties (STRATMAP v2)
City Limits (STRATMAP v2)
Major Highways
2010 Model C2010 (Ranks 1 and 2)
2010 Model C2010 (Ranks 3 and 4)

FIGURE 7. PATCH SIZE DISTRIBUTION FOR THE 2007/2008 TAMU HABITAT MODEL.

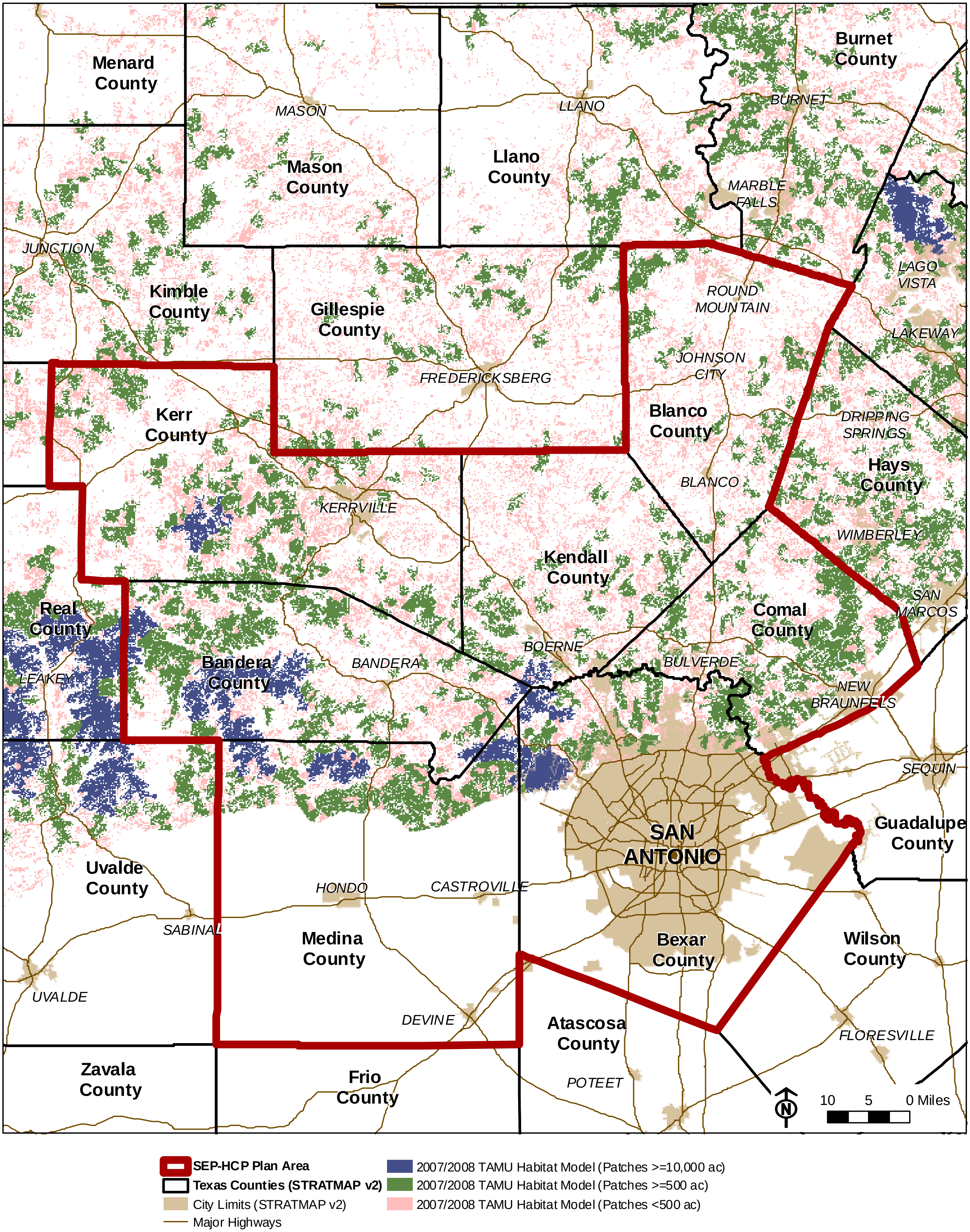


FIGURE 8. PATCH SIZE DISTRIBUTION FOR MODEL C2010.

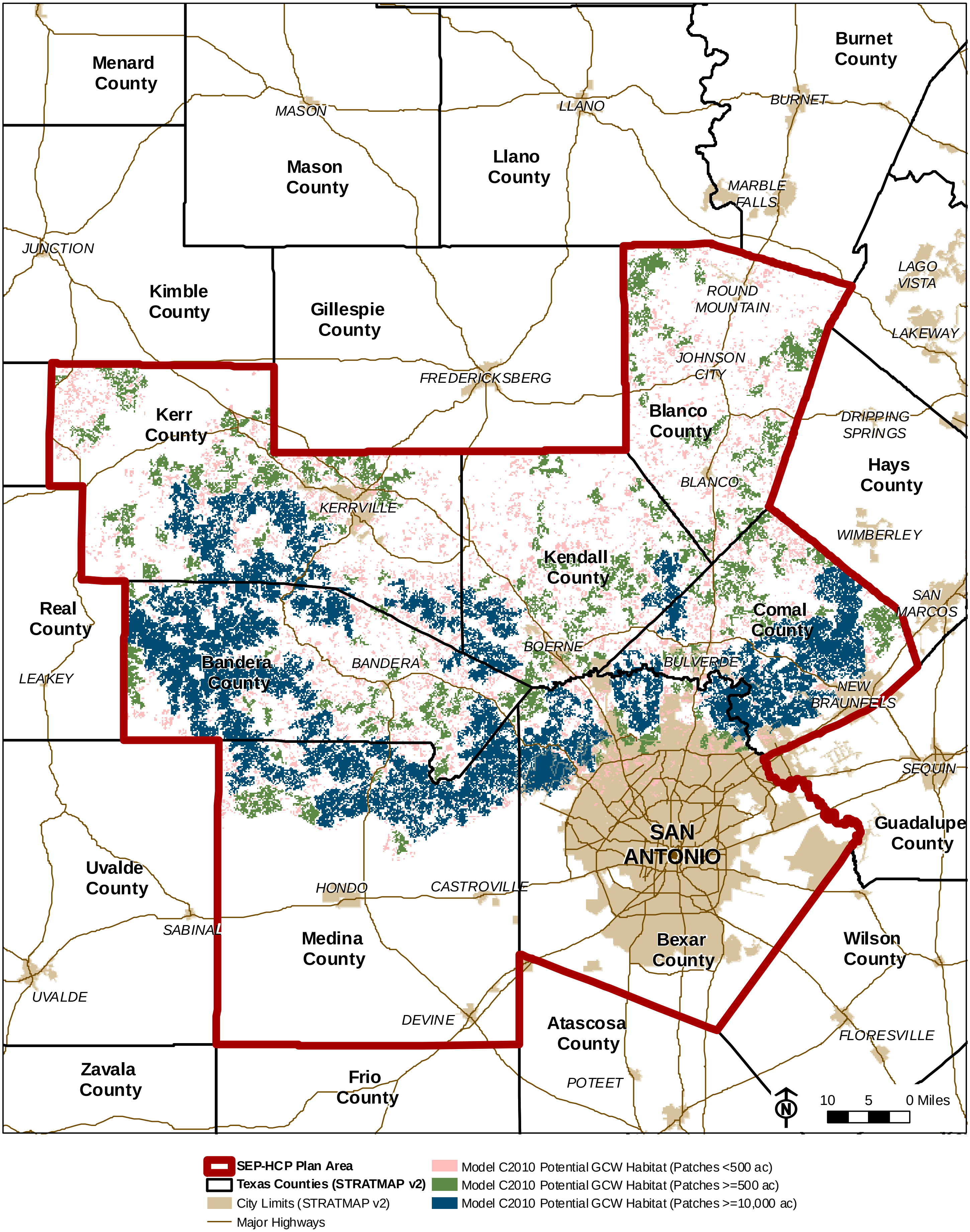


FIGURE 9. GENERALIZED KNOWN GCW LOCALITIES.

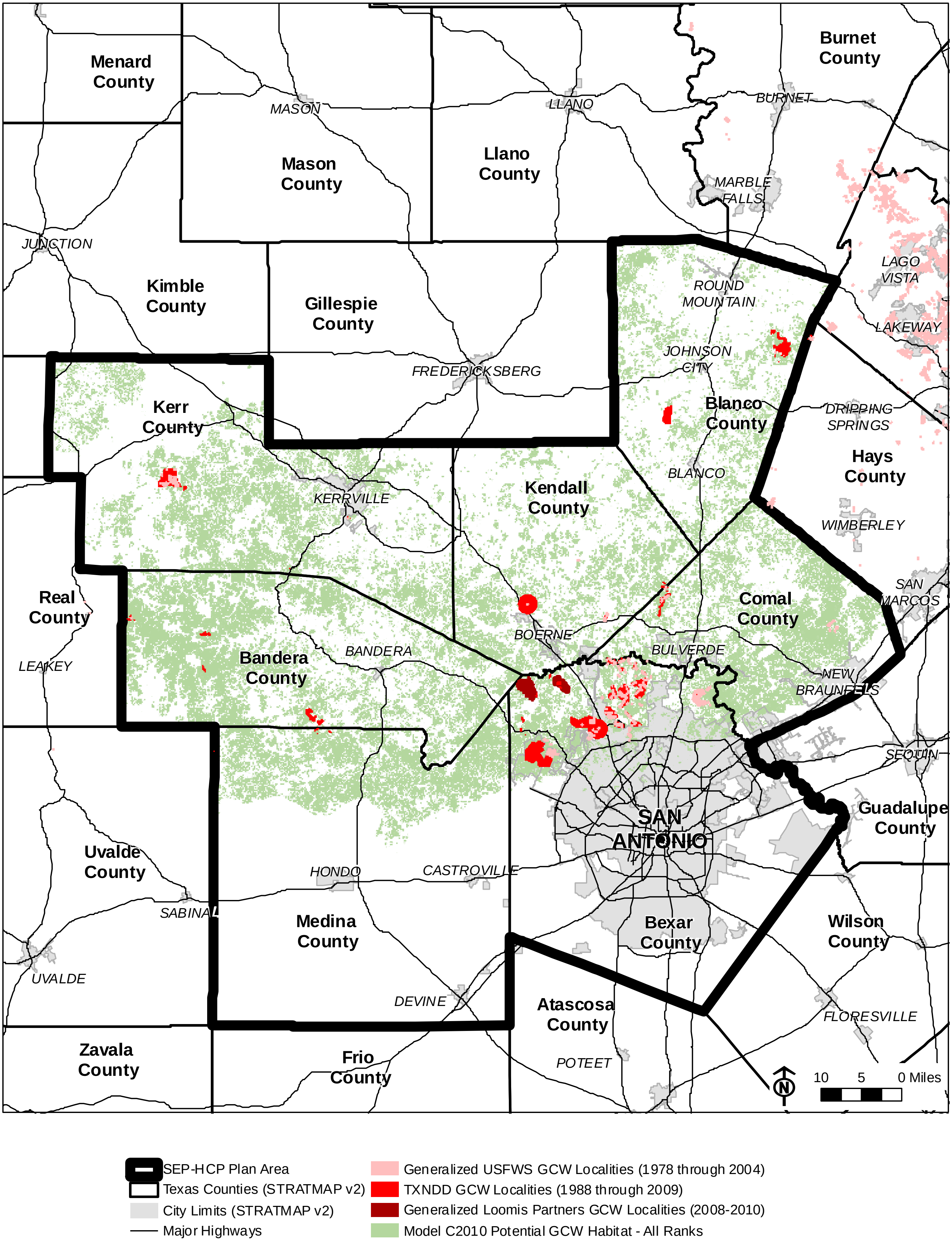
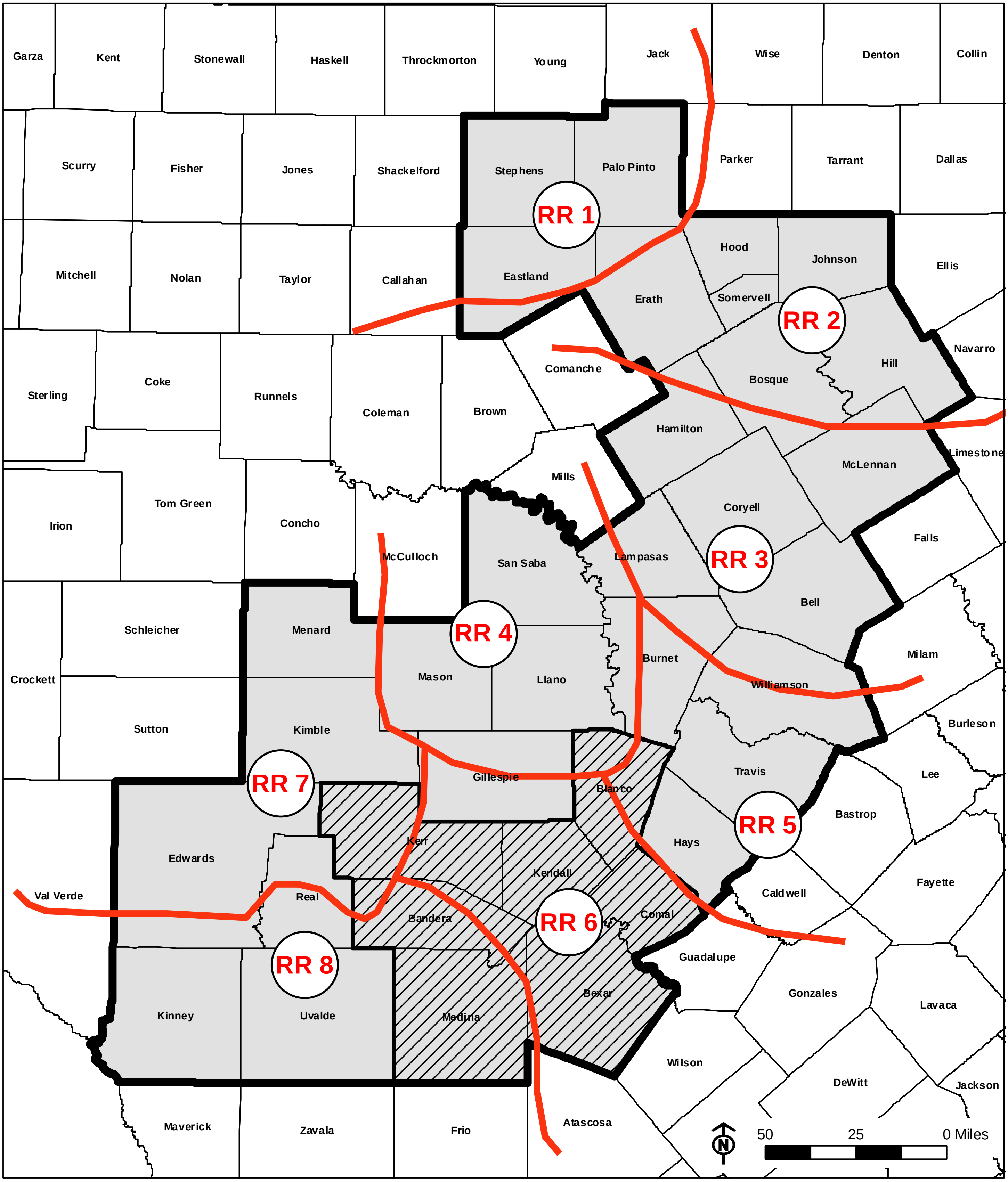


