NOTES

RANGE EXTENSION AND STATUS UPDATE FOR THE OKLAHOMA CAVE CRAYFISH, *CAMBARUS TARTARUS* (DECAPODA: CAMBARIDAE)

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ABSTRACT—The range of the single-site endemic cave crayfish, *Cambarus tartarus,* is expanded to an additional cave system (Long's Cave), but is still restricted to the Spavinaw Creek watershed within Delaware County, Oklahoma. Censuses of these 2 populations in 2001 and 2004 produced record high counts: 17 individuals in January-Stansbury Cave and 63 in Long's Cave. January-Stansbury Cave, with at least 52 species of animals, is the most species-rich subterranean habitat in Oklahoma to date. Conservation activities are summarized. *Cambarus tartarus* remains extremely vulnerable to degraded habitat quality, and further protection is recommended.

RESUMEN—La distribución del camarón de agua dulce *Cambarus tartarus,* endémica de un sólo sitio, se extiende a un sistema de cuevas adicionales (Long's Cave), pero continúa restringida a la cuenca Spavinaw Creek en el condado de Delaware, Oklahoma. Los censos de estas dos poblaciones en el 2001 y 2004 produjeron records altos de conteos: 17 individuos en January-Stansberry Cave y 63 en Long's Cave. January-Stansberry Cave, con al menos 52 especies de animales, es la cueva más rica en especies en Oklahoma hasta la fecha. Se resumen actividades de conservación. *Cambarus tartarus* permanece extremadamente vulnerable a la degradación de la calidad del hábitat, y se recomienda más protección.

The Ozark Plateaus ecoregion is rich in aquatic biodiversity, due in part to a highly endemic crustacean fauna (e.g., Crandall, 1998). Recent explorations of the subterranean ecosystems of Oklahoma have produced many species new to science, making the Oklahoman Ozark Mountains a regional hotspot of cave biodiversity (Culver et al., 2000). Numerous crayfish species physiologically and morphologically adapted to groundwater environments (stygobites) occur in the Ozark Plateaus ecoregion, but their rarity, cryptic behavior, morphological similarities, and paucity of male specimens has hindered taxonomic determination. At least 13 taxonomically identified populations of stygobitic crayfishes exist in Oklahoma, and at least that many undetermined populations exist.

At present, 2 species of stygobitic crayfishes are described from Oklahoma: *Cambarus tartarus* Hobbs and Cooper, 1972, and *Cambarus subterraneus* Hobbs, 1993. *Cambarus tartarus* is known from only one site (January-Stansbury Cave, Delaware County, Oklahoma). It is also rare, with fewer than 10 individuals ever observed at one time. *Cambarus tartarus* was only recently given a vernacular name: Oklahoma cave crayfish (Williams et al., 1989). Virtually nothing is known of its life history, and the population has been monitored only sporadi-

cally (Willis, 1984; Mehlhop-Cifelli, 1990; Vaughn and Certain, 1992).

January-Stansbury Cave was bioinventoried as part of a regional, multi-agency effort (the Ozark Subterranean Biodiversity Project) to determine the status and distribution of rare cave fauna. Two other caves in Delaware County (Long's Cave and McGee's Cave) were also surveyed because of the discovery of resident stygobitic crayfish by B. and B. Howard (National Speleological Society, pers. comm.) in the 1980s and determination of the generic status *Cambarus* by Vaughn and Certain (1992).

The type locality of Oklahoma cave crayfish, January-Stansbury Cave (also known as Stansberry-January Cave), is a phreatic conduit 1,800 m long, with secondary vadose development, and it concentrates and discharges a subterranean stream of approximately 1 m^3 per min. With snorkeling gear, we censused the Oklahoma cave crayfish on 5 April 2004 with the assistance of S. Hensley and R. Stark (both with United States Fish and Wildlife Service); 17 individuals were counted and released after collection of morphometric data. This subterranean habitat harbors 8 other stygobites and troglobites (cave-adapted fauna): the isopods *Caecidotea antricola* and *C. ancyla*; the amphipods *Stygobromus alabamensis, S. onondagaensis,* and *S. ozarkensis*; grotto salamander (*Eurycea spelaea*); Black's cave millipede (*Trigenotyla blacki*); and cave dung fly (*Spelobia tenebrarum*) (Black, 1971; Looney, 1971; Hobbs and Cooper, 1972; Vaughn and Certain, 1992; this study). Because of this concentration of obligate species and because it has at least 52 total species, January-Stansbury Cave is now the most species-rich cave in Oklahoma to date and it is one of the most biologically important caves in the Ozark Plateaus ecoregion.

