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Conservation status of United States tiger beetles

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Summary
This study evaluates the conservation status of all of the United States species and subspecies of tiger beetles on the basis of the published literature, unpublished reports, museum and private collections, our personal field work and contact with collectors. We provide a brief summary of the status of the four species already listed and the two candidates for listing by the U. S. Fish and Wildlife Service. We indicate three taxa believed to be extinct and evaluate 62 others that we deem sufficiently rare to be considered for listing as endangered or threatened. We used a 1, 2, 3 grading system that is generally comparable to the terminology of critically imperiled, imperiled, and vulnerable designations, respectively, used in NatureServe Explorer. Fifty-two of these taxa are from the western states and Texas and most of them are named subspecies with extremely limited distributions and habitats. We assigned seven taxa a 1+ grade, our highest level of rarity and/or threats; of these there is presently sufficient information available to consider two of them-- *Cicindelidia floridana* Cartwright and *Cicindela tranquebarica joaquinensis* Knisley and Haines-- as the U. S. forms most in danger of extinction. Future prospects for conservation and listing of tiger beetles seem bleak because of the limited budget and personnel available for Endangered Species in the U. S. Fish and Wildlife Service and the current economic and political climate in the United States.

Keywords
Cicindela; conservation; endangered species; rare species; threatened species; tiger beetles

Introduction

From the passage of the Endangered Species Act in 1973 through the 1980s, there was relatively little interest and published research on insect conservation in the United States. The few insects studied for conservation efforts were primarily butterflies

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(Pyle, 1976). The earliest attempts to raise awareness of insect conservation were a review by Pyle et al. (1981) and a book by Collins and Thomas (1991). In the past 20 years, however, there has been an explosion of research and publications on rare insects including several comprehensive books (Samways, 1994, 2005; Samways et al., 2010; New, 2010, 2012), specialized insect conservation journals, and a corresponding increase in research published in a variety of journals. However, interest and research on insect conservation in the United States has paled in comparison to past and recent work being done in other countries, especially Europe and Australia. Insect listings by the U. S. Fish and Wildlife Service (hereafter,USFWS) increased from 17 endangered or threatened taxa in 1989 to 71 by 2014 (http://www.fws.gov/endangered/). Although this increase is significant and encouraging for insect conservation, it illustrates that insects are still vastly underrepresented in the list of threatened and endangered species. For example, even though insects make of 59% of all described animal species in the U.S., less than 0.1% of the 91,000 U. S. insect species are listed as endangered or threatened (http://libraryindex.com/pages/3077/-insects).

In an early review of insect conservation in the U.S., Bossart and Carlton (1992) examined insects listed by various states primarily through their Natural Heritage Programs and found that these listings often did not correspond to taxa listed as endangered or threatened by the USFWS. While information generated from the state lists remain a valuable source for considerations of listing, Bossart and Carlton (1992) found a significant taxonomic bias toward the charismatic orders such as butterflies, dragonflies, and ground and cave beetles as well as an uneven distribution and involvement of taxonomic specialists. The authors also found that some states listed few or no insects even though there was obvious justification for doing so. New (2012) cited as serious challenges for listing the need for sufficient research and data to determine which species deserve priority. Historically, entomologists associated with academic institutions have undertaken much of the research on rare species; today however a majority of entomologists specialize in agricultural or medically important insects and entomology departments have shown little or no support for studies of insect conservation.

Among the 71 U. S. insects currently listed as threatened or endangered, 30 are Lepidoptera and 18 Coleoptera, two orders that include popular and charismatic insects that are widely collected and studied by amateurs or non-professional entomologists (http://www.fws.gov/endangered/). Tiger beetles, which belong to the carabid subfamily Cicindelinae, are well represented on the list; *Cicindela ohlone* Kavanaugh and Freitag and *Ellipsoptera nevadica lincolniana* Casey are endangered, *Habrosceliomorpha dorsalis dorsalis* Say and *C. puritana* G.H. Horn are threatened, and *Cicindela albissima* Rumpp and *Cicindelidia highlandensis* Choate are candidates for listing. However, as many as 33 of the 223 (15%) named forms were reported to be declining or sufficiently rare to be considered for listing by the USFWS (Pearson et al. 2006). In addition to their being well studied and having broad appeal for entomologists and amateurs, tiger beetles have been recognized as an important conservation focus group because of their value as indicators of habitat quality (Knisley and Schultz, 1997; Knisley, 2011) and of biodiversity (Pearson and Cassola, 1992). For insects, species and subspecies may be eligible for listing and is based on the following criteria established by USFWS: 1. Present or threatened destruction, modification or reduction in range; 2. Overutilization for commercial, scientific, recreational or educational purposes; 3. Disease or predation; 4. Inadequacy of existing regulatory mechanisms; 5. Other natural or manmade factors affecting its continued existence. Interestingly, while the six tiger beetles species listed above include a wide range of these criteria, one of the documented factors— rarity— is only implied in the criteria. Although other insects have been approved for listing, some of them have not received official sanction because other species deemed "higher priority" displaced them in status. Prioritization is based on 12 criteria including level and immediacy of the threats and taxonomy.

The objective of our report is to expand upon and update information on tiger beetle conservation found in Knisley and Schultz (1997) and Pearson et al. (2006), as well as the NatureServe Explorer website (http://explorer.natureserve.org) by providing detailed and current information on all U. S. tiger beetles we consider rare.

Methods

In this study we evaluated the conservation status of all 109 species and 111 subspecies (three subspecies found only in Canada are not included) of U.S. tiger beetles included in Pearson et al. (2006) using information obtained from various sources. We relied on published literature, unpublished reports, records compiled from museums and individual collections, and our own records and notes from a combined nearly 100 years of collecting, research and interacting with professional and amateur tiger beetle workers and collectors. The first author has conducted extensive research on many of the rare U. S. tiger beetle species including systematic surveys of the distribution and abundance for some forms (see below). All three authors have extensive field experience studying tiger beetles and their habitats throughout the U. S.

To develop a consistent ranking of tiger beetle conservation status we examined the tiger beetle accounts in the NatureServe Explorer data base. This website uses the following definitions for conservation status: 1-- Critically Imperiled are those forms with a very high risk of extinction, restricted range, few populations and severe threats; 2-- Imperiled forms are those with more known sites but at a high risk of extinction, significant threats and recent declines; and 3-- Vulnerable forms at a moderate risk of extinction, with evidence of decline or threats. The website suggests that these grades should not be used to advocate listing by the USFWS, but rather to provide information useful for evaluating taxon rarity. We found that for many taxa, the NatureServe