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Geographic variation in U. S. populations of the tiger beetle *Cicindela obsoleta* Say (Coleoptera: Cicindelidae)

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Abstract. Geographic variation and subspecific taxonomy of United States populations of the tiger beetle *Cicindela obsoleta* Say are reviewed. Study of primary types and 1,424 museum specimens indicates that four subspecific entities are present in the U.S., for which the valid names are *C. o. obsoleta* Say, *C. o. santaclarae* Bates, *C. o. vulturina* LeConte, and *C. o. neojuvenilis* Vogt. All four subspecies are illustrated, including many color variants. ArcView Geographic Information System (GIS) computer software is used to study the distribution of these subspecies in the United States. *Cicindela o. obsoleta* and *C. o. santaclarae* are only partially allopatric, with extensive areas in Arizona, New Mexico, and Texas where their distributions overlap. Specimens intermediate in their elytral markings between *C. o. obsoleta* and *C. o. santaclarae* are reported from localities in New Mexico and Texas where these two subspecies co-occur. In contrast, *C. o. vulturina* and *C. o. neojuvenilis* are largely allopatric and show little intergradation with the *C. o. obsoleta* - *C. o. santaclarae* complex. It has been suggested recently that disjunct (but as yet unnamed) populations of *C. o. vulturina* in Missouri and Arkansas may represent a separate subspecies of *C. obsoleta*. However, the color and elytral pattern characteristics which have been interpreted as diagnostic features of these disjunct populations are also found in many Texas populations of *C. o. vulturina*, suggesting that the Arkansas and Missouri populations do not merit recognition as a separate subspecies on the basis of these characters alone.

Introduction

Cicindela obsoleta Say is the largest species of *Cicindela* Linnaeus in North America (Pearson et al. 2006) and one of the largest species in this genus worldwide. This tiger beetle is generally distributed throughout the dry grassland ecosystems of the south-central United States, where the emergence of the adult beetles is closely associated with the onset of summer or autumn rains (Knisley 1984, Pearson et al. 2006). Adults of *C. obsoleta* are well known among tiger beetle collectors for their great agility and extraordinary evasive maneuvers, which may include straight-line escape flights of up to 100 meters (Wickham 1900, Kippenhan 1994). This species has also come to the attention of conservation biologists in recent decades: the subspecies *C. o. neojuvenilis* Vogt from southern Texas has been considered for formal protection under the U. S. Endangered Species Act, due to its rarity and the large-scale conversion of its habitat to intensive agricultural plantations (Knisley and Schultz 1997).

Cicindela obsoleta is one of the most variable tiger beetles in North America, with many populations exhibiting green, brown, black, and/or blue individuals which may be variously marked with white or yellow maculae and/or fasciae. Amidst this wealth of variation, several putative subspecific taxa have been described, largely on the basis of the shape, size, and number of the white or yellow markings on the elytra. Four subspecies of *C. obsoleta* are currently recognized from America north of Mexico (Freitag 1999). These forms have not yet been the subject of a comprehensive revision, although Cazier (1954) treated two of these subspecies in his study of the Mexican species of *Cicindela*.

The present review was prompted by statements in a recently-published field guide (Pearson et al. 2006) that the loss of type specimens had placed the identity of two of these subspecific taxa into doubt. In fact, aside from the type of Thomas Say's *Cicindela obsoleta* (which has long been assumed to have been lost, along with the rest of Say's collection; see Mawdsley 1993), the type specimens of the forms of *C. obsoleta* known from America north of México are still extant.

This paper is based on my examination of surviving primary type specimens and 1,424 additional museum specimens. On the basis of my studies of this material, I am able to confirm the traditional assessment that the U. S. populations of *C. obsoleta* can be readily classified into four subspecies. However, I also note that the group of species to which *C. obsoleta* belongs is very much in need of a thorough revision on the basis of characters beyond those of adult coloration. It seems possible that some of the taxa currently recognized as subspecies of *C. obsoleta* (specifically, *C. o. vulturina* and *C. o. neojuvenilis*) may eventually be recognized as separate species once additional information becomes available. Future revisionary studies would ideally incorporate data derived from studies of larval morphology, in-depth investigations of ecology and life history, and analyses of DNA sequences. As discussed below, more detailed studies of the Mexican forms are also needed. It is my hope that the present review, while limited in its scope, will help to inspire further investigations of these fascinating insects.

Materials and Methods

I examined pinned adult specimens of *C. obsoleta* from the following institutional collections: American Museum of Natural History, New York City, New York (**AMNH**); Carnegie Museum of Natural History, Pittsburgh, Pennsylvania (**CMNH**); Field Museum of Natural History, Chicago, Illinois (**FMNH**); Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts (**MCZC**); and National Museum of Natural History, Smithsonian Institution, Washington, D. C. (**NMNH**).

I examined primary type specimens for each of the taxa that were placed as subspecies or synonyms of *C. obsoleta* by Freitag (1999) in the most recent catalogue of Nearctic Cicindelidae. The holotype of *C. obsoleta* Say is lost (Freitag 1999; Mawdsley 1993) but I was able to locate and examine extant primary types for the taxa *C. prasina* LeConte (MCZC), *C. obsoleta* var. *santaclarae* Bates (NMNH), *C. vulturina* var. *anita* Dow (AMNH), *C. vulturina* LeConte (MCZC), and *C. obsoleta neojuvenilis* Vogt (NMNH). Full label data from each of these primary type specimens is provided under the relevant subspecies accounts below.