Long's Cave, located 10.8 km from January-Stansbury Cave, was surveyed on 31 August 2001. This phreatic karst complex is often flooded and can only be surveyed with snorkeling gear during low-flow conditions. A census of the entire complex revealed 63 *C. tartarus* distributed relatively evenly along the entire passage length of approximately 350 m and in the following 3 general size classes: 19 small (<2.5 cm); 31 medium (2.5 to 5 cm); and 13 large (>5 cm). A male crayfish specimen was collected live from Long's Cave (under United States Fish and Wildlife Service Permit TE834518-3 and Oklahoma Department of Wildlife Conservation Permits 3404 and 3156). The specimen was held in an environmental chamber until it molted into reproductive Form I 5 months later, and then it was euthanized by lowering body temperature in a freezer to 3°C, and subsequently preserved in 70% ethanol. The specimen will be deposited in the National Museum of Natural History—Smithsonian Institution (NMNH). Horton Hobbs III determined the specimen to be *C. tartarus* by comparison of type specimens of other stygobitic cambarids from NMNH. Genetic analyses by Koppelman and Figg (1995) have confirmed previous determinations based solely upon meristic characters. Our survey of Long's Cave also included 11 Ozark cavefish (*Amblyopsis rosae*), several *E. spelaea,* and an undescribed species of stygobitic isopod (*Caecidotea*).

McGee's Cave, located directly across Spavinaw Creek from Long's Cave, was censused on 31 August 2001. The habitat in McGee's Cave is a karst window having only 100 m of accessible passage before it quickly descends into a terminal groundwater sump. One female stygobitic *Cambarus* was seen, and upon handling, was noted to be a ganadromorph, having ischial hooks on the pereiopods. In previous studies at McGee's Cave, 7 cambarids were sighted in 1990 (B. Howard, National Speleological Society, pers. comm., 2001), and one in 1991 (Vaughn and Certain, 1992). Although Long's and McGee's caves are not physically connected, their groundwater recharge zones are contiguous (Aley and Aley, 1999). For this reason, the stygobitic crayfish populations are hypothesized to be conspecific; future non-lethal tissue sampling and genetic analysis will be performed. In McGee's Cave, at least 15 other species occur, including the following stygobites and troglobites: *A. rosae*; an undescribed genus of troglobitic dipluran (Japygidae); a troglobitic silverfish (Nicoletiidae); and *E. spelaea*.

Cambarus tartarus is now known from at least 2 subterranean ecosystems formed in Mississippian-aged limestones of the Boone Formation, but is still restricted to Spavinaw Creek in Oklahoma, a sub-basin of the Neosho River watershed (Fig. 1). Because of the proximity of other stygobitic crayfish populations to January-Stansbury Cave, other habitats in the vicin-