FIGURE 10. 1992 GCW RECOVERY REGION BOUNDARIES.



GCW Recovery Region Boundaries (USFWS 1992)
SEP-HCP Plan Area
GCW Breeding Range (USFWS 1992)
Texas Counties (STRATMAP v2)

FIGURE 11. NLCD FOREST COVER CHANGE (1992 - 2001).

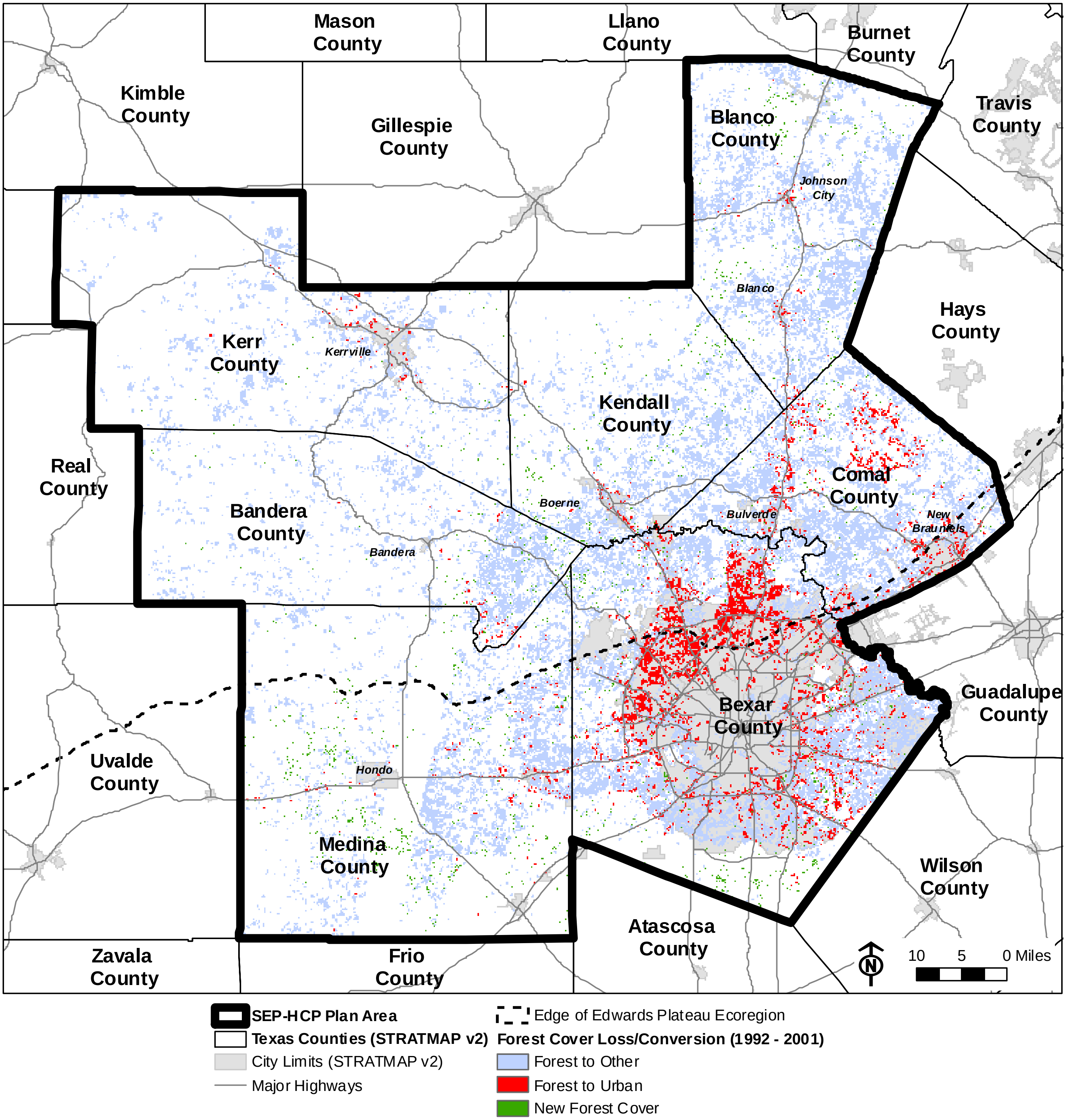


FIGURE 12. MODEL C2 HABITAT LOSS 2005 - 2010 (DIAMOND ET AL. 2010).

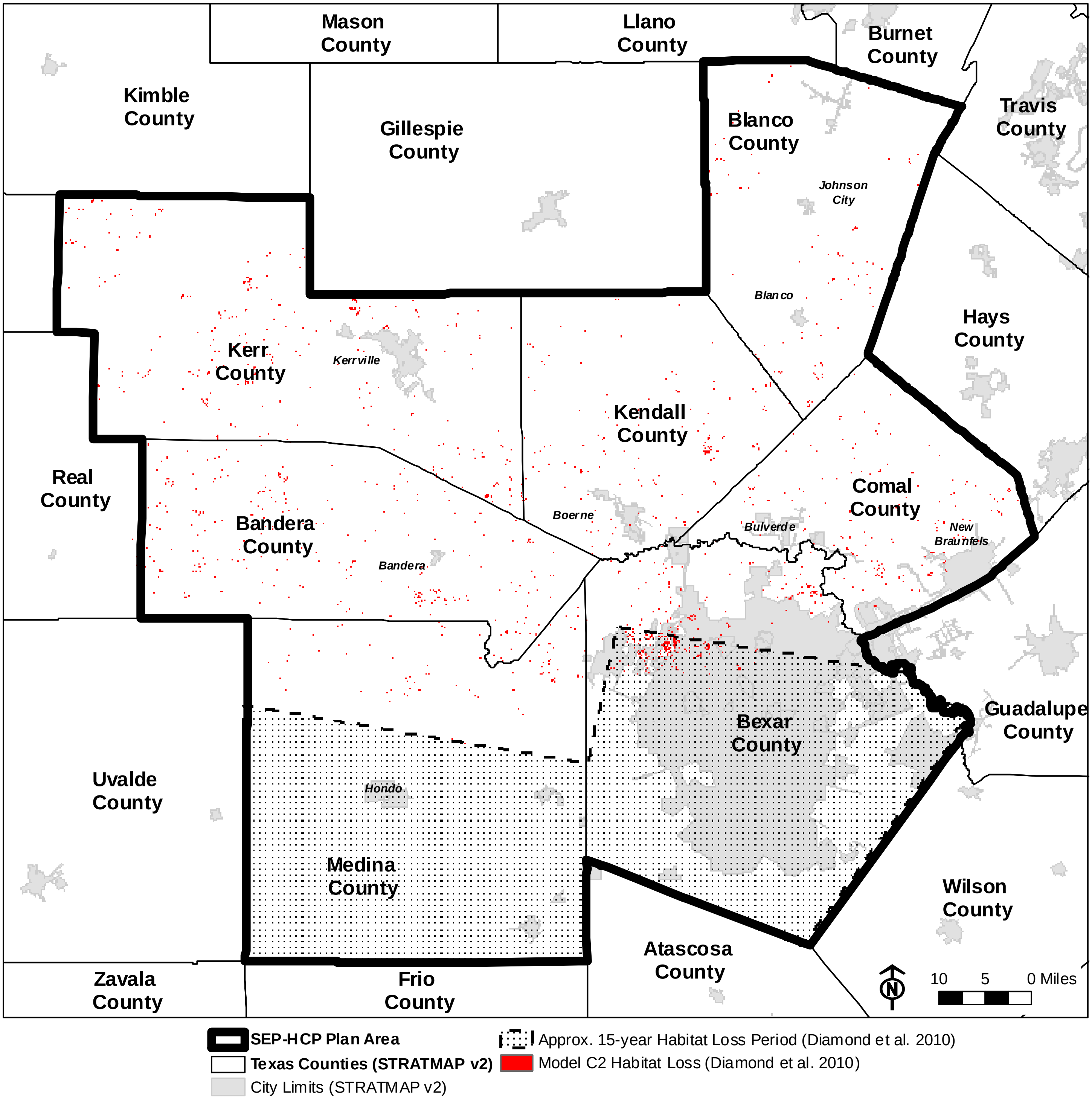


TABLE 1. GCW POPULATION AND HABITAT STATUS SUMMARY.

Category	Value	Section Reference for Addl. Information
Suitable GCW Habitat		
Range-wide	2,778,208 ac to 4,148,138 ac (Morrison et al. 2010 - Model III)	Section 5.1.1
SEP-HCP Plan Area	674,059 ac to 892,990 ac (16% to 22% of Plan Area)	Section 5.1.2
GCW Density in Suitable Habitat within the Plan Area	4.1 singing males per 100 ac of habitat (range of 1.1 to 10.2 singing males per 100 ac of habitat)	Section 3.2.2
Estimated Population Size		
Range-wide	175,000 to 265,000 adult males or >370,000 total adults (Morrison et al. 2010)	Section 5.2.1
SEP-HCP Plan Area	13,500 to 27,000 singing males or 22,950 to 45,900 total adults (extrapolated from Diamond et al. 2010, Pulich 1976, and Cooksey 2007)	Section 5.2.2
Recovery Needs per Region		
Estimated Size of a Viable GCW Population	3,000 pairs	Section 6.2
Estimated Acres of Protected Habitat Needed to Achieve Recovery for Region 6	75,000 acres of relatively high quality habitat	Section 6.2
Recent Habitat Losses (1992 - 2010)		
SEP-HCP Plan Area	Approx. 0.5% to 0.7% loss annually	Section 7.1
Bexar County	Approx. 1.1% to 1.6% loss annually	Section 7.1
GCW Habitat on Currently Protected Lands	Approx. 55,000 to 60,000 acres of potential habitat (see Existing Protected Lands resource assessment)	Section 8.0

TABLE 2. HISTORIC AND RECENT RANGE-WIDE ESTIMATES OF SUITABLE GCW HABITAT.