In addition to the primary type specimens, I also examined 1,424 additional pinned adult specimens of *C. obsoleta* in the museum collections listed above. Using the criteria of elytral color pattern which have been traditionally used to delimit subspecies in *C. obsoleta* (Cazier 1954, Werner 1993, Kippenhan 1994, Pearson et al. 2006), I attempted to assign each of the museum specimens to one of the four currently recognized subspecies, as characterized by Pearson et al. (2006).

I also compiled information on the geographic distribution of the various color forms in *C. obsoleta*. For each collecting locality for *C. obsoleta* represented in the museum collections, I recorded several attributes: number of specimens; number of specimens having each of the known types of elytral ground coloration (green, brown, black, blue); and number of specimens having each of the four elytral pattern types (which correspond in turn to the four subspecies and the one known intergrade). These data were collected in Microsoft Excel spreadsheets which were then converted into dBASE format for import into version 3.2 of the ArcView Geographic Information System (GIS) software package.

Collecting localities were assigned latitude and longitude coordinates using the U. S. Geological Survey's Geographic Names Information Service (USGS 2006). Although this method of assigning coordinates undoubtedly introduces some error at fine scales, these errors are likely not significant, given the very large geographic scale and qualitative nature of this study.

Using the ArcView Geographic Information System (GIS) software, I created separate data layers for each of the elytral pattern types, and then compared the distribution of these forms in a qualitative assessment.

Results - Taxonomy

Cicindela obsoleta Say

Cicindela obsoleta Say (1823:143) Type destroyed, but identity well established.

Diagnosis. A large to very large tiger beetle (length 13-20 mm) associated with desert grasslands and woodlands in Arizona, Colorado, Kansas, New Mexico, Oklahoma, and Texas, with isolated populations in Arkansas and Missouri. Dorsal coloration may be matte black, brown, blue, olive-green, or bright green, but never strongly iridescent. Elytral markings variable, with yellow or white maculae and/or fasciae

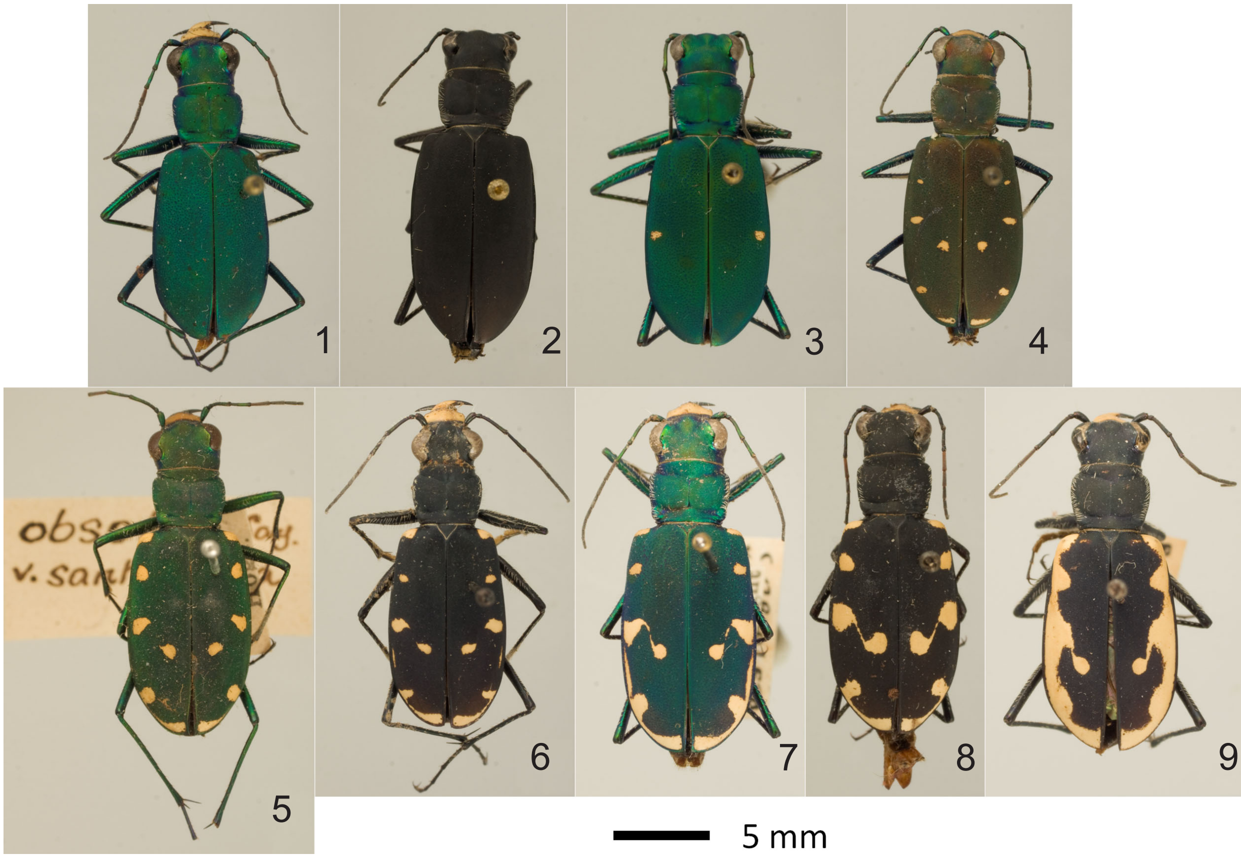

Figure 1-9. Adult habitus photographs of pinned specimens of *Cicindela obsoleta* in NMNH. **1)** *Cicindela obsoleta obsoleta* Say, male, Silver City, NM. **2)** *Cicindela obsoleta obsoleta*, female, Carrizo Creek Picnic Area, Baca Co., CO. **3)** *Cicindela obsoleta obsoleta*, male, Silver City, NM. **4)** *Cicindela obsoleta obsoleta* X *Cicindela obsoleta santaclarae*, female, Silver City, NM. **5)** *Cicindela obsoleta santaclarae* Bates, syntype female, Santa Clara, Chihuahua, México. **6)** *Cicindela obsoleta santaclarae*, male, Ft. Wingate, NM. **7)** *Cicindela obsoleta santaclarae*, female, Ft. Wingate, NM. **8)** *Cicindela obsoleta santaclarae*, female, Ft. Wingate, NM. **9)** *Cicindela obsoleta santaclarae*, male, Ft. Wingate, NM.