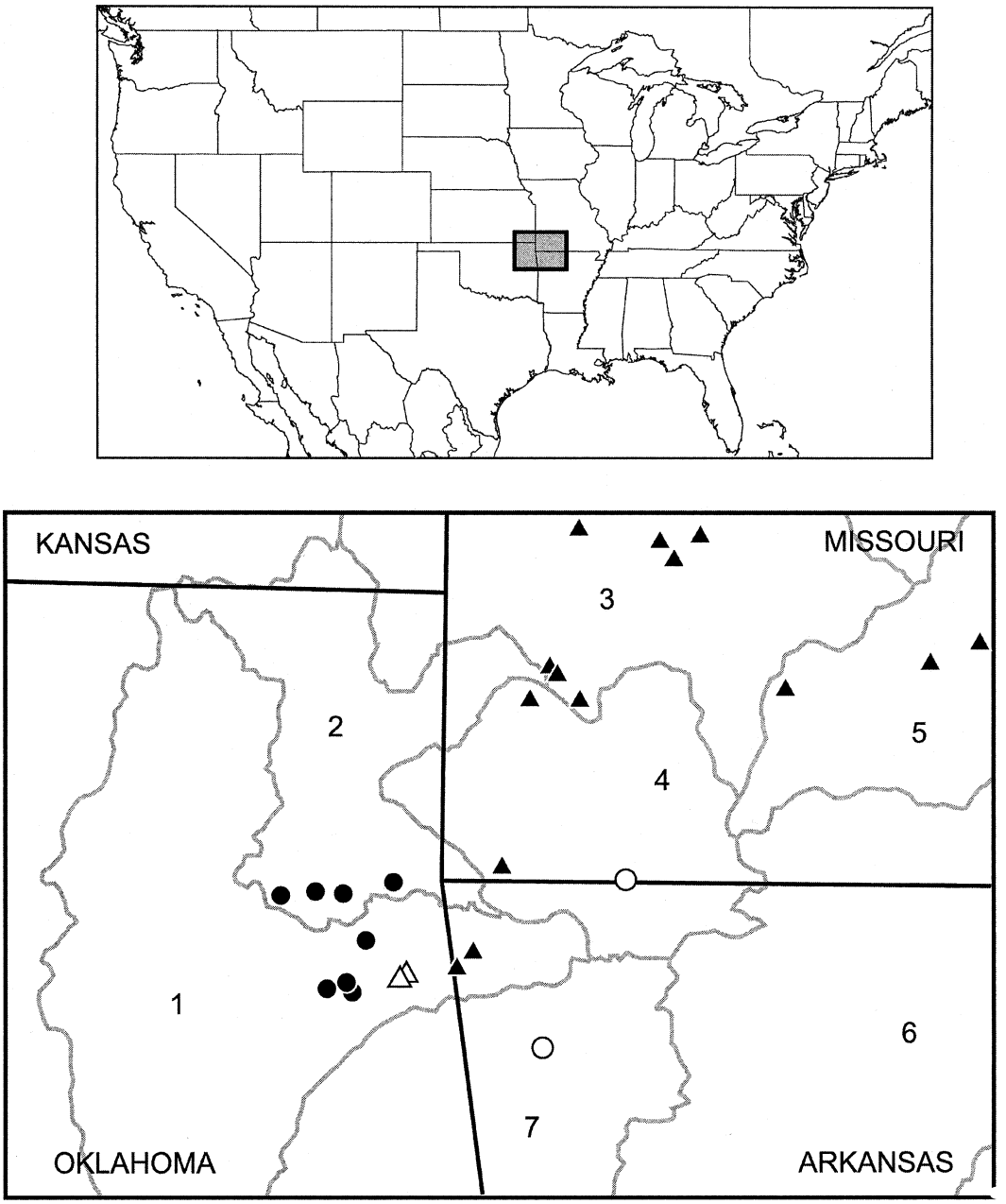

FIG. 1—Overview map and detail map of the distribution of stygobitic crayfishes in Oklahoma and surrounding states of Kansas, Missouri, and Arkansas (demarcated by black lines) in relation to major watersheds (gray polygons, numbered clockwise, where 1 = Lower Neosho River, 2 = Lake o' the Cherokees, 3 = James River, 4 = Elk River, 5 = Spring River, 6 = Beaver Reservoir, 7 = Illinois River). Symbols indicate published locations of each species: white triangles = *Cambarus tartarus*; black triangles = *C. setosus*; black circles = *C. subterraneus*; and white circles = *C. aculabrum*.

TABLE 1—All known visual census data for the Oklahoma cave crayfish (*Cambarus tartarus*). Asterisk indicates incomplete census of entire subterranean habitat.