Geographic Area	Approximate Time Period	Acres of Suitable GCW habitat	Source	Comments
GCW Range (specific counties undefined)	1962	908,619 acres	Pulich (1976)	Based on Soil Conservation Service estimates of virgin juniper habitat.
GCW Range (specific counties undefined)	1974	731,081 acres	Pulich (1976)	Based on Soil Conservation Service estimates of virgin juniper habitat.
GCW Range (specific counties undefined)	1974 - 1981	835,302 acres	USFWS (1992)	Corrected estimates based on Wahl et al. (1990); habitat detected by LANDSAT imagery from 1974, 1979, and/or 1981.
GCW Range (specific counties undefined)	1989	586,043 acres	USFWS (1992)	Corrected estimates based on Wahl et al. (1990); habitat detected by LANDSAT imagery and refined by scattered groundtruthing.
33 counties in central Texas (Pulich 1976)	1992	1,869,552 acres	DeBoer and Diamond (2006)	Based on 1992 NLCD forest cover types and buffered back from the edge of forest cover by 75 meters.
35 counties identified in 1992 Recovery Plan	mid to late 1990's	4,427,841 acres	Diamond (2007)	"Model C" considering percent forest/woodland within a circle of radius 200 meters, adjusted for edge.
35 counties identified in 1992 Recovery Plan and limited to the Edwards Plateau and Cross Timbers Ecoregions	2001	4,149,478 acres	Loomis Partners (2009)	Potential high, medium, and low quality habitat identified by a spatial analysis of 2001 NLCD Percent Canopy Cover, with additional information on probability of occuancy.
43 counties currently known or expected to harbor the species	2004	1,363,807 acres	SWCA (2007)	Delineated from aerial imagery based on density of woodland, relative proportions of Ashe juniper and deciduous trees, size of trees, woodland patch size, and land use at local and landscape scales.
35 counties identified in 1992 Recovery Plan	2005 - 2007	3,597,747 acres	Diamond (unpublished data)	"Model C2" modified from the original Model C by using more recent land cover data and considering stands of live oak as not representative of GCW habitat.
35 counties identified in 1992 Recovery Plan and limited to the Edwards Plateau Ecoregion	2007/2008	4,148,138 acres	Morrison et al. (2010)	Based on classification of satellite data as woodland having greater than 30 percent canopy cover or non-woodland. Accuracy verified by comparison to 2008 aerial imagery.

TABLE 3. ESTIMATES OF CURRENTLY AVAILABLE POTENTIAL GCW HABITAT IN THE PLAN AREA.

	Total Geographic Area (ac)	2007/2008 TAMU Model (Morrison et al. 2010)		2010 Model C2010 (Diamond et al. 2010)	
		All Potential Habitat (ac)	Potential Habitat with >=50% Probability of Occupancy (ac)	All Potential Habitat (ac)	Potential Habitat in Ranks 3 and 4 (ac)
Bandera	510,109	230,555	211,703	222,634	165,752
Bexar	804,048	97,649	79,153	100,120	74,408
Blanco	456,500	122,754	65,535	85,698	46,530
Comal	367,819	154,227	109,129	160,462	115,808
Kendall	423,972	134,133	89,102	109,839	65,268
Kerr	708,103	248,067	220,656	183,771	113,984
Medina	855,078	123,191	117,712	126,713	92,307
Plan Area Total	4,125,629	1,110,577	892,990	989,237	674,059

TABLE 4. PATCH SIZE DISTRIBUTION FOR POTENTIAL GCW HABITAT, AS IDENTIFIED BY THE FULL EXTENTS OF THE TAMU MODEL AND MODEL C2010.

Patch Size	2007/2008 TAMU Model		2010 Model C2010)[2 & 3]	
	Number of Patches	Total Acres in Class[1]	Number of Patches	Total Acres in Class[1]
7-County Plan Area				
< 10 ac	5,197	36,174	23,614	19,137
10 to <100 ac	6,891	200,194	3,000	96,706
100 to <250 ac	763	118,342	392	59,256
250 to <500 ac	330	115,868	148	52,611
500 to <1,000 ac	178	119,806	77	53,354
1,000 to <5,000 ac	162	333,172	70	138,700
5,000 to <10,000 ac	19	122,258	7	51,958
>= 10,000 ac	10	156,478	14	520,524
Plan Area Total	13,550	1,202,293	27,322	992,246
Patches >= 500 ac	369	731,715	168	764,537
Bandera County				
< 10 ac	743	5,174	4,197	3,301
10 to <100 ac	1,041	31,368	490	15,704
100 to <250 ac	127	19,909	68	10,510
250 to <500 ac	48	16,624	19	6,871
500 to <1,000 ac	31	21,385	12	8,382
1,000 to <5,000 ac	37	80,590	11	18,427
5,000 to <10,000 ac	6	38,991	2	15,010
>= 10,000 ac	7	122,944	5	339,633
Bandera County Total	2,040	336,984	4,804	417,839
Patches >= 500 ac	81	263,910	30	381,453
Bexar County				
< 10 ac	315	2,168	2,141	1,994
10 to <100 ac	414	11,506	256	7,392
100 to <250 ac	46	7,565	42	6,501
250 to <500 ac	22	7,670	12	3,762
500 to <1,000 ac	19	12,785	8	5,017
1,000 to <5,000 ac	17	36,751	4	7,730
5,000 to <10,000 ac	1	7,677	1	7,646
>= 10,000 ac	3	38,456	6	192,311
Bexar County Total	387	124,578	2,470	232,355
Patches >= 500 ac	40	95,669	19	212,705

TABLE 4. PATCH SIZE DISTRIBUTION FOR POTENTIAL GCW HABITAT, AS IDENTIFIED BY THE FULL EXTENTS OF THE TAMU MODEL AND MODEL C2010.

Patch Size	2007/2008 TAMU Model		2010 Model C2010)[2 & 3]	
	Number of Patches	Total Acres in Class[1]	Number of Patches	Total Acres in Class[1]
Blanco County				
< 10 ac	987	6,898	3,069	2,862
10 to <100 ac	1,326	37,397	570	18,655
100 to <250 ac	142	21,923	68	10,174
250 to <500 ac	54	19,283	31	11,170
500 to <1,000 ac	24	16,770	14	9,900
1,000 to <5,000 ac	16	38,804	14	27,139
5,000 to <10,000 ac	1	7,084	2	13,856
>= 10,000 ac	-	-	-	-
Blanco County Total	2,550	148,159	3,768	93,755
Patches >= 500 ac	41	62,658	30	50,895
Comal County				
< 10 ac	680	4,770	2,719	2,175
10 to <100 ac	882	25,068	311	10,160
100 to <250 ac	99	14,813	48	7,281
250 to <500 ac	44	15,165	25	9,295
500 to <1,000 ac	21	14,917	7	5,051
1,000 to <5,000 ac	21	53,435	9	18,253
5,000 to <10,000 ac	8	54,897	2	16,299
>= 10,000 ac	-	-	5	132,311
Comal County Total	1,755	183,066	3,126	200,824
Patches >= 500 ac	50	123,249	23	171,914
Kendall County				
< 10 ac	1,064	7,364	2,512	2,071
10 to <100 ac	1,263	36,225	479	16,331
100 to <250 ac	115	17,742	73	10,825
250 to <500 ac	56	20,132	31	11,388
500 to <1,000 ac	17	12,019	16	11,670
1,000 to <5,000 ac	26	48,936	16	31,214
5,000 to <10,000 ac	-	-	1	7,646
>= 10,000 ac	1	13,167	5	80,518
Kendall County Total	2,542	155,584	3,133	171,664
Patches >= 500 ac	44	74,122	38	131,049

TABLE 4. PATCH SIZE DISTRIBUTION FOR POTENTIAL GCW HABITAT, AS IDENTIFIED BY THE FULL EXTENTS OF THE TAMU MODEL AND MODEL C2010.

Patch Size	2007/2008 TAMU Model		2010 Model C2010)[2 & 3]	
	Number of Patches	Total Acres in Class[1]	Number of Patches	Total Acres in Class[1]
Kerr County				
< 10 ac	1,231	8,588	6,157	4,993
10 to <100 ac	1,694	50,836	736	24,026
100 to <250 ac	219	34,238	93	13,723
250 to <500 ac	96	33,907	36	12,448
500 to <1,000 ac	54	34,563	23	15,729
1,000 to <5,000 ac	53	103,407	21	44,446
5,000 to <10,000 ac	1	5,455	-	-
>= 10,000 ac	1	10,230	4	244,732
Kerr County Total	3,349	281,225	7,070	360,097
Patches >= 500 ac	109	153,656	48	304,907
Medina County				
< 10 ac	210	1,455	2,813	1,807
10 to <100 ac	358	11,063	200	6,148
100 to <250 ac	49	7,797	20	3,258
250 to <500 ac	26	8,995	6	2,074
500 to <1,000 ac	18	11,420	2	1,329
1,000 to <5,000 ac	24	49,938	2	4,596
5,000 to <10,000 ac	4	21,060	2	14,439
>= 10,000 ac	4	51,211	4	317,506
Medina County Total	693	162,939	3,049	351,157
Patches >= 500 ac	50	133,629	10	337,870

[1]Patches may extend beyond the boundary of the Plan Area and/or individual counties, resulting in higher acreage totals than reported in Table 3.

[2]Corner-touching patches are considered to be separate.

[3]Analysis was limited to the extent of the Plan Area boundary. Patches that cross the Plan Area boundary are cut off or fragmented into multiple, smaller parts.

TABLE 5. NLCD LAND COVER CHANGES IN THE PLAN AREA BETWEEN 1992 AND 2001.

	1992 Forest Cover (acres)	2001 Forest Cover (acres)	1992 Forest Acres Converted to Other Types (acres)			New 2001 Forest Acres	Net Acre Change in Forest Cover (1992 to 2001)	Net % Change in Forest Cover (1992 to 2001)
			to Urban	to Other	Total Converted			
Bandera	247,462	240,664	247	8,956	9,203	2,406	(6,797)	-3%
Bexar*	132,696	116,251	8,191	10,337	18,527	2,082	(16,445)	-12%
Blanco	172,090	156,146	467	18,861	19,328	3,386	(15,941)	-9%
Comal*	197,202	175,721	3,006	20,466	23,472	1,991	(21,482)	-11%
Kendall	164,443	155,973	289	11,140	11,429	2,959	(8,470)	-5%
Kerr	256,087	247,519	232	8,959	9,191	620	(8,571)	-3%
Medina*	142,274	140,343	25	1,403	1,428	479	(948)	-1%
Total Plan	1,312,254	1,232,616	12,456	80,122	92,578	13,923	(78,655)	-6%

* Analysis limited to the extent of the Edwards Plateau ecoregion and does not include the entire county.

TABLE 6. ESTIMATED LOSS OF POTENTIAL GCW HABITAT IN THE PLAN AREA BASED ON DIAMOND ET AL. (2010).

	Model C2 GCW Habitat[1] (acres)	Fate of Model C2 Potential Habitat in 2010		Estimated Habitat Loss 2005 - 2010[2] (% of Model C2 habitat)
		Change to Non-forest	No Change	
Bandera	231,704	4,726	226,977	2.0%
Bexar[2]	97,710	5,535	92,174	5.7%
Blanco	74,438	1,372	73,066	1.8%
Comal	147,746	2,740	145,006	1.9%
Kendall	117,905	2,799	115,106	2.4%
Kerr	170,025	4,585	165,439	2.7%
Medina[2]	120,489	1,312	119,177	1.1%
Total Plan Area	960,017	23,070	936,947	2.4%

[1] Model C2 habitat was resampled into a 30-meter resolution format for the forest change analysis (original resolution is 10-meters). The resampled acreages are reported in this table and may differ from the original Model C2 results.

[2] Some of this forest change occurred over a 15-year time period.

BLACK-CAPPED VIREO

RESOURCE ASSESSMENT

FOR THE SOUTHERN EDWARDS PLATEAU

HABITAT CONSERVATION PLAN

SEPTEMBER 1, 2011

1.0 INTRODUCTION

This resource assessment describes the basic biology and current status of the black-capped vireo (*Vireo atricapilla*, BCV) in the Southern Edwards Plateau Habitat Conservation Plan (SEP-HCP), which includes Bexar, Medina, Bandera, Kerr, Kendall, Blanco, and Comal counties. The purpose of this assessment is to help develop the conceptual framework for the SEP-HCP and provide the basic background information for the Habitat Conservation Plan and associated Environmental Impact Statement.