often present. Pronotum subquadrate, with a thin band of reclinate setae along the lateral edges of the disc.

Subspecific taxonomy. Four subspecies are recognized here, confirming the traditional taxonomic arrangement in *Cicindela obsoleta* (Freitag 1999; Pearson et al. 2006). Of the 1,424 specimens that I examined, 1,393 could be unequivocally assigned to a single subspecies on the basis of their elytral markings. The remaining 31 specimens are more or less intermediate between the two forms that have been conventionally recognized as *C. o. obsoleta* and *C. o. santaclarae* Bates. As discussed below, I interpret these forms as intergrades between these two subspecies.

Cazier (1954) reviewed the Mexican subspecies of *C. obsoleta* and recognized two additional subspecific taxa, *C. o. latemaculata* Becker from Durango and *C. o. juvenilis* Horn from Jalisco, Sinaloa, and Sonora. However, Cazier's treatment of *C. obsoleta* is limited, as it was based on material collected at just 11 localities in México (Cazier 1954). A more extensive study of the Mexican forms is needed; Murray (1979) reports the discovery of Mexican specimens which do not fit into any of the currently-recognized subspecific taxa. Even the status of the two subspecific taxa *C. o. latemaculata* and *C. o. juvenilis* can be questioned. Cazier (1954) relied on the presence of wide elytral markings to separate *C. o. latemaculata* from the other subspecies of *C. obsoleta*. However, similar markings are present in individuals from U.S. populations of *C. o. santaclarae* (e.g. Figure 7, 9). Thus, *C. o. latemaculata* may ultimately prove to be a synonym of *C. o. santaclarae*. Likewise, *C. o. juvenilis* differs from the other subspecies of *C. obsoleta* in