Census date	Count	Data source
January-Stansbury Cave		
11 July 1970	*2	Hobbs Jr. and Cooper, 1972
11 April 1971	*1	Hobbs Jr. and Cooper, 1972
1972	4	H. Hobbs III, unpublished data
1984	6	Willis, 1984; USFWS, 1989
13 February 1985	*2	A. Brown, pers. comm., 2001
10 July 1986	*1	A. Brown, pers. comm., 2001
12 November 1989	7	Mehlhop-Cifelli, 1990
26 October 1991	6	Vaughn and Certain, 1992
6 January 2001	16	S. Hensley, pers. comm., 2002
5 April 2004	17	This study
Long's Cave		
1990	*9	B. Howard, pers. comm., 2001
27 September 1991	*1	Vaughn and Certain, 1992
1999	24	B. Howard, pers. comm., 2001
31 August 2001	63	This study

ity were hypothesized to contain *C. tartarus*. The nearest population is found on the opposite bank of Spavinaw Creek (Mitchell's Cave System); Mehlhop-Cifelli (1990) reported the presence of a stygobitic cambarid in Mitchell's Cave #1, but survey efforts, including ours in 2002, have failed to detect any crayfish. Hobbs et al. (1977) tentatively assigned stygobitic specimens at Rodman Cave, Star Cave, and Jail Cave (all in Delaware County) to *C. tartarus* because of their proximal locations within the Spavinaw Creek watershed. However, specimens at Jail and Star Caves were later assigned to *C. subterraneus* (Hobbs, 1993), and the population at Rodman Cave remains undetermined. Farther upstream on Spavinaw Creek in Arkansas, *C. setosus* has been identified in several subterranean habitats and is hypothesized to exist in Oklahoma (Graening et al., in litt.). Furthermore, *C. setosus* is the closest phylogenetically to *C. tartarus* (Koppelman and Figg, 1995). Thus, proximity to the type locality has been an inconsistent explanation for distribution of *C. tartarus*. Every known stygobitic population of *Cambarus* in Oklahoma is found within a different groundwater basin (Aley and Aley, 1999) and might represent separate colonization events. However, all of these sites are contained within the Neosho River basin, and a common ancestor is hypothesized to have colonized these groundwater habitats via this river corridor.

Cambarus tartarus was known from only 6 individuals, but is now considered to number approximately 80 individuals; Table 1 summarizes all known censuses. The national Natural Heritage Program and The Nature Conservancy consider *C. tartarus* to be critically imperiled (NatureServe, 2005), the World Conservation Union (IUCN) considers this crayfish to be critically endangered (IUCN, 2003), and Oklahoma has designated it a state endangered species. Our discovery of a new population of this crayfish should not alter these rankings, but such range extension and population increase does reduce the immediate concern of extinction.

However, *C. tartarus* remains vulnerable to extirpation, primarily because of habitat degradation. Spavinaw Creek is designated an impaired waterbody by Oklahoma under Section 303(d) of the federal Clean Water Act (40 CFR 130.7) because of excessive nutrient loading; numerous confined animal feeding operations are located upstream of the crayfish habitats, and the City of Colcord discharges treated municipal sewage into the watershed (Aley and Aley, 1999). The Neosho River also is designated impaired due not only to organic enrichment, but also low dissolved oxygen, altered

pH, and the presence of priority toxic organics, metals, and pesticides. Stygobitic crayfishes might be susceptible to degraded water quality because of their highly specialized adaptations to stable environmental conditions (Dickson and Franz, 1980) and because of their longevity, which might allow toxins to accumulate to lethal concentrations (Dickson et al., 1979).