Table 1 summarizes some of the important information related to the status of the black-capped vireo and its habitat. Additional discussion of this information is addressed in the referenced sections.

TABLE 1. BCV POPULATION AND HABITAT STATUS SUMMARY.

Category	Value	Section Reference for Addl. Information
Suitable BCV Habitat		
Range-wide	1,450,441 ac	Section 5.1
SEP-HCP Plan Area	181,630 ac (4% of Plan Area)	Section 5.1
Total Population Size		
Range-wide	unknown	Section 5.2
SEP-HCP Plan Area	unknown	Section 5.2
Known Population Size		
Range-wide	6,269 breeding units	Section 5.2
SEP-HCP Plan Area	527 breeding units	Section 5.2

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TABLE 1. BCV POPULATION AND HABITAT STATUS SUMMARY.

Category	Value	Section Reference for Addl. Information
Recovery Needs		
Estimated Size of a Viable BCV Population	500 to 1,000 pairs	Section 6.2
Populations in the Plan Area with Some Degree of Protection and/or Management	420 breeding units	Section 5.2

2.0 SPECIES DESCRIPTION

The black-capped vireo is a small, insectivorous bird that is approximately 4.5 inches long. Characteristic features of the male vireo include a black crown, nape, and face, and white "spectacles" formed by white eye-rings (interrupted over the eye) with a white band connecting the eye-rings. Females of the species are similar, but are duller and have a slate-gray cap. For both sexes, the back of the bird is olive green, the wings and tail are blackish with yellow-green edgings, the breast and belly are white with greenish-yellow flanks, and the wings have two pale yellow wing bars. The bill is black and the irises are brownish-red to red (Oberholser 1974, Farrand 1983). Figure 1 includes photos of the black-capped vireo.

FIGURE 1. PHOTOGRAPHS OF BCVS.

Photo 1. BCV in Burnet County (June 2009). Photo by J. Blair, Loomis Partners.

Photo 2. BCV in live oak tree (April 2009). Photo by J. Blair, Loomis Partners.

3.0 LIFE HISTORY CHARACTERISTICS

3.1 RANGE AND MIGRATORY PATTERNS

Black-capped vireos are migratory and are present in Texas during their breeding season. The present known breeding range of the black-capped vireo extends from central Oklahoma through Dallas, the Edwards Plateau, Concho Valley, Callahan Divide, and Big Bend National Park in Texas to the Mexican states of Nuevo Leon and Tamaulipas. The species winters entirely in Mexico along the Pacific slopes of the Sierra Madre Occidental from southern Sonora to Oaxaca (Wilkins et al. 2006).

The vireos arrive in Texas from late March to mid-April, with adult males arriving before females and first-year males. The majority of black-capped vireo breeding activities occur between mid-April and the end of July. However, the species is known to produce more than one clutch per season and adults may continue to rear young until mid-September (Grzybowski 1995). The black-capped vireos leave their breeding grounds in the late summer and early fall, generally beginning in August and continuing through September and early October (Grzybowski 1995). Adult males are typically the last to migrate south (USFWS 1991).

3.2 TERRITORIAL CHARACTERISTICS

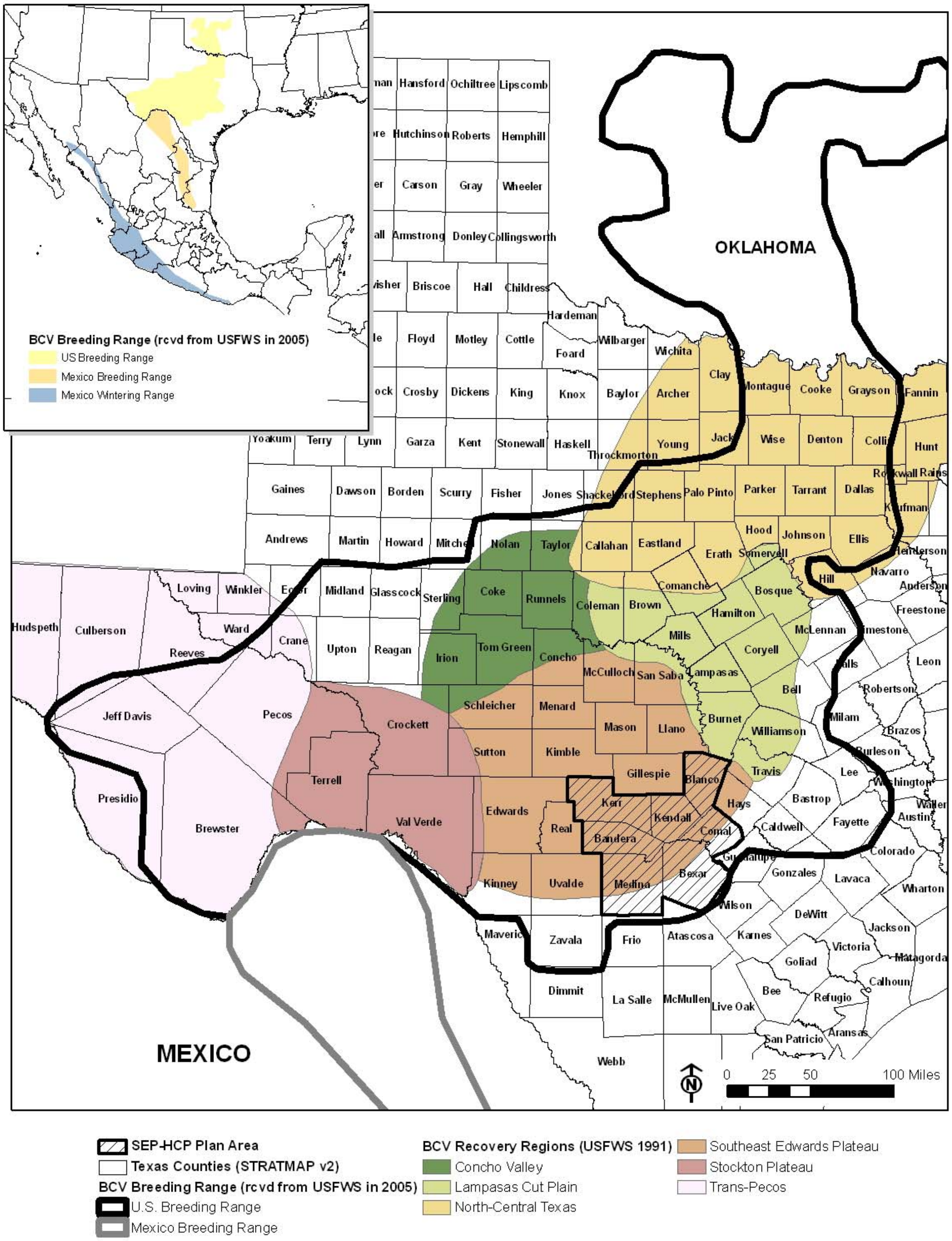
Black-capped vireos are territorial, and territories tend to be clustered in patches of suitable habitat. Territory clusters either tend to be small (less than ten territories) and composed of primarily young, second-year males, or large (frequently 15 or more territories) and composed of older, after-second-year males (USFWS 1991). Reproductive success and survivorship has been positively associated with cluster size (USFWS 1991). Second-year males tend to occupy poorer quality habitats that have vegetation characteristics more similar to areas of non-habitat than areas occupied by older males (Grzybowski et al. 1994).

Individual black-capped vireo territories are generally between 2.5 and 25 acres (with most covering approximately two to four acres) (Wilkins et al. 2006, Graber 1957, Tazik and Cornelius 1989). Unpublished data collected by The Nature Conservancy on Fort Hood in Bell and Coryell counties (reported in Balley and Thompson 2007) indicated an average vireo territory size of approximately 3.5 acres. Territories are defended by the male through song and occasionally aggressive behaviors (Graber 1957). Adult male black-capped vireos, particularly those from large territory clusters, exhibit strong site fidelity and usually return to the same site and territory each year. Females also usually return to the same site each year, but may move among territories in the cluster both between seasons and between same-season nesting attempts (Graber 1957). Members of smaller breeding clusters tend to disperse more frequently to other sites (Graber 1957, USFWS 1991).

3.3 DIET AND FORAGING BEHAVIOR

Black-capped vireos are active birds that glean insects, spiders, larvae, and other food items from foliage, usually within the upper strata of the canopy (Graber 1957, Grzybowski 1995). Both males and females seem to prefer deciduous substrates (especially oaks) (Graber 1961, Grzybowski 1995). Foraging behavior typically involves gleaning from leaves, twigs and small branches, as well as from the trunks of trees (Grzybowski 1995).

FIGURE 2. BCV RANGE AND 1991 RECOVERY UNITS.



3.4 NESTING BEHAVIOR

Nesting begins upon the arrival of females and continues through August. Nests are small, open-cup, hanging structures constructed in the forks of branches (USFWS 1991). Most vireo nests are constructed in very dense, deciduous foliage (most often in oak species) (Wilkins et al. 2006); although, nests have also been found in Ashe juniper (*Juniperus ashei*) and other non-juniper woody evergreen species (Balley and Thompson 2007, Wilkins et al. 2006, USFWS 1991). Nests are typically placed one to four feet from the ground. Both sexes are known to contribute to nest building (Graber 1957). Black-capped vireos may attempt up to six clutches in a single season, which typically lasts from early April through late July (USFWS 1991). A new nest is constructed for each nesting attempt (Graber 1957).

Egg laying begins the day after completion of the nest. Individual clutches contain three to four eggs (Graber 1957), with an estimated total seasonal clutch size of between 12 and 20 eggs (USFWS 1991). Male vireos aggressively guard active nests (USFWS 1991). The incubation period extends from 14 to 19 days, which is longer than most other small, open-cup nesting passerines, and duties are shared by both parents. Hatchlings stay in the nest for nine to 12 days, and are fed by both adults. Females brood newly hatched young for four to six days. Fledglings are attended by one or both parents for usually 30 to 45 days after leaving the nest (Graber 1957, USFWS 1991).

4.0 HABITAT DESCRIPTION

The black-capped vireo typically uses heterogeneous scrub habitat that has a patchy distribution of shrub clumps and thickets with a few scattered trees and abundant deciduous foliage to ground level (Graber 1957, 1961; USFWS 1991; Grzybowski 1995). While the habitats occupied by the vireo may differ greatly across its range, the most common and distinguishing habitat element throughout the range of the species is the presence of dense, low, deciduous foliage at ground level to approximately ten feet (USFWS 1991, Grzybowski et al. 1994, Maresh 2005). This low, dense, deciduous cover provides foraging and nesting sites, as well as protective cover from adverse weather and predators (Grzybowski et al. 1994).

Other black-capped vireo habitat variables, such as the amount of heterogeneity in vegetation structure, the degree of openness in the woody canopy, and the species composition of the habitat are highly variable throughout the range of the species and within regional areas. Due to the high degree of variation in these other habitat variables, they are thought to be less influential in comprising suitable vireo habitat than presence of low, dense, deciduous foliage (Maresh 2005).

Along the eastern edge of the Edwards Plateau (i.e., representative of the SEP-HCP Plan Area), black-capped vireos typically occupy weathered and eroded highlands and stream corridors (but outside of floodplains) where site conditions favor the growth of suitable vegetation (Graber 1961). Campbell (2003) also describes typical black-capped vireo habitat as occurring over rocky limestone soils with shrub habitat mixed with a tree canopy that may vary from open or sparse to moderate canopy cover. Within this region, vireos were found to utilize areas with a relatively high degree of shrubby vegetative cover (regardless of whether this cover was composed of deciduous shrubs or Ashe juniper) and relatively less cactus cover (Gryzbowski et al. 1994).

Black-capped vireos may co-occur with golden-cheeked warblers (*Setophaga chrysoparia*), where vireos utilize the dense, deciduous foliage at the edge of warbler habitat patches (Grzybowski et al. 1994).

Photos of typical black-capped vireo habitat are included in Figure 3.

FIGURE 3. TYPICAL BCV HABITAT.

Photo 1. Typical BCV Habitat in the Texas Hill Country. Photo by A. Aurora, Loomis Partners.

Photo 2. Extensive shrubland BCV habitat at the western edge of the Texas Hill Country. Photo by A. Aurora, Loomis Partners.

Photo 3. Dense shrub cover typical of BCV habitat at approximately 6 feet from ground. Photo by A. Aurora, Loomis Partners.

Photo 4. Patchy shrub clusters used by BCVs. Photo by A. Aurora, Loomis Partners.