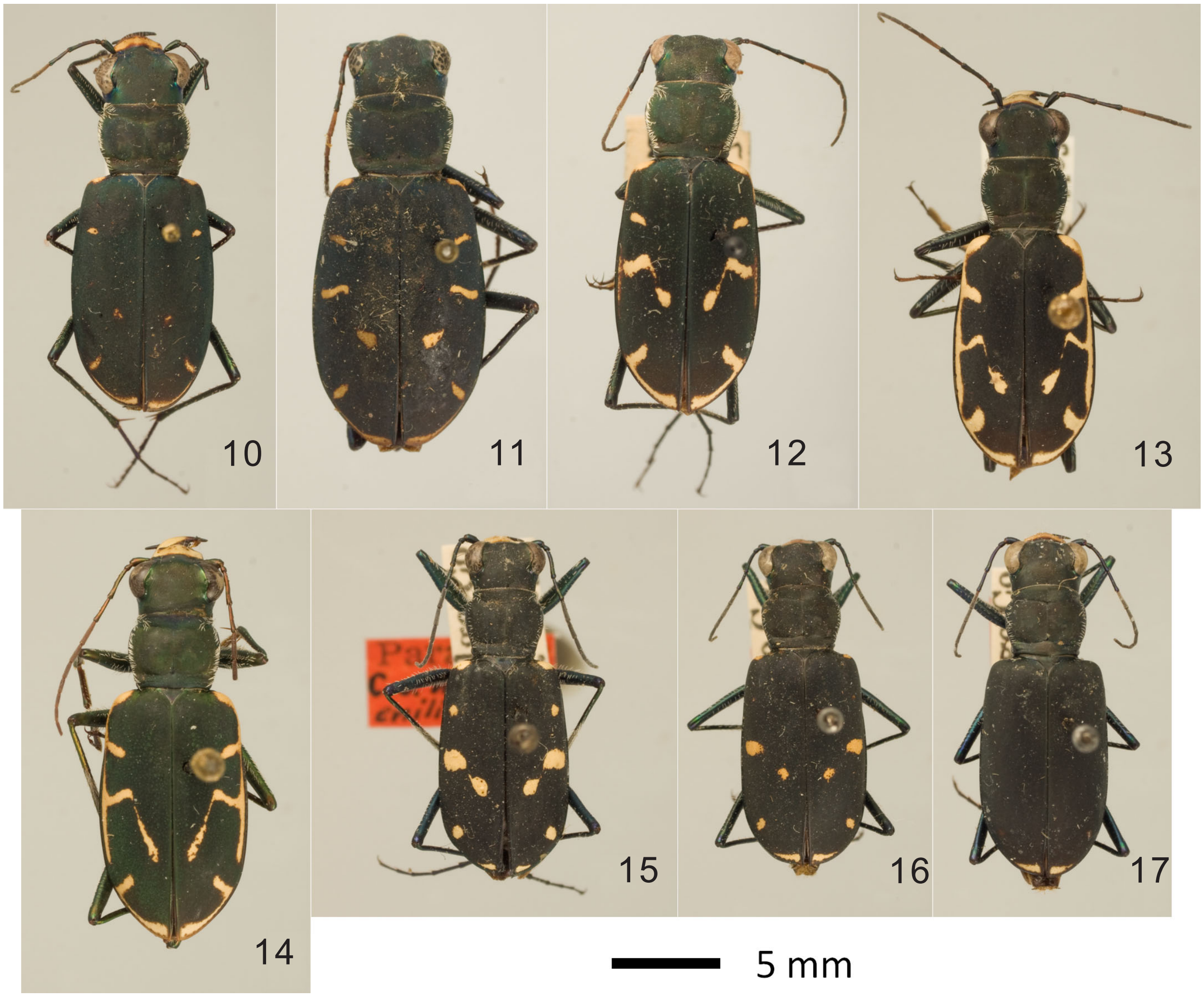

Figure 10-17. Adult habitus photographs of pinned specimens of *Cicindela obsoleta* in NMNH. **10)** *Cicindela obsoleta vulturina* LeConte, female, Cisco, TX. **11)** *Cicindela obsoleta vulturina,* female, Henrietta, TX. **12)** *Cicindela obsoleta vulturina,* male, Forestburg, TX. **13)** *Cicindela obsoleta vulturina,* male College Station, TX. **14)** *Cicindela obsoleta vulturina,* male, 2.5 miles SW Calico Rock, AR. **15)** *Cicindela obsoleta neojuvenilis* Vogt, paratype male, S. W. Hidalgo Co., TX. **16)** *Cicindela obsoleta neojuvenilis*, paratype female, S.W. Hidalgo Co., TX. **17)** *Cicindela obsoleta neojuvenilis*, paratype female, S. W. Hidalgo Co., TX.

lacking dense setae on the proepisterna and metepisterna (Cazier 1954), a significant morphological distinction which suggests that *C. o. juvenilis* may actually be a separate species. Additional material of these forms from additional collecting localities is needed in order to resolve these questions.

The following key is offered to assist in the separation of the U.S. subspecies of *C. obsoleta* Say. Users should be aware that putative intergrades between *C. o. obsoleta* and *C. o. santaclarae* have been collected in New Mexico and Texas and may also occur in Arizona (see further discussion in the section on intergrades below). These intergrades will run to *C. o. santaclarae* in this key.

Key to U.S. subspecies of *Cicindela obsoleta* Say

1. Elytra black with thin narrow yellow or white lines (Figure 10-14); fully-marked specimens with an inverted “V” at mid-elytron (Figure 12-14); central and eastern Texas and Oklahoma, with