Conservation efforts began with the acquisition of land surrounding the cave entrances and restricting access via cave gates. January-Stansbury Cave and the surrounding 60 acres were donated by the Looney Family to the United States Fish and Wildlife Service, creating the Mary Looney Unit of the Ozark Plateau National Wildlife Refuge, and the Looney homestead has been converted into a speleological research station. The Long Family sold 151 acres containing Long's Cave and McGee's Cave to The Nature Conservancy in 1997, which now manages the caves within the Eucha Nature Preserve. Groundwater recharge zone delineations and hazard assessments have been performed for Long's Cave (recharge area of 313 ha) and McGee's Cave-Parchcorn Spring (4,087 ha) by Aley and Aley (1999). The groundwater basin of January-Stansbury Cave has yet to be delineated; this should be performed immediately to focus conservation actions. Because of recent habitat transformation and degradation of water quality, we recommend that *C. tartarus* receive further protection under state and federal laws.

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DISTRIBUTION OF THE BLACK-CAPPED VIREO AT FORT HOOD, TEXAS

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ABSTRACT—We provide complete, updated data on the status of the endangered black-capped vireo (*Vireo atricapilla*) and its habitat on Fort Hood Military Reservation, Texas. We searched 74,880 ha of Fort Hood during spring and summer 2002 and 2003, noting the locations of potential habitat patches and vireos. We mapped 6,971 ha of potential habitat, 90% of which was occupied. Such high occupancy suggests that vireos have colonized most of the available vireo habitat on Fort Hood. We detected 1,846 male vireos. The area of occupied habitat and number of male vireos both exceed goals set in the Endangered Species Management Plan for Fort Hood. Assuming that half of the male vireos had mates, Fort Hood alone would exceed the previously published recovery goal of 750 breeding pairs for the Lampasas Cut Plains set in the recovery plan for the black-capped vireo.

RESUMEN—Proveemos información completa y reciente sobre el estado del ave en peligro vireo capa negra (*Vireo atricapilla*) y su hábitat en Fort Hood Military Reservation, en Texas. Conducimos muestreos en 74,880 ha de Fort Hood durante la primavera y el verano del 2002 y 2003, y registramos las localizaciones de los vireos y también áreas de hábitat potencial. Trazamos mapas de 6,971 ha de hábitat potencial, 90% del cual estaba ocupado. Un nivel de ocupación tan alto indica que los vireos han colonizado la mayoría del hábitat disponible en Fort Hood. Detectamos 1,846 vireos machos. La cantidad de hábitat ocupado y el número de vireos machos exceden las metas propuestas por el Endangered Species Management Plan de Fort Hood. Asumiendo que la mitad de los machos vireos tuvo hembras, sólo Fort Hood podría exceder la previamente publicada meta de recuperación de 750 parejas maduras en Lampasas Cut Plains prescrita en el plan para la recuperación del vireo gorra negra.

The largest breeding population of the federally endangered black-capped vireo (*Vireo atricapilla*) under a single management authority likely occurs on Fort Hood Military Reservation, central Texas. However, determining the extent of vireo habitat and the size of the population on Fort Hood has been a challenge. Vireos nest in clumped and patchy broadleaf shrublands (Grzybowski, 1995). Remote sensing technologies have not been able to successfully identify such habitat (Rowell, 1998). Thus, currently, vireo habitat can best be delineated through intensive searches by observers on foot. Due to the size of Fort Hood (88,500 ha), such searches require considerable time and effort. Because of the time and

effort required, previous searches have been non-systematic and restricted in scope. Additionally, vireo habitat often represents an early stage of succession and, thus, is transient. Consequently, the distribution of the vireo shifts as new shrublands are created and old shrublands mature into forests. Therefore, previous searches might not reflect current vireo distribution.

Because no complete and up-to-date survey of vireo distribution is available for Fort Hood, we conducted a systematic, installation-wide survey of vireo habitat. Additionally, we calculated a coarse estimate of the size of the vireo population at Fort Hood using data from this survey. These data should improve efforts to manage and protect habitat for the vireo, as well as facilitate the design of research and monitoring projects that would statistically represent Fort Hood. Furthermore, they will allow us to evaluate progress made toward reaching previously published recovery goals (United States Fish and Wildlife Service, 1991; Hayden et al., 2001).