4.1 SPECIES COMPOSITION

Typical plant species in black-capped vireo habitat on the Edwards Plateau include plateau live oak (*Quercus fusiformis*), shin oak (*Quercus sinuata*), and various sumacs (*Rhus* spp.). Less common species include Texas mountain laurel (*Sophora secundiflora*), agarito (*Berberis trifoliolata*), and beebrush (*Aloysia gratissima*). Ashe juniper is usually not the dominant species, although it may be co-dominant with the oaks (Graber 1961, USFWS 1991, Grzybowski 1995).

4.2 CANOPY COVER AND HEIGHT

Black-capped vireos utilize patchy, shrubland habitat. Horizontal woody canopy cover in vireo habitat generally averages between 30 and 60 percent, with most of this cover due to deciduous shrubs (USFWS 2007). However, Maresh (2005) reports a much wider variation in horizontal woody canopy cover, with canopy cover at several sites across Texas ranging from less than 10 percent to greater than 90 percent. Ashe juniper generally comprises less than 10 percent of the total woody canopy cover.

Closely spaced shrub clusters separated by grassy vegetation create the heterogeneous cover required by the species (USFWS 1991).

Dense, vertical cover of deciduous foliage between ground level and approximately 10 feet is a primary characteristic of black-capped vireo habitat. Vireos place nests in this low shrub cover, usually within areas of the densest foliage (USFWS 1991).

While vireos are typically associated with low, shrubby habitat, they have also been observed utilizing dense foliage “aprons” around widely spaced clusters of tall trees in open woodlands and at the edge of patches of dense woodlands, where the canopy height may exceed 20 feet (Maresh 2005).

4.3 PATCH SIZE AND LANDSCAPE MATRIX

Black-capped vireos nest in clusters of individual territories, and the minimum size for a patch of suitable habitat is thought to be between ten and 12 acres (Graber 1957). Graber (1957) also suggests that linear clusters of shrubby vegetation, such as along fence lines and road sides, do not constitute suitable black-capped vireo habitat.

Black-capped vireo habitat may also be associated with certain geologic formations (i.e., Fredericksburg limestones in Texas), poor soils, and topographic features that might create more favorable conditions for maintaining low, patchy, shrublands (USFWS 1991). However, any potential relationships between soils, geology, and vireo habitat are poorly understood.

4.4 FIRE AND OTHER DISTURBANCES

In many parts of the black-capped vireo range (including the eastern edge of the Edwards Plateau), the shrubland vegetation used by the species is an early successional vegetation type frequently maintained by fire or moderate browsing by wildlife or livestock (although, heavy browsing can reduce vireo habitat). Other land management practices may also create or maintain suitable habitat conditions for the vireo. In some parts of the species’ range, suitable breeding habitat is a stable vegetation type maintained by the abiotic characteristics of the area (Farquhar and Gonzalez 2005).

Some researchers have found that black-capped vireos tend to occupy sites with a history of severe disturbance (Grzybowski et al. 1994). Where vegetation succession occurs fairly rapidly, severe disturbances, such as those caused by fire, may retard the growth of Ashe juniper and favor the bushy growth of deciduous species such as oaks and sumacs (USFWS 1991, Wilkins et al. 2006). Periodic disturbance of the habitat may be beneficial for maintaining suitable vireo habitat, depending on site conditions and proper implementation (Grzybowski 1995). Vireos have been shown to recolonize sites as little as two years after a fire (Tazik et al. 1993), and the habitat benefits from such disturbances have been estimated to last up to 20 or 30 years (Tazik et al. 1993, Dufault 2004). Burning intervals suggested for maintaining vireo habitat have ranged from four to ten years (Campbell 2003) or even 25 years (Tazik et al. 1993).

5.0 HABITAT AVAILABILITY AND POPULATION ESTIMATES

5.1 HABITAT AVAILABILITY

Reliable estimates of available habitat for black-capped vireos are generally unavailable, particularly at large scales (i.e., county level or larger). Habitat for this species is difficult to identify and delineate from aerial imagery or other types of remote sensing information, due in large part to the wide variation in some of the characteristics of suitable habitat and the relatively fine-scale heterogeneity of the shrub cover used by the species. Further, suitable black-capped vireo habitat tends to be relatively short-lived, since much of the vegetation used by the species (particularly along the eastern edge of the Edwards Plateau ecoregion) is typically representative of an early successional stage following vegetation disturbance (such as a fire or mechanical brush management). The short-lived nature of this early successional vegetation stage generally results in a shifting pattern of suitable black-caped vireo habitat across the landscape over relatively short time periods (i.e., 5 to 15 years).

The best available estimates of the amount of suitable black-capped vireo habitat across Texas are reported in Wilkins et al. (2006) and are based on the results of roadside surveys conducted in the late 1990's (Maresh and Rowell 2000). These roadside surveys were conducted along two 30-mile transects in each of 53 Texas counties with known or suspected black-capped vireo breeding populations. The survey transects were located along public roads and were generally driven twice, once to assess the amount of potentially suitable habitat visible along the route and once to briefly listen for the presence of the species at 0.3-mile intervals within suitable habitat (Maresh and Rowell 2000).

In Texas, approximately 1.45 million acres of potentially suitable breeding habitat for the black-capped vireo may exist (Wilkins et al. 2006). There are no estimates of the amount of breeding habitat available in other parts of the species' breeding range. There are also no available estimates of black-capped vireo wintering habitat (Wilkins et al. 2006).

As extrapolated by Wilkins et al. (2006), these surveys estimate that approximately 181,630 acres of potentially suitable black-capped vireo habitat may occur in the 7-county SEP-HCP Plan Area (see Table 2 for more information). The geographic distribution of this potential habitat across the Plan Area is not available. Further, this habitat estimate should be interpreted with caution. Maresh and Rowell (2000) caution that their survey data are extremely limited and that: 1) the lack of black-capped vireo detections at a survey point cannot be assumed to imply the absence of the species, since the duration of the surveys was very brief; 2) the identification of suitable habitat vs. non-habitat was highly subjective; and 3) the study lacked the statistical rigor that would be necessary to make wider inferences about the available and occupancy of black-capped vireo across the breeding range in Texas. Wilkins et al. (2006) noted that the county-wide estimates of potential vireo habitat are likely to overestimate the amount of occupied and potential suitable habitat, and cautioned that these estimates may not be reliable and are of limited utility.

TABLE 2. ESTIMATED ACRES OF SUITABLE BCV HABITAT AND KNOWN BCV POPULATION*.

Geographic Area	Acres of Suitable Habitat	Known Males or Territories Documented Since 2000
Bexar County	47,854	45
Medina County	62,292	4
Bandera County	7,599	28
Kerr County	53,074	436
Kendall County	4,945	-
Blanco County	2,275	14
Comal County	3,591	-

TABLE 2. ESTIMATED ACRES OF SUITABLE BCV HABITAT AND KNOWN BCV POPULATION*.

Geographic Area	Acres of Suitable Habitat	Known Males or Territories Documented Since 2000
SEP-HCP Plan Area (7 counties)	181,630	527
BCV Recovery Region 3 - Southeast Edwards Plateau**	678,641	1,018
BCV Texas Breeding Range (53 counties)	1,450,441	6,010
BCV Breeding Range (Texas, Oklahoma, & Mexico)	unknown	6,269

* Estimates per Wilkins et al. (2006)
** Assumed to include all of the following counties: Mc Culloch, San Saba, Schleicher, Menard, Sutton, Kimble, Mason, Llano, Gillespie, Blanco, Hays, Edwards, Real, Kerr, Bandera, Kendall, Comal, Kinney, Uvalde, Medina, and Bexar

5.2 KNOWN POPULATIONS

Wilkins et al. (2006) conducted a review of all published records and available unpublished records of black-capped vireo observations in order to assess the total size of the currently known breeding population of the species. Wilkins et al. (2006) defined "current" populations as those with species observations recorded between 1996 and 2005. Their review identified a total of 527 black-capped vireo breeding units (i.e., direct counts of males, pairs, or territories) observed on private and public lands in the 7-county SEP-HCP Plan Area (see Table 2 for more information). Many of these known populations occurred on public lands or designated nature preserves, including: the Kerr Wildlife Management Area in Kerr County (358 males); the Love Creek Nature Preserve and Hill Country State Natural Area in Bandera County (10 males and 7 males, respectively); and Camp Bullis and Rancho Diana in Bexar County (13 territories and 32 males respectively) (Wilkins et al. 2006). The total size of the currently known vireo population on these properties is approximately 420 breeding units (Wilkins et al. 2006).

USFWS (2005) also notes that the species is known to occur on the Friedrich Wilderness Park in San Antonio, and black-capped vireos were also reported from the Heart of the Hills State Fish Hatchery in Kerr County and Lost Maples State Natural Area in Bandera and Real counties in 2009 (Julie Groce, Texas A&M Institute of Renewable Natural Resources, pers. comm. 2010). The number of individuals present on these properties is unknown.

Data from Camp Bullis reported in (Cooksey and Edwards 2008) indicate that approximately 153 acres of vireo habitat was identified on the installation in 2001 and that vireo detections seem to have declined regularly since 2004, with 2 detections in 2007 and no detections in 2008.

Wilkins et al. (2006) did not identify any recent records of black-capped vireos from Kendall or Comal counties. However, given the increasingly optimistic status of the vireo overall (the recent status review proposed that the species be downlisted in part due to the larger number of known populations) (USFWS 2007), the documented presence of the species on many private lands in the region (USFWS

2007), and the likely abundance of potential habitat in these counties (Wilkins et al. 2006), the species is likely to occur in these two counties.

The currently known breeding population of the black-capped vireo reported in Wilkins et al. (2006) is likely to represent only a small proportion of the total breeding population because many areas of potential habitat within the breeding range have not been surveyed. Most of the range occurs on private properties that are not accessible for surveys (Wilkins et al. 2006). However, where private lands are accessible or have been systematically surveyed, the species is often found (Wilkins et al. 2006).

The Texas Natural Diversity Database element of occurrence records maintained by the Texas Parks and Wildlife Department (which is a limited dataset based on voluntary submissions of sighting records) identify 57 occurrences of the black-capped vireo in the SEP-HCP Plan Area between 1985 and 2007 (Texas Parks and Wildlife Department 2010). These data indicate that the species has been recorded from Bexar, Medina, Bandera, Kerr, and Blanco counties. Additional black-capped vireo locality data were obtained from USFWS Austin Ecological Services in September 2009 in GIS format (i.e., “HistoricBirdSurveys_Observations.mdb”). The data included point records with attribute fields for the observation year and source, notes regarding the quality of the data, and other comments. The data were compiled from the work of several different surveyors and were dated from between the years 1989 and 2003.

Generalized black-capped vireo localities available from the Texas Natural Diversity Database and the USFWS are shown on Figure 4.

6.0 REGULATORY STATUS AND RECOVERY CRITERIA

6.1 CURRENT REGULATORY STATUS

The USFWS lists the black-capped vireo as endangered. The species was first proposed for endangered status on December 12, 1986 (51 FR 44808) and was given endangered status on October 6, 1987; the rule becoming effective on November 5, 1987 (52 FR 37420). The USFWS has not designated critical habitat for the black-capped vireo.