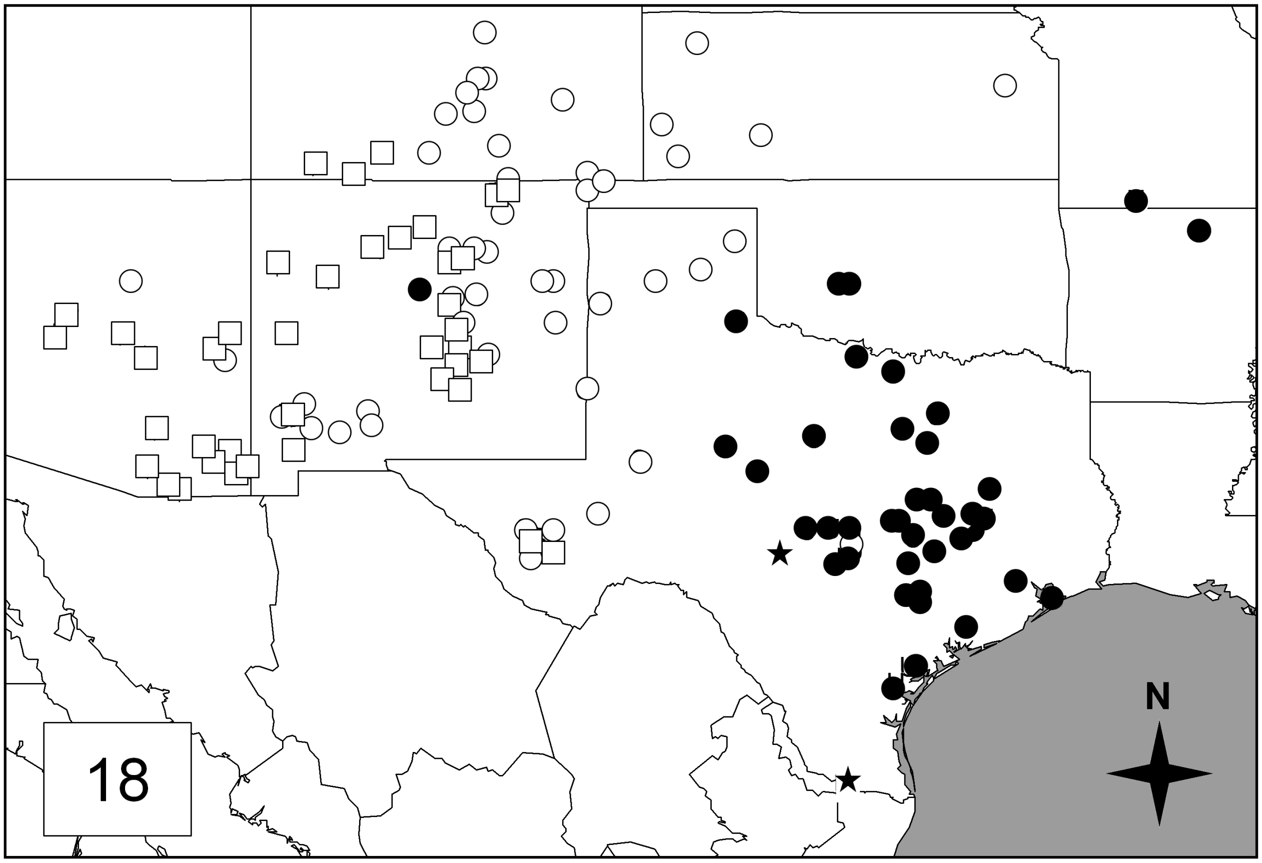

Figure 18. Collecting localities for the tiger beetle *Cicindela obsoleta* in the United States, mapped using ArcView GIS software. Open circles represent collecting localities for *Cicindela obsoleta obsoleta*; open squares represent *Cicindela obsoleta santaclarae*; closed circles represent *Cicindela obsoleta vulturina*; and closed stars represent *Cicindela obsoleta neojuvenilis*.

disjunct populations in Arkansas, Missouri, and possibly New Mexico ....
.... ***Cicindela obsoleta vulturina*** **LeConte**

— Elytral markings rounder and more robust (when present); distribution not as above **2**

2(1). Body size small (overall length 13-16 mm), associated with mesquite forests along the lower Rio Grande valley .... ***Cicindela obsoleta neojuvenilis*** **Vogt**

— Body size larger (overall length 15-20 mm), associated with grasslands in Arizona, Colorado, Kansas, New Mexico, Oklahoma, or western Texas **3**

3(2). Elytra immaculate or nearly so, with at most four small white markings (Figure 1-3) ....
.... ***Cicindela obsoleta obsoleta*** **Say**

— Elytra with more extensive and conspicuous white markings, which may be connected along the elytral margins (Figure 5-9) .... ***Cicindela obsoleta santaclarae*** **Bates**

Cicindela obsoleta obsoleta **Say**

Figure 1-3

Cicindela obsoleta Say (1823: 143) Type destroyed, but identity well established.

Cicindela prasina LeConte (1860: 31) Syntype male in MCZC, labeled with green disk, red and white label "Type 33", and handwritten J. L. LeConte label "C. prasina / Lec.", MCZ type # 33 (examined).

Diagnosis. A very large, uniformly green, black, or brown tiger beetle found in dry grasslands across the south-central United States. This subspecies usually lacks white or yellow markings but may have up to four small, round white or yellow maculae on each elytron (Kippenhan 1994).

Notes. Say's original published description refers to the black color morph of this subspecies while LeConte's description of *C. prasina* refers to the green color morph. Both forms are found in populations of this species from the high plains of the central United States, although the black forms predominate towards the northern limits of the species' range (Kippenhan 1994).

Material examined. 426 adult specimens from the following localities. **AZ:** Apache Co., White Mountains; Coconino Co., 26 miles E Flagstaff. **CO:** Alamosa Co., Alamosa; Arapahoe Co., Cherry Creek Reservoir; Baca Co., Carrizo Creek Picnic Area, Carrizo Picnic Area, Picture Canyon Picnic Area; El Paso Co., 10 miles S Colorado Springs, Camp Carson, I-25 Exit 119; Fremont Co., 6.5 km NE Canon City, Canon City, Florence; Huerfano Co., Walsenburg; Otero Co., La Junta; Pueblo Co., Pueblo. **KS:** Douglas Co.; Grant Co.; Hamilton Co.; Meade Co.; Morgan Co. **NM:** Colfax Co., 5 miles SE Maxwell, Clayton, Koehler, Koehler Junction, Maxwell, Raton Pass; Curry Co., Clovis; Dona Ana Co., Las Cruces, Radium Springs; Grant Co., Santa Clara, Silver City; Guadalupe Co., I-40 6 miles E Santa Rosa; Lincoln Co., 30 miles N Capitan, 40 miles E Corona, Lincoln; Luna Co.; Mora Co., Optimo; Quay Co., 1 mile NE Tucumcari, 1.7 miles E Tucumcari, 2 miles E Tucumcari, 2.2 miles E and 1.2 miles N Tucumcari, Tucumcari; San Miguel Co., 8 miles SE Trujillo, Las Vegas; Santa Fe Co., 1 mile S junction NM 344 and 372, 2.7 miles N Moriarty. **OK:** Cimarron Co., 3 miles N Kenton. **TX:** Blanco Co., 5 miles W Cypress Mills, Cypress Mills; Brewster Co., Alpine; Hemphill Co., Canadian; Jeff Davis Co., Davis Mountains, 6.5 miles W Fort Davis, 18 miles W Fort Davis, Nunn Hill; Gray Co., Pampa; Midland Co., Midland; Parmer Co., 10 miles N Friona; Pecos Co., 8 miles E Fort Stockton; Potter Co., Amarillo; Presidio Co., Marfa; Yoakum Co., Bronco.

Cicindela obsoleta obsoleta X *Cicindela obsoleta santaclarae*

Figure 4

Notes. Specimens which are intermediate in the extent of the white or yellow elytral markings between the forms described as *C. obsoleta obsoleta* Say and *C. obsoleta santaclarae* Bates have been collected at sites in New Mexico and Texas where these two subspecies co-occur. Given the pattern of distributional overlap between these two subspecies illustrated in Figure 18, intermediate forms might also be expected from sites in Arizona where *C. o. obsoleta* and *C. o. santaclarae* also co-occur.