Fort Hood is an active military post located in the Crosstimbers and Southern Tallgrass Prairie and the Edwards Plateau ecoregions in Bell and Coryell counties (The Nature Conservancy, 1997). Since their discovery on Fort Hood in 1978, management and monitoring of the vireo has become a priority (e.g., Tazik et al., 1993*a*, 1993*b*; Hayden et al., 2001). Commonly, Fort Hood has disturbances that create and maintain shrubby vegetation suitable for vireos. Some of these disturbances (off-road traffic by heavy vehicles and wildfires ignited by ordnance or flares) are unique to military training lands.

We conducted surveys on Fort Hood between 1 April and 19 July in both 2002 and 2003. We did not conduct surveys after 1400 CDT. We could not conduct surveys in restricted access areas (Fig. 1). During each year, 8 to 11 observers walked across Fort Hood and mapped large patches (i.e., patches that could contain a 100-m-diameter circle) of potential vireo habitat. Observers delineated these habitat patches on digital orthophoto quadrangle (DOQ) maps, which we later digitized in Arcview 3.3 (Environmental Systems Research Institute, Inc., Redlands, California) to calculate the area of each patch. Observers categorized each patch as donut, shrubland, or

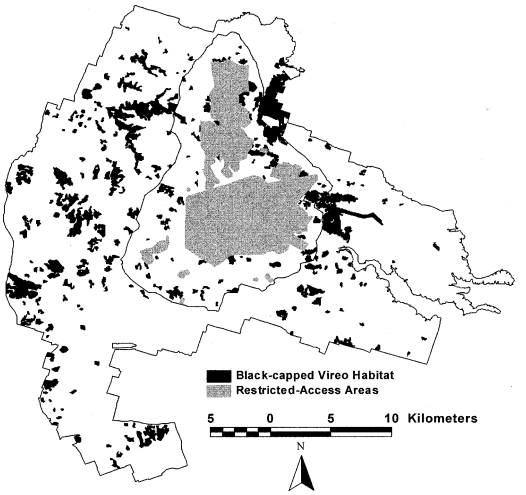

FIG. 1—We mapped 6,971 ha of black-capped vireo (*Vireo atricapilla*) habitat during an installation-wide survey of Fort Hood, Texas during 2002 and 2003. The outer line represents the boundary of Fort Hood. The inner line represents the boundary of the Live Fire training areas to which we had irregular access.

mixed (habitats defined in Table 1). Our rationale for only mapping large patches was that habitat manipulation on smaller patches would be inefficient and, thus, small patches would be of less interest from a management perspective. A result of this protocol was that we did not map patches of brush pile or linear habitat (Table 1) because both are <100 m wide.

Upon finding a large patch of potential habitat, observers moved systematically through it, frequently stopping to listen for singing male vireos. If none were heard, observers stopped every 100 m within the patch to broadcast recorded vireo song for ≥30 s and then listen and watch for responding vireos for ≥60 s. If male vireos were still not detected, an observer revisited the patch at least 2 weeks later. Additionally, observers recorded whether smaller patches (e.g., brush pile and linear habitats) were occupied by vireos. Observers obtained UTM coordinates for all detected vireos using a global positioning system (GPS) unit or DOQ maps. To reduce the chance that a bird would be recorded more than once, observers did not record the location of any vireo <100 m from another vireo unless they could simultaneously see or hear both birds. We then used

TABLE 1—Black-capped vireo (*Vireo atricapilla*) habitat types at Fort Hood, Texas.