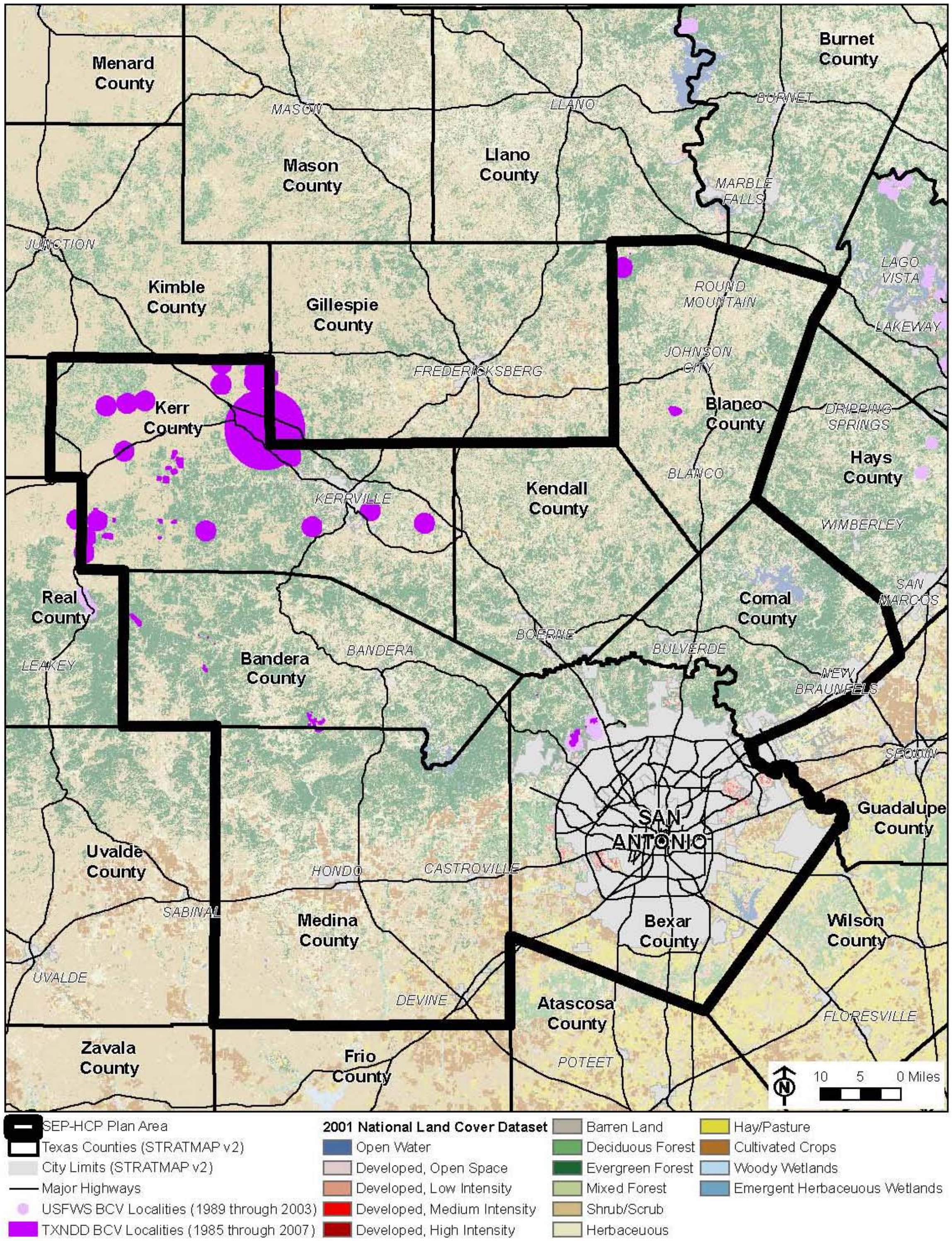
The black-capped vireo was state-listed as threatened on March 1, 1987 and endangered on December 28, 1987.

6.2 STATUS REVIEW AND RECOVERY CRITERIA

The USFWS includes the SEPHCP Plan Area within the black-capped vireo Recovery Region 3 – Southeast Edwards Plateau Recovery Region (USFWS 1991). A status review of the vireo by the USFWS was completed on June 19, 2007. The review assessed the current status of the species and recommended that the species be downlisted to threatened status (USFWS 2007).

The recommendation for downlisting is based on observations that the total known population of black-capped vireos in Texas is much larger than that known at the time of listing, due to an increase in the overall population size and/or increased survey efforts that identified populations at new locations (including on private lands). Given a larger known population, the magnitude of the major threats to the species may be generally less than previously suspected. However, the status review cautions that threats to this species still exist and its recovery depends on the implementation of management actions to reduce these threats (USFWS 2007).

FIGURE 4. GENERALIZED KNOWN BCV LOCALITIES.



The 1991 Black-capped Vireo Recovery Plan is currently considered to be out-of-date and in need of revision (USFWS 2007), primarily because the known vireo population is currently much larger than the known population at the time of listing and the relative magnitude of the primary threats to the species is likely to have changed since listing. However, the recovery criteria listed in the 1991 Recovery Plan included a call for the protection of at least one viable vireo population composed of at least 500 to 1,000 breeding pairs in each of six recovery regions in Texas, Oklahoma, and Mexico.

As described in Section 5.2, many of the known black-capped vireo populations in the Plan Area occurred on public lands or designated nature preserves that are protected to some degree from future land development threats, and the size of the currently known population on these properties is approximately 420 breeding units (Wilkins et al. 2006). The Kerr Wildlife Management Area contains approximately 85 percent of these breeding units as a single population with regular habitat management.

7.0 THREATS AND HISTORIC TRENDS

The major threats to the black-capped vireo cited at the time the species was listed as endangered included habitat loss through conversion to other uses, heavy grazing and browsing pressure by domestic livestock and wildlife, and brood parasitism by brown-headed cowbirds (*Molothrus ater*) (USFWS 2007). Since listing, new information suggests that vegetational succession may also be a major concern for the species (USFWS 2007). The recent status review of the vireo by the USFWS states that habitat loss, grazing and browsing, brood parasitism, and vegetational succession remain the primary threats to the species, although the relative importance of each of these threats may have changed since the time of listing (USFWS 2007).

The 2007 status review found that habitat loss and fragmentation due to the conversion of rangeland to other uses has likely decreased the amount of available habitat for the black-capped vireo across Texas, particularly on the Edwards Plateau, and remains a major threat (USFWS 2007).

The status review found that fewer domestic livestock on the Edwards Plateau, particularly goats, may have decreased the overall threat from grazing and browsing. However, heavy grazing and browsing by domestic livestock may still have an important negative impact on localized vireo populations. While the density and abundance of domestic livestock on the Edwards Plateau may be decreasing, the populations of white-tailed deer (*Odocoileus virginianus*) and other exotic, browsing ungulates may have increased, which may be of concern to the species (USFWS 2007).

Brood parasitism by brown-headed cowbirds has been identified as a major factor in the low reproductive success of some black-capped vireo populations. Cowbird abundance is correlated with the number and proximity of domestic livestock feeding areas, and the relative abundance of cowbirds in Texas has generally been decreasing over the last ten years. In addition to the general decline of the abundance of cowbirds in North America, cowbird trapping and removal efforts are likely to have reduced parasitism rates on many of the managed populations. The status review states that the overall threat to the species from brood parasitism in Texas has likely decreased since the time of listing (USFWS 2007).

Vegetational succession, particularly the invasion and growth of Ashe juniper into formerly open rangelands, has limited vireo habitat across much of the range of the species. The status review identifies fire suppression, overgrazing, and drought as contributing factors to the increase of Ashe juniper in the landscape. The status review suggests that vegetational succession may be an increasing threat to the vireo, but little data is available to quantify the magnitude of the threat (USFWS 2007).

In addition to the major threats to the species, the status review identifies predation from red-imported fire ants (*Solenopsis invicta*) as a potentially increasing threat to the species (USFWS 2007).

8.0 EXISTING PROTECTIONS AND PROGRAMS

A variety of public and private lands in the SEP-HCP Plan Area currently receive some level of protection from future land development activities, and some of these are managed as natural areas or wildlife preserves with a focus on the protection and management of endangered species. As described in Section 5.2, black-capped vireos are known to occur on a number of public properties and other designated nature preserves within the Plan Area. Wilkins et al. (2006) reported that the size of the known population on such properties was approximately 420 breeding units (mostly occurring on the Kerr Wildlife Management Area). However, black-capped vireos and vireo habitats on these public lands or nature preserves may not be protected and managed in a manner suitable to maintain the long-term conservation value of these properties for the species.

9.0 DATA GAPS AND UNCERTAINTIES

The lack of spatially explicit, landscape-scale estimates of potentially suitable habitat for the black-capped vireo hamper efforts to evaluate the current status of the species and conduct effective regional conservation planning for the species. Further, few systematic surveys for the black-capped vireo, such as a USFWS protocol presence/absence survey, have been conducted on the existing conservation properties in the SEP-HCP Plan Area. This lack of detailed survey data makes an accurate accounting of the currently protected population of black-capped vireos difficult to determine. Additionally, this lack of data complicates efforts to fine-tune estimates of territory density and habitat preferences particular to this region.

10.0 SIGNATURES

This report was prepared by certified wildlife biologists covered by USFWS Threatened and Endangered Species Permit TE-841353 with authorizations for the black-capped vireo at the consulting firm of Loomis Partners, Inc. in conformance with the methods and limitations described herein.

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Centruroides vittatus scorpion captures *Ceuthophilus cunicularis* cave cricket at a cave entrance in Bexar County.

Prepared for Loomis Partners, Inc.
3101 Bee Cave Road, Suite 100
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12 September 2011

Introduction

The Southern Edwards Plateau Habitat Conservation Plan (SEP-HCP) Plan Area currently has nine federally endangered karst invertebrates that are each known only to occur in Bexar County (65 FR 81419). The U.S. Fish and Wildlife Service's (USFWS) recovery priority number for all nine listed invertebrates is 2c, which indicates that they face a high degree of threat with a high potential for recovery and there may be conflict between species recovery and economic development. All of these species are subterranean obligates known to occur only in the caves and mesocaverns of Bexar County, Texas.

The following descriptions and species summaries were taken largely from the Bexar County Karst Invertebrates Draft Recovery Plan (USFWS 2008) and the final rule published in the Federal Register that established critical habitat for seven of these species (USFWS 2003).

Species Descriptions

Government Canyon Bat Cave Spider *(Neoleptoneta microps)*
The Government Canyon Bat Cave spider (Araneae: Leptonetidae) is a small, short-legged, essentially eyeless spider. It was first collected on August 11, 1965 by J. Reddell and J. Fish (Reddell 1993). The species was originally described by Gertsch (1974) as *Leptoneta microps* and later reassigned to *Neoleptoneta* following Brignoli (1977) and Platnick (1986). The species was initially reported from two caves in Government Canyon State Natural Area: Government Canyon Bat Cave and Surprise Sink. The specimen collected from Surprise Sink, however, has not been confirmed as *Neoleptoneta microps* (Joel Ledford, pers. comm. 2010).

Figure 1. *Neoleptoneta* new species to show general morphology of the genus. Photo by James Cokendolpher.

Madla Cave Meshweaver *(Cicurina madla)*
The Madla Cave meshweaver (Araneae: Dictynidae) is a pale, eyeless, troglobitic spider first collected on October 4, 1963 by J. Reddell and D. McKenzie (Reddell 1993) and described by Gertsch (1992). The Madla Cave meshweaver has been confirmed in eight Bexar County caves. Molecular markers were used to identify juvenile specimens at eleven additional sites in Bexar County (Paquin and Hedin 2004). Eight of these eleven additional sites are caves that include other listed species and are either located within critical habitat areas or

areas that are not included in the critical habitat designation due to the provision of adequate special management. The remaining three of the eleven additional sites are caves where authorization for take of *C. madla* was granted to La Cantera under a Section 10(a)(1)(B) permit (USFWS 2001). One of these three latter caves has been heavily impacted and is not expected to contribute to the species' recovery. The other two caves occur in mitigation preserves and are not expected to be impacted (Allison Arnold- pers. comm.2010).

Figure 2. *Cicurina madla*. Photos by Jean Krejca.

Robber Baron Cave Meshweaver *(Cicurina baronia)*
The Robber Baron Cave meshweaver (Araneae: Dictynidae) is a small, eyeless spider known from two localities (USFWS 2008; Krista McDermid, pers. comm. 2010). It was first collected in Robber Baron Cave on February 28, 1969 by R. Bartholomew (Reddell 1993) and described by Gertsch (1992).

Figure 3. *Cicurina baronia* from Robber Baron Cave. Photos by Jean Krejca.

Bracken Bat Cave Meshweaver *(Cicurina venii)*
The Bracken Bat Cave meshweaver (Araneae: Dictynidae) is a small, eyeless, or essentially eyeless, troglobitic spider. The species description is based on one female collected on November 22, 1980 by G. Veni and described by Gertsch (1992). Bracken Bat Cave remains the only location known to contain this species (USFWS 2008).

Government Canyon Bat Cave Meshweaver *(Cicurina vespera)*
The Government Canyon Bat Cave meshweaver (Araneae: Dictynidae) is a pale, eyeless, troglobitic spider. The female holotype was first collected on August 11, 1965 by J. Reddell and J. Fish (Reddell 1993) and described by Gertsch (1992). The species is currently known from only Government Canyon Bat Cave in Government Canyon State Natural Area (USFWS 2008). A second cave, called "unnamed cave five miles northeast of Helotes", was once thought to also contain the species but was subsequently ruled out as a locality. The individual collected from this unnamed cave was determined to be a new species, *Cicurina neovespera* (Reddell and Cokendolpher 2004). Molecular analyses of both *Cicurina vespera* and another federally listed spider, *Cicurina madla*, have suggested a possible synonymy between the two species (Paquin and Hedin 2004). These results, however, have not been confirmed by morphological analysis and no formal synonymy was proposed in Paquin and Hedin (2004).

Cokendolpher Cave Harvestman *(Texella cokendolpheri)*
The Cokendolpher cave harvestman (Opilionida: Phalangodidae) is a small, pale orange, essentially eyeless, troglobitic harvestman. Juvenile specimens are known to be white to yellowish-white in color. *Texella cokendolpheri* was first collected in 1982 and described by Ubick and Briggs (1992). It is known from one locality (i.e., Robber Baron Cave) in Bexar County (USFWS 2008).