Material examined. 31 adult specimens from the following localities. **NM:** Grant Co., Silver City; Lincoln Co., 2 miles N Angus, 40 miles E Corona, Lincoln; Mora Co., Optimo; Sandoval Co., Jemez Springs; Santa Fe Co., 1 mile S junction NM 344 and 372. **TX:** Jeff Davis Co., 6.5 miles W Fort Davis, 18 miles W Fort Davis.

Cicindela obsoleta santaclarae Bates

Figure 5-9

Cicindela obsoleta var. *santaclarae* Bates (1890: 493) Syntype female in NMNH labeled "Santa Clara / Chihuahua / Höge" (examined; Figure 5).

Cicindela vulturina var. *anita* Dow (1911: 271) Syntype male in AMNH, labeled "Ft. Wingate / N. Mex", AMNH type # 1205 (examined).

Diagnosis. A very large (length 15-20 mm) green, black, brown, or blue tiger beetle found in grasslands in southern and eastern Arizona, western and northern New Mexico, southwestern Colorado, and western Texas. The elytra have large, round or rectangular white or yellow markings, including humeral and post-humeral maculae, a more or less complete median band (which may, however, be broken into lateral and discal maculae), and subapical and apical maculae (Figure 5-8). In certain individuals some or all of the maculae may be joined along the elytral margin, forming a narrow or broad marginal band (Figure 7, 9).

Notes. Bates' description of *C. obsoleta* var. *santaclarae* refers to the green color morph of this subspecies while Dow's description of *C. vulturina* var. *anita* refers to the black color morph. Both forms are commonly found in U.S. populations, as are brown and blue morphs. A large series in AMNH and NMNH from Fort Wingate, New Mexico, (the type locality of *C. vulturina* var. *anita* Dow) has 31 black and 25 green individuals. I do not judge it necessary to designate a lectotype for *C. obsoleta* var. *santaclarae*, as the identity of this form is well established.

Material examined. 488 adult specimens from the following localities. **AZ:** Apache Co., 4 miles S Springerville, 5.5 miles W Eager, 9 miles NW Springerville, White Mountains; Cochise Co., 0.5 miles S of entrance Chiricahua National Monument, 1.5 miles E entrance Chiricahua National Monument, 10.4 miles NE Chiricahua National Monument, 16 miles SE Dos Cabezas, 4 miles SE Willcox, 9 miles W Montezuma Pass, 29 miles SE Willcox, 35 miles SE Willcox, 36 miles SE Willcox, Bear Canyon, Chiricahua Mountains, Chiricahua National Monument, Huachuca Mountains, mouth of Pinery Canyon, Palmerlee, Pinery Canyon 5040', Pinery Canyon 5200', Pinery Canyon 5250', Pinery Canyon mouth, west side Chiricahua Mountains; Gila Co., Payson, Sierra Ancha Mountains; Pima Co., Santa Rita Mountains; Yavapai Co., Hassayampa District, Humboldt; Pinal Co., Peppersauce Canyon, 8 miles SE Oracle. **CO:** Archuleta Co., Pagosa Junction; La Plata Co., Allison, Durango. **NM:** Catron Co., 6 miles W Red Hill, Lupa; Cibola Co., Mt. Taylor; Colfax Co., Koehler, Koehler Junction, Raton; Grant Co., Silver City; Hidalgo Co., 1 mile N Rodeo, 2.3 miles NW Rodeo, Cloverdale; Lincoln Co., 2 miles N Angus, 30 miles N Capitan, 40 miles E Corona, Lincoln, Ruidoso; McKinley Co., Fort Wingate; Mora Co., Optimo; San Miguel Co., 4 miles E Las Vegas, near Las Vegas hot springs; Sandoval Co., Bandelier National Monument, Jemez Mountains, Jemez Springs; Santa Fe Co., 1 mile S junction NM 344 and 472, 2 miles E Barton, 2.7 miles N Moriarty, 11 miles S Galisteo; Torrance Co., Mountainair, Willard. **TX:** Brewster Co., Alpine; Jeff Davis Co., 6.5 miles W Fort Davis, 18 miles W Fort Davis.

Cicindela obsoleta vulturina LeConte

Figure 10-14

Cicindela vulturina LeConte (1853: 439) Syntype male in MCZC labeled with red disk, red and white label "Type / 43," and handwritten J. L. LeConte label "C. vulturina / Schott. Lec.", MCZ type # 43 (examined).

Diagnosis. A large black or olive-green tiger beetle found in woodland areas of eastern Texas and adjacent portions of Oklahoma, with disjunct populations in Missouri, Arkansas, and possibly New Mexico. Linear white or yellow elytral markings are almost always present, but may be reduced or incomplete (Figure 10-11). The elytral markings are slender and elongate, not strongly rounded as in *C. o. santaclarae*. In more completely marked individuals, the median elytral fascia is sharply angled on disc, forming an inverted "V" on each elytron (Figure 12-14). In individuals with reduced elytral markings, the oblique, narrow line(s) at mid-elytron and/or apical third are diagnostic.

Notes. It has recently been suggested that the disjunct populations in northern Arkansas and southern Missouri may be subspecifically distinct from the nominate populations of this subspecies in Texas and Oklahoma (Pearson et al. 2006). Characters which have been suggested as diagnostic for these populations include a preponderance of olive green (as opposed to black) individuals and a large number of individuals with complete (as opposed to reduced) white elytral markings (Figure 14). However, olive green individuals can be found in a number of Texas populations, including series that I examined for this study which were collected at the following localities: 2 miles N. of Somerville, 3 miles E. of Kosse, 3.5 miles E. of Kosse, 3.5 miles S. of Alvarado, 4 miles E. of Kosse, 5 miles E. of Henrietta, 5 miles E. of Kosse, 12 miles E. of Buffalo, Calvert, Cisco, College Station, Fedor, Forestburg, Henrietta, Kosse, and Smith

Point. Moreover, most of these populations also contain representatives with fully marked elytra (Figure 13), as do populations at 2 miles SW. of Somerville, 7 miles N. of Smithville, Bastrop, Cypress Mills, and Madisonville. Furthermore, seven of the specimens that I examined from Arkansas and Missouri had incomplete markings, and Raney (2003) provides a photograph of a specimen from Arkansas with incomplete markings which is also black rather than olive-green.