Habitat type	Definition
Brush pile	Ashe juniper (*Juniperus ashei*) windrow within which broadleaf shrubs grow and form a dense, bushy canopy over the windrow.
Donut	Occurs in areas used frequently by military vehicles for training activities. Characterized by multiple shrub clumps, mostly less than 20 m wide, within a network of trails created by vehicle traffic. The shrub clumps (''donuts''), which are comprised primarily of oaks (*Quercus fusiformis* and *Q. sinuata*), elbow-bush (*Forestiera pubescens*), and redbud (*Cercis canadensis*), surround one to a few large trees (i.e., the ''donut holes''), usually oaks (*Q. fusiformis* or *Q. stellata*) or cedar elm (*Ulmus crassifolia*). The donuts are maintained in a shrubby state because their margins are periodically crushed by vehicles. Occasional vehicular traffic on the trails ensures separation of neighboring donuts.
Linear	A thin band of shrubby vegetation that borders roads and trails.
Mixed	A mixture of donut and shrubland habitat types.
Shrubland	Areas where ≥50% of the horizontal vegetation coverage was woody and ≥75% of that woody coverage was 1 to 2.5 m high. Woody cover is comprised primarily of Ashe juniper, shin oak (*Q. sinuata*), redbud, and Texas ash (*Fraxinus texensis*).

vireo location data as a sample from which we determined the proportion of the Fort Hood population that occupied each habitat type. We also used location data to calculate a coarse estimate of the size of the vireo population at Fort Hood.

In 2003, observers verified habitat mapped in both 2002 and 2003. For verification, an observer other than the original observer would visit the mapped patch to confirm its location, shape, and type. All patches of mapped habitat outside of Live Fire training areas were verified by a second observer. Due to irregular access, only 14 of the 81 patches mapped in Live Fire were verified.

During 2002 and 2003, we searched 74,880 ha (85%) of Fort Hood, identifying and mapping 6,971 ha of potential vireo habitat. Most (4,859 ha; 70%) of this habitat was shrubland. We categorized lesser proportions as donut (1,080 ha; 15%) and mixed (1,032 ha; 15%) habitats. Vireos occupied 90% of the mapped habitat. Only 7% (350 ha), 18% (193 ha), and 15% (153 ha), respectively, of the mapped shrubland, donut, and other habitat types were unoccupied. We detected 1,846 adult male vireos. Most (1,081; 58.6%) occurred in shrubland habitat. Smaller percentages occurred in linear (306; 16.6%), donut (298; 16.1%), mixed (127; 6.9%), and brush pile (34; 1.8%) habitats.

Hayden et al. (2001) estimated that at least 4,170 ha of habitat would be needed to achieve the minimum population goal of 1,000 male vireos on Fort Hood, and we mapped habitat in excess of that. Only 10% of the mapped habitat was unoccupied by vireos, suggesting that most of the currently available vireo habitat on Fort Hood has been colonized, at least by territorial males. It remains unclear, though, whether occupied habitat is at carrying capacity. Thus, the growth potential of the Fort Hood vireo population remains unknown.

Furthermore, the 1,846 male vireos that we detected exceed the goal of 1,000 males stated in the endangered species management plan for Fort Hood (Hayden et al., 2001). Assuming that half of these males had a mate, Fort Hood alone would meet the previously published regional (Lampasas Cut Plains) goal of 750 breeding pairs (United States Fish and Wildlife Service, 1991). It should be noted, however, that the current Black-capped Vireo Recovery Plan (United States Fish and Wildlife Service, 1991) is under revision, and we anticipate changes to the plan, recovery units, and population goals.

Our data provide the most complete map to date of vireo habitat on Fort Hood. This map should be valuable for designing and implementing future studies of black-capped vireos and their habitat at Fort Hood by providing an explicit sampling frame from which statistically representative samples can drawn. However, because vireo habitat is often a transient, early successional stage, the results of our survey

only provide an accurate assessment of the current distribution of vireo habitat on Fort Hood. We do not know how long the results of our survey will remain reasonably accurate. Therefore, this type of survey must likely be repeated in the future.

Finally, our survey data only provide a coarse estimate of the size of the vireo population at Fort Hood. Indeed, we suspect that the vireo population at Fort Hood might be substantially larger than our survey data indicate. For example, significant expanses of habitat suitable for vireos seemed to exist within restricted access areas. Also, our survey data reveal nothing about vireo density and are inadequate for estimating the number of vireos on Fort Hood with a known level of precision. We are in the process of collecting data with which to formulate a more precise population estimate for the vireos at Fort Hood.

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