Figure 4. *Texella tuberculata* to show general morphology of the genus.
Photo by Jean Krejca.

Beetle (No Common Name) *Rhadine exilis*

The beetle *Rhadine exilis* (Coleoptera: Carabidae) is a small, slender-bodied, essentially eyeless, troglobitic ground beetle. It was first collected in 1959 and described by Barr and Lawrence (1960) as *Agonum exile* and later assigned to the genus *Rhadine* (Barr 1974). The species is currently known from 52 caves in Bexar County (USFWS 2008; Krista McDermid, pers. comm. 2010).

Figure 5. *Rhadine exilis*. Photo by Jean Krejca.

Beetle (No Common Name) *Rhadine infernalis*

Rhadine infernalis (Coleoptera: Carabidae) is a small, slender-bodied, essentially eyeless, troglobitic ground beetle. It was first collected in 1959 and initially described by Barr and Lawrence (1960) as *Agonum infernale*, but later assigned to the genus *Rhadine* (Barr 1974). There are two recognized subspecies: *Rhadine infernalis ewersi* and *R. infernalis infernalis*, (Barr 1960). A third possible subspecies, *R. infernalis* ssp., was characterized as valid but has not been formally described (Reddell 1998.) All three subspecies are included under *R. infernalis* and are protected under the federal listing as endangered. *R. infernalis* is known from 36 caves located in Bexar County (USFWS 2008).

Figure 6. *Rhadine infernalis*. Photo by Jean Krejca.

Helotes Mold Beetle *(Batrisodes (Excavodes) venyivi)*

The Helotes mold beetle (Coleoptera: Staphylinidae) is a small, troglobitic, reddish-brown beetle that resembles an ant. It was first collected in 1984 and described by Chandler (1992). The species is currently known from eight caves in Bexar County (USFWS 2008).

Figure 7. Batrisodes gravesi to show general morphology of the genus. Photos by James Cokendolpher.

Life History

All of the listed invertebrates are obligate cave species known as "troglobites." They spend their entire life cycle underground and are characterized by reduced or absent eyes, lack of pigmentation, elongation of sensory appendages, and low metabolic rates.

Many troglobites are thought to be ancient "relicts" of formerly surface dwelling species. It's been theorized that these surface-dwelling ancestors may have retreated into more stable subterranean environments as surface conditions became less hospitable, as would have been the case during drastic climatic changes that occurred during the Pleistocene epoch (Barr 1968, Elliott and Reddell 1989).

As the ancient surface communities migrated to more suitable habitats, subsurface populations adapted to the cave environment and began colonizing other subterranean habitats, leading to vicariance events. Vicariance is defined as the separation or division of a group of organisms by a geographic barrier resulting in differentiation of the original group into a new, distinct species. Fragmentation and subsequent isolation of subterranean populations, due to erosion or faulting, could have contributed to vicariance events among cave-dwelling taxa (Elliot and Reddell 1989, Veni 1994). The distribution of the Bexar County troglobites may have also been influenced by dispersal or an organism's ability to move into and colonize new areas. Porter (2007), however, suggests that the patterns of distribution among subterranean fauna may be more clearly explained by a combination of both vicariance and dispersal events.

Compared to surface species, troglobitic species generally have smaller geographic ranges and specific limitations to a particular geographic area making them biogeographically distinct (Porter 2007, Christman et al. 2005) and particularly susceptible to extinction (Elliott and Reddell 1989, Culver et al. 2000). Three of the nine listed Bexar County karst species are currently known to be single-site endemics. Of these three species, Cicurina vespera and Cicurina venii are known only from holotypes (i.e., the only specimen to have ever been collected) (USFWS 2008).

Physical factors in caves that affect the life history of the Bexar County karst species include absence of sunlight, low nutrient flow (due to lack of primary production), and a stable environment with uniform temperature and humidity. These parameters favor the evolution of troglomorphic characteristics, including reduction or loss of eyes, reduced pigmentation, and attenuated limbs and olfactory organs (USFWS 2008). Additionally, nearly all cave-adapted organisms exhibit the following characteristics: delayed reproduction, larger eggs, relatively small number of total eggs produced, and increased longevity (Culver 1982).

Although the average life span of any of the listed troglobitic invertebrates is currently unknown (USFWS 2008), it is likely to be multiple years for some species, such as the Cicurina spiders (Bennett 1985, Cokendolpher 2004).

Ecology

Currently, very little is known about the ecology of the nine federally listed Bexar County karst species. However, these listed troglobites are known to be the top predators in their ecosystem (USFWS 2008) and are dependent on the stability of their prey base that make up the lower trophic levels of the karst ecosystem (Taylor et al. 2004).

Cave crickets (Ceuthophilus spp.) are a particularly important component of the cave ecosystem and serve as a dependable source of nutrient input from the surface environment (Barr 1968, Reddell 1993, Lavoie et al. 2007). Cave crickets generally roost and lay their eggs in caves during the day and forage for food on the surface at night. Cricket eggs provide a food source for a variety of troglobites (Mitchell 1971). Some federally listed troglobites also feed on cave cricket feces (Barr 1968, Poulson et al. 1995) and on the crickets themselves (Elliott 1994).

Habitat Requirements

Habitat for the nine federally listed Bexar County karst invertebrates occurs in limestone caves and mesocaverns (i.e., humanly impassable voids within the bedrock). Within this environment, these animals are dependent on high humidity, stable temperatures, and an influx of nutrients from the surface in the forms of leaf litter, animal droppings, and animal carcasses (USFWS 2008).

General habitat characteristics for the federally listed Bexar County karst invertebrates are described below. Tables 1 and 2 summarize specific habitat variables measured for three of these species.

Humidity and Temperature
Troglobites require stable temperatures and high humidity approaching near saturation (Barr 1968, Culver 1982, Elliott and Reddell 1989). Generally, areas within caves that have low humidity are almost entirely devoid of cave fauna (Elliott and Reddell 1989). To sustain humid conditions, it is necessary to protect both the surface and subsurface drainage basins. This serves to maintain the supply of moisture to the cave and connected karst areas and also to insulate the karst system from extreme temperature fluctuations (USFWS 2008).

Drainage Basins
Water enters the karst ecosystem through both groundwater and surface drainage basins. Water is rapidly transported through cave openings, fractures, and solutionally enlarged bedding planes with little or no purification. Consequently, karst systems are highly sensitive to pollution from contaminated water traveling through the surface and subsurface drainage basins. The potential for pollutants, such as pesticides, fertilizers, and leakage from sewer lines, may be heightened in some karst areas relative to others based on local geologic features (USFWS 1994). Because of these factors, protecting caves' drainage basins is of vital importance (USFWS 2008).

Surface Communities
Due to insufficient and limited photosynthesis capabilities underground, the karst ecosystem relies almost entirely upon surface plant and animal communities for nutrient input. Surface plant communities provide nutrients through leaf litter that enters caves or karst voids and from root masses that may grow directly into caves (Howarth 1983). Surface plant communities also serve as a buffer against changes to moisture and temperature regimes within the karst ecosystem (Biological Advisory Team 1990, Veni 1988). Surface animals provide food for trogloxenes (i.e., animals that spend only a portion of their life cycle in the subterranean environment), such as cave crickets, bats, toads and frogs (USFWS 2008). Primary sources of nutrients in the karst ecosystem are leaf litter, cave crickets, small mammals, and other animals that defecate or die in the cave (USFWS 2003).

Mesocavernous Habitat
The use of interstitial zones or mesocaverns by troglobites may play an important part in these species' viability. These areas are defined as small, humanly inaccessible, solutionally enlarged voids that provide potential habitat for cave-dwelling species in the areas between caves (Veni 1994). Troglobites most likely use these areas the majority of the time, since humidity and temperature levels remain more stable than in larger caves (Howarth 1983). Use of interstitial spaces by troglobites has been observed in Japan, Hawaii, and Texas (Howarth 1983, Sprouse and Krejca 2009, Peter Sprouse pers. comm. 2010) and it is common to visit a cave several times before detecting the presence of a karst species. Krejca and Weckerly (2007) assessed the detection probabilities of three karst invertebrates, including *Rhadine exilis*, during karst faunal surveys. Their results suggest that ten to 22 visits may be required in order to confirm presence. Furthermore, central Texas endangered karst invertebrates have been found in caves that immediately prior to sampling had no humanly accessible entrances (Horizon Environmental Services 1991, Veni 2002, Mark Sanders pers. comm. 2009).

In order to support karst invertebrates, mesocavernous spaces should be a minimum width of five to 10 millimeters, which also corresponds to the threshold of turbulent groundwater flow that could potentially carry nutrients to karst species (Howarth 1983, Veni 1994).

In 2006, Veni and Associates quantified specific habitat characteristics for three of the listed species occurring on Camp Bullis (i.e., *Rhadine exilis*, *Rhadine infernalis*, and *Cicurina madla*). The results of this study are summarized below.

Table 1. Number of individuals observed within caves zones and seasons (Veni and Associates 2006).

Species	**Total Individuals Observed**	**Cave Zones**		
		Entrance Zone	**Twilight Zone**	**Dark Zone**
Rhadine exilis	64	4	18	47
Rhadine infernalis	23	6	10	7
Cicurina madla	75	0	3	72
		Seasonal Observations		
		Fall	**Spring**	**Summer**
Rhadine exilis	64	12	37	15
Rhadine infernalis	23	1	13	9
Cicurina madla	75	*	*	*

*data not specified

Table 2. Mean temperature and humidity for recorded observations of three Bexar County endangered karst invertebrates (Veni and Associates 2006).

Species	**Mean Temp (°C /°F)**	**Standard Deviation (°C)**	**Mean Humidity (%)**	**Standard Deviation**
Rhadine exilis	21.44/ 70.59	1.24	93.5	3.62
Rhadine infernalis	22.05/71.69	2.62	90.5	3.44
Cicurina madla	20.03/68.0	0.82	94.01	2.24

Regulatory Status

The nine Bexar County karst invertebrates were federally listed as endangered species on December 26, 2000 (65 FR 81419). All species have a recovery priority of 2c, and critical habitat was designated on April 8, 2003 for all of the species, except the Government Canyon Bat Cave spider (Neoleptoneta microps) and Government Canyon Bat Cave meshweaver (Cicurina vespera). None of these species or their habitats receives direct protection under Texas state law, since invertebrates are not included on the Texas Parks and Wildlife Department's (TPWD) list of threatened and endangered species.

Species Status and Distribution

Karst Zones in Bexar County

The northern portion of Bexar County is located on the Edwards Plateau, a broad and flat expanse of Cretaceous carbonate rock that ranges in elevation from approximately 1,100 feet to 1,900 feet above mean sea level. The principal, cave-containing rock units of the Edwards Plateau are the upper Glen Rose, Edwards Limestone, Austin Chalk, and Pecan Gap Chalk formations. One-third of the cavernous rock exposed at the surface in Bexar County is of the Edwards Limestone formation, making it the most cavernous unit in the county (Veni 1988, Veni 1994).

Based on the geologic restrictions on the distribution of cave fauna and the locations of known caves, Veni (1994) delineated five karst zones that reflect the relative likelihood of finding any of the Bexar County listed troglobites (and other rare or endemic karst species). These five zones are defined as:

- Zone 1: Areas known to contain one or more of the listed karst invertebrates.
- Zone 2: Areas having a high probability of suitable habitat for the listed karst invertebrates.
- Zone 3: Areas that probably do not contain listed karst invertebrates.
- Zone 4: Areas that require further research, but are generally equivalent to Zone 3, although they may include sections that could be classified as Zone 2 or Zone 5.
- Zone 5: Areas that do not contain listed karst invertebrates.

Under contract with the USFWS, Veni (2002) re-evaluated and, where applicable, redrew the boundaries of each karst zone originally delineated in Veni (1994). Revisions were based on current geologic mapping, further studies of cave and karst development, and the most current information available on the distribution of listed and non-listed troglobites (Veni 2002).