Clearly these two color characters cannot be used unequivocally to diagnose the Missouri and Arkansas populations as a separate subspecific taxon. Further study of the taxonomic status of these populations is needed. Future studies should probably utilize molecular systematic approaches, which have been useful in resolving relationships among other "difficult" groups of tiger beetles (e.g. Morgan et al. 2000).

The status and distribution of *C. o. vulturina* in New Mexico also merit further investigation. Freitag (1999) included New Mexico in the distribution of this subspecies but Pearson et al. (2006) did not. There are two older specimens of this subspecies in NMNH labeled simply "N. Mex." I also examined a pair of specimens in AMNH which had been collected along U.S. Route 41 at the Santa Fe-Torrance Co. line in New Mexico. From examination of the distribution map in Figure 18, it is apparent that this locality is highly disjunct from the other known collecting sites for this subspecies. Further investigations are needed to determine whether these specimens represent a resident population.

Material examined. 478 adult specimens from the following localities: **AR:** Stone Co., 2.5 miles SW Calico Rock, 4 miles S White River. **MO:** Taney Co., Branson. **NM:** Santa Fe-Torrance Co. line, U.S. Route 41. **OK:** Comanche Co., Lawton, Wichita Mountains. **TX:** Bastrop Co., 7 miles N Smithville, Bastrop; Bell Co., Temple; Blanco Co., 5 miles W Cypress Mills, Cypress Mills; Brazos Co., 4 miles NE Kurten, College Station; Brown Co., Brownwood; Burleson Co., 0.5 miles NW Somerville, 2 miles N Somerville, 2 miles SW Somerville, 10 miles SW Caldwell; Burnet Co., 6 miles NE Marble Falls on US 281; Chambers Co., Smith Point; Childress Co., Lake Childress; Clay Co., 5 miles E Henrietta, Henrietta; Dallas Co., Dallas; Eastland Co., Cisco; Harris Co., Houston; Jackson Co., Texas Highway 35; Johnson Co., 3.5 miles S Alvarado; Lee Co., Dime Box, Fedor, Giddings; Leon Co., 9 miles W Normangee, 12 miles E Buffalo; Limestone Co., 3 miles E Kosse, 3.2 miles E Kosse, 3.5 miles E. Kosse, 4 miles E Kosse, 5 miles E Kosse, 6 miles E Kosse, Kosse; Llano Co., Llano; Madison Co., Madisonville; Mason Co., 8 miles E Mason; Matagorda Co., Palacios; McLennan Co., Cameron Park, Waco; Milam Co., Thorndale; Montague Co., Forestburg; Refugio Co., Refugio; Robertson Co., Calvert; San Patricio Co.; Tarrant Co.; Taylor Co., Abilene.

***Cicindela obsoleta neojuvenilis* Vogt**
Figure 15-17

Cicindela obsoleta neojuvenilis Vogt (1949: 4) Holotype male plus eight paratypes, NMNH; Holotype male labeled "S. W. Hidalgo Co. / Tex. H. 6-X-46 / George B. Vogt", NMNH type # 59056; Paratypes: four females labeled "S. W. Hidalgo Co. / Tex. H. 20-X-46 / George B. Vogt", one also labeled "Clearing, mes- / quite forest"; one male and two females labeled "S. W. Hidalgo Co./Tex. H. 6-X-46/George B. Vogt", male also labeled "Clearing, mes- / quite forest"; one male labeled ""S. W. Hidalgo Co. / Tex. H. 1-XII-46 / George B. Vogt" and "Roadway thru/mesquite forest" (examined; Figure 14-16). According to Bellamy (1991) the type locality for this species (which is indicated by the letter "H." on the specimen labels) is "five miles southwest of Mission, Hidalgo County, Texas."

Diagnosis. A moderately large black tiger beetle with white markings similar to those of *C. o. santaclarae* but with the body noticeably smaller in size (length only 13-16 mm) and with the elytra somewhat more slender. Several of the female paratype specimens have one or more sets of the elytral markings reduced (e.g. Figure 16 and 17), with the extreme represented by a female which lacks all markings except a small white macula at the apex of each elytron (Figure 17). The type series was collected in clearings and roadways in mesquite forests. The rounded markings, generally smaller body size, and different habitat will separate this subspecies from *C. o. vulturina*.

Notes. Very few specimens of this tiger beetle are known. Pearson et al. (2006) report it from the Rio Grande valley from Maverick County south to Hidalgo County. The specimen from Kimble County in AMNH represents both a new county record and a northern extension of the known range for this subspecies.

Material examined. 1 adult specimen in addition to the type series. **TX:** Kimble Co., 9 miles E Junction.

Results - Geographic Information System (GIS) Analysis

Figure 18 illustrates the distribution within the United States of each of the currently recognized subspecies of *C. obsoleta*, based on the specimens that were examined for this study. It is clear from Figure 18 that the forms recognized as *C. o. obsoleta* and *C. o. santaclarae* are only partially allopatric, with extensive areas of overlap in Arizona, New Mexico, and Texas. Individuals of both subspecies have been collected at fourteen sites in Arizona, New Mexico, and Texas (White Mountains, Arizona; 1 mile S junction NM 344 and 472, 2.7 miles N Moriarty, 8 miles SE Trujillo, 30 miles N Capitan, 40 miles E Corona, Koehler, Koehler Junction, Lincoln, Optimo, and Silver City, New Mexico; and Alpine, 6.5 miles W Fort Davis, and 18 miles W Fort Davis, Texas). The putative intergrades between these two subspecies were collected at eight of the fourteen sites where specimens of both subspecies were collected, and at one additional site where only adults of *C. o. santaclarae* were collected. In contrast, *C. o. vulturina* and *C. o. neojuvenilis* are largely allopatric, both with respect to each other and to the *C. o. obsoleta* - *C. o. santaclarae* complex. This latter observation could be interpreted as evidence in support of the hypothesis that these taxa actually are separate species.

The highly disjunct nature of the one New Mexico locality for *C. o. vulturina* is readily apparent from Figure 18. Further investigations are needed to determine whether this record is valid, or whether the two specimens in AMNH were somehow mislabeled as to the collecting locality. There is also a highly disjunct record for *C. o. obsoleta* in eastern Kansas, which is based on two specimens from Douglas Co. in CMNH; this record likewise requires confirmation.

Finally, there are two records of *C. o. obsoleta* in Blanco Co., Texas, which are located well within the range of *C. o. vulturina*: 5 miles W of Cypress Mills and Cypress Mills (Figure 18). These two records also require additional investigation to determine whether the records are valid or whether the specimens were somehow mislabeled.

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Literature Cited

Bates, H. W. 1890. Additions to the Cicindelidae fauna of Mexico, with remarks on some of the previously-recorded species. Transactions of the Entomological Society of London 3: 493-510.

Bellamy, C. L. 1991. Notes on the G. B. Vogt Collection, Part I: South Texas (Coleoptera & Hemiptera). Proceedings of the Entomological Society of Washington 93(3): 733-736.

Cazier, M. A. 1954. A review of the Mexican tiger beetles of the genus *Cicindela* (Coleoptera: Cicindelidae). Bulletin of the American Museum of Natural History 103(3): 231-309.

Dow, R. P. 1911. On some rare Cicindelidae (Coleop.). Entomological News 22(6): 271-272.

Freitag, R. 1999. Catalogue of the tiger beetles of Canada and the United States. NRC Research Press; Ottawa. 195 p.

Kippenhan, M. G. 1994. The tiger beetles (Coleoptera: Cicindelidae) of Colorado. Transactions of the American Entomological Society 120(1): 1-86.

Knisley, C. B. 1984. Ecological distribution of tiger beetles (Coleoptera: Cicindelidae) in Colfax County, New Mexico. The Southwestern Naturalist 29(1): 93-104.

Knisley, C. B., and T. D. Schultz. 1997. The biology of tiger beetles and a guide to the species of the South Atlantic states. Virginia Museum of Natural History; Martinsville. 210 p.

LeConte, J. L. 1853. Descriptions of some new Coleoptera from Texas, chiefly collected by the Mexican Boundary Commission. Proceedings of the Academy of Natural Sciences of Philadelphia 4: 439-448.

LeConte, J. L. 1860. Revision of the Cicindelae of the United States. Transactions of the American Philosophical Society, Second Series 11: 69-90.

Mawdsley, J. R. 1993. The entomological collection of Thomas Say. Psyche 100: 163-171.

Morgan, M., C. B. Knisley, and A. P. Vogler. 2000. New taxonomic status of the endangered tiger beetle *Cicindela limbata albissima* (Coleoptera: Cicindelidae): Evidence from mtDNA. Annals of the Entomological Society of America 93(5): 1108-1115.

Murray, R. R. 1979. The *Cicindela* fauna of Mexico: range extensions, additions, and ecological notes (Coleoptera: Cicindelidae). The Coleopterists Bulletin 33(1):49-56.

Pearson, D. L., C. B. Knisley, and C. J. Kazilek. 2006. A field guide to tiger beetles of the United States and Canada: Identification, natural history, and distribution of the Cicindelidae. Oxford University Press; New York. vii + 227 p.

Raney, H. 2003. Tiger beetles. World Wide Web document available at: http://www.hr-rna.com/RNA/Other%20insect%20pages/Tiger%20Beetle%20other%20page.htm (accessed May 21, 2009).

Say, T. 1823. Description of coleopterous insects collected in the late expedition to the Rocky Mountains, performed by order of Mr. Calhoun, Secretary of War, under the command of Major Long. Journal of the Academy of Natural Sciences of Philadelphia 3(1): 139-216.

USGS [United States Geological Survey]. 2006. Geographic Names Information System. World Wide Web document available at: http://geonames.usgs.gov/pls/gnis/web_query.gnis_web_query_form (accessed May 14, 2008).

Vogt, G. B. 1949. Three new Cicindelidae from south Texas with collecting notes on other Cicindelidae (Coleoptera). Bulletin of the Brooklyn Entomological Society 44(1): 1-9.

Werner, K. 1993. The Beetles of the World, Volume 18, Cicindelidae, Part 3, Regionis Nearcticae 1: Tribes Collyrini, Megacephalini, Cicindelini 1. Sciences Nat; Venette, France. 163 p. + 24 pl.

Wickham, H. F. 1900. Notes on some Cicindelidae from the southwestern United States. Societas Entomologica 15(11): 81-82.

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