Additionally, Veni (1994) established six geographic areas called Karst Faunal Regions (KFRs) within the Bexar County Karst Zones. These divisions were defined by hydrogeologic barriers and/or other restrictions to the migration of troglobitic species over evolutionary time (Veni 2009). These six KFRs were used in the USFWS final rule designating critical habitat to define the ranges of the listed species and are as follows:

1. Stone Oak
2. UTSA
3. Helotes
4. Government Canyon
5. Culebra Anticline
6. Alamo Heights

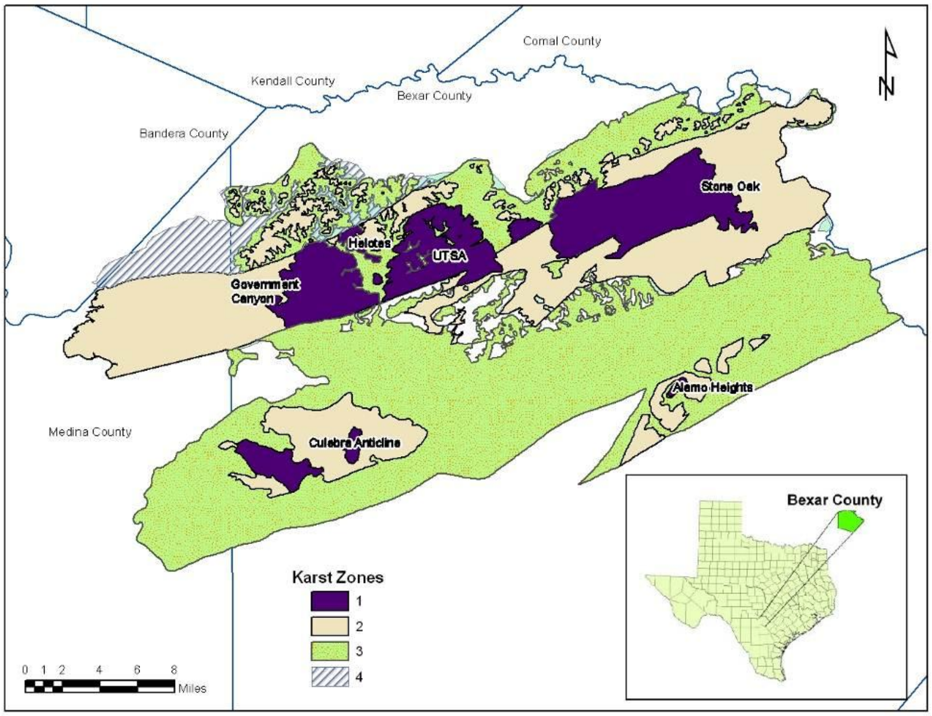

Figure 8. Bexar County karst zones and KFR's (Veni 2003).

The known distributions of the nine federally listed Bexar County karst invertebrates throughout the six delineated KFRs are summarized in Table 3.

As of December 2002, 475 caves were known to occur in Bexar County, some of which have been biologically surveyed for listed karst invertebrates. At least 97 of these caves were sealed or destroyed before they could be biologically surveyed (Veni 2003). Many of the remaining caves in the county have not been adequately surveyed and could be found to contain one or more of the listed species (USFWS 2003). A total of 68 caves have been confirmed to contain listed karst invertebrates and another 25 sites serve as unconfirmed or potential localities (USFWS 2008, K. McDermid pers. comm.).

The current status of species' populations in most of these caves is unknown. Also, many of these sites are lacking the recommended protection of a minimum of 59 to 89 acres of contiguous, unfragmented, undisturbed land (USFWS 2008) to maintain both the native plant and animal communities around the feature that will help protect the integrity of the cave community (USFWS 2003).

Current Conservation Efforts

The following information was taken from the draft USFWS Bexar County Karst Invertebrates Recovery Plan (2008):

Government Canyon Karst Management and Maintenance Plan
Some of the listed species have been verified from seven caves in the 8,622-acre Government Canyon State Natural Area (GCSNA). These seven caves, along with four more caves containing listed species on the adjacent Lowder Tract, are biologically monitored and managed by GCSNA.

Table 3. Distribution of federally listed Bexar County karst invertebrates in KFRs and number of localities for each (Veni 2003).

Species	KFR	Number of known localities
Rhadine exilis	Government Canyon	52
	UTSA	
	Helotes	
	Stone Oak	
Rhadine infernalis (including subspecies)	Government Canyon	36
	UTSA	
	Helotes	
	Stone Oak	
	Culebra Anticline	
Batrisodes venyivi	Government Canyon	8
	Helotes	
Texella cokendolpheri	Alamo Heights	1
Neoleptoneta microps	Government Canyon	2
Cicurina baronia	Alamo Heights	2
Cicurina madla	Government Canyon	8*
	UTSA	
	Helotes	
	Stone Oak	
Cicurina venii	Culebra Anticline	1
Cicurina vespera	Government Canyon	1
	UTSA	
* Based on a study conducted by Paquin and Hedin (2004), 12 more localities for Cicurina madla may exist.		

Camp Bullis Management Plan for the Conservation of Rare and Endangered Karst Species
The Camp Bullis Training Site is a 43.7-square mile facility under the jurisdiction of Fort Sam Houston (U.S. Army), Texas. It contains 26, possibly 28, caves with listed karst invertebrates. The two questionable localities are awaiting taxonomic confirmation (Krista McDermid, pers. comm. 2010). The listed species found on Camp Bullis are Cicurina madla, Rhadine exilis, and Rhadine infernalis. A management plan for endangered karst invertebrates on Camp Bullis was developed in 1999 (Veni 1999) and revised in 2002 (Veni et al. 2002). The plan includes red-imported fire ant control, in-cave biological surveys, cave gate construction, and preservation of karst management areas around cave entrances.

City of San Antonio Proposition 3
On May 6, 2000, the citizens of San Antonio passed a "Parks Development and Expansion Venue Project Proposition" (Prop 3) to raise $65 million through a temporary 1/8 cent sales tax increase for the acquisition of open space over the Edwards Aquifer recharge zone and for parkland along Salado and Leon creeks. A total of $40.5 million was reserved for the purchase of land or conservation easements in the contributing and recharge zones of the aquifer. Most of the Prop 3 land that was purchased surrounded GCSNA and is not known to include sites for the listed species. Two exceptions were the Medallion and Crownridge Canyon properties. Rhadine infernalis infernalis is known from a cave on the Crownridge Canyon property and Cicurina madla has been confirmed from one cave on the Medallion

property. In addition, Prop 3 funds were used for the purchase of the Thrift tract and increased protection of the surface drainage basin for John Wagner Ranch Cave No. 3, a locality for Rhadine exilis and Rhadine infernalis infernalis.

La Cantera Habitat Conservation Plan

Three listed karst invertebrate species, *Cicurina madla*, *Rhadine infernalis,* and *R. exilis* are known to occur on the approximately 1,000-acre La Cantera property. The property contained over 400 potential karst features and at least three caves known to contain listed karst invertebrates. A habitat conservation plan (HCP) was developed in association with a request for an incidental take permit to develop the property. The La Cantera HCP (USFWS 2001) resulted in the establishment of several karst preserves. Two 1-acre development setbacks were established around two on-site caves known to contain listed species, and five preserves were established on off-site mitigation properties, totaling 179 acres. These off-site preserves include the type localities for *Rhadine infernalis*, *Cicurina madla,* and *Batrisodes venyivi*. The large number of off-site preserves was, in part, due to the fact that the size of the on-site setbacks was considered inadequate to ensure the survival of the covered species.

Critical Habitat Designation

The USFWS issued a Final Rule on April 8, 2003 designating critical habitat for seven of the nine listed species (USFWS 2003). Critical habitat defines areas that are essential to the conservation of a listed species and that may require special management considerations or protection. The critical habitat designation consists of 22 separate units, with a total area of approximately 1,063 acres. The lands within the critical habitat units are under private, city, or state ownership. A total of 31 caves known to contain one or more of the listed species are located within these critical habitat units (USFWS 2003).

Caves on GCSNA and Camp Bullis were excluded from the critical habitat designation (under Sections 3(5)(A)(i) and 4(b)(2) of the Endangered Species Act) because conservation plans already implemented were deemed to provide sufficient karst management and protection. Also, because two of the species, *Neoleptoneta microps* and *Cicurina vespera*, are known only from caves on GCSNA, critical habitat was not designated for them.

Texas Cave Management Association (TCMA)

The TCMA owns and manages Robber Baron Cave, which is the single known locality for *Texella cokendolpheri* and one of two localities known for *Cicurina baronia*.

Recovery Goals

The recovery goal, as stated in the draft Bexar County Karst Invertebrate Recovery Plan (USFWS 2008), is "to reduce or remove threats to the species such that their long-term survival is secured; the species are no longer endangered or threatened and can be delisted." To meet this goal, the draft recovery plan states that six or more karst faunal areas (KFAs) should be protected for each species (more than one species may occur in a protected KFA). A KFA is defined as "locations protected in perpetuity, known to support one or more sites of rare or endangered species and are distinct by acting as individual systems separated from other karst fauna areas by geologic and hydrologic features and/or processes that create barriers to the movement of water, contaminants, and troglobitic fauna". Geographic distance between KFAs should be substantial enough to protect the species against catastrophic loss in one area of its range and preserve the genetic diversity within the species (USFWS 2008, Veni 2009).

Factors to consider when selecting KFAs include the preserve area's ability to ensure long-term protection for listed species, the current level of habitat disturbance, past and present land-uses, the character of the surface communities, ease of protection (e.g., landowner cooperation), and the surface and subsurface drainage basins (USFWS 1994, USFWS 2008, Veni 2009). Additionally, areas that exhibit high species diversity and contain other rare or listed species should also be considered (USFWS 1994).

The Draft Bexar County Karst Invertebrate Recovery Plan states "the quality of a KFA is based on the probability of long-term survival of the species in that area and the amount of active management necessary to maintain those species." Characteristics outlined by the Recovery Team that constitute a healthy karst ecosystem and, therefore, a high quality KFA are:

- High water quality of both surface and subsurface drainage basins;
- Natural quantities of both vertebrate matter and plant matter input;
- Healthy native surface plant and arthropod communities;
- Low red-imported fire ant predation;
- High humidity and stable temperatures within karst features;
- Healthy cave cricket population;
- Adjacent karst features for cave cricket metapopulations; and
- Good connectivity with mesocaverns for population dynamics of troglobites.

High quality KFAs tend to be larger (60 to 90 acres) and require less active management, while low quality KFAs may be impacted by human activities and have a low potential for reasonable remediation. Medium quality KFAs (40 to 60 acres), although having some compromised characteristics of a high quality preserve, still have some potential for reasonable remediation (USFWS 2008).

In order for a listed karst species to be considered for downlisting, the Bexar County Karst Invertebrate Recovery Team suggests the following criteria and number of KFAs that would need to be protected for that species (USFWS 2008):

1) at least one high quality KFA protected in each KFR;
2) at least three total KFAs protected in each KFR;
3) a minimum of six KFAs protected rangewide.

Table 3. Nine listed Bexar County invertebrates and the suggested number of KFAs needed to achieve recovery (USFWS 2008).

Species	**Number of KFAs to protect**
Rhadine exilis	12
Rhadine infernalis	15
Batrisodes venyivi	8
Texella cokendolpheri	6
Neoleptoneta microps	6
Cicurina baronia	6
Cicurina madla	12
Cicurina venii	6
Cicurina vespera	8

Threats and Impacts Assessment

The primary threat to these species is habitat loss due to increased human expansion and urbanization throughout the karst terrain in Bexar County (USFWS 2003, USFWS 2008). Threats associated with increased urbanization include filling in and collapsing of caves, alteration of drainage patterns, alteration of surface plant and animal communities, contamination, and vandalism.

In addition, the continued spread of non-native, invasive species, such as the red-imported fire ant (Solenopsis invicta), poses a serious threat to karst invertebrates through direct predation and competition with native species (Taylor et. al 2003, USFWS 2008). This is a particularly important issue for listed invertebrates in central Texas because many of the caves in this region are shallow and provide refuge to red-imported fire ants during temperature extremes. Red-imported fire ants have also been directly observed attacking and carrying off cave crickets, a species that serves an integral role in the karst ecosystem (Elliott 2000, Paul Fushille pers. comm. 2010). This threat may be intensified by edge effects associated with the soil disturbance and disruption to native communities that come with urbanization (Reddell 1993).

Due to low known population densities, the rarity of encountering some species (Krejca and Weckerly 2007), and the potential for numerous confounding variables, potential impacts affecting karst invertebrates are inherently difficult to detect. Population responses may not be immediate and/or detectible (Howarth 1983, Miller and Reddell 2005).

Uncertainties and Data Gaps

Population estimates for any of the listed species are currently unavailable. This is mostly due to the inaccessibility of habitat, low detection probabilities, and lack of adequate sampling techniques.

Also, as previously mentioned, many features in Bexar County that could potentially have listed species have not been biologically investigated. Access to these unexplored features could contribute substantially to information on the distribution of these species.

More information on the life history of these species is needed, particularly with respect to topics such as longevity, fecundity, reproductive cues, predator-prey relationships, and others.

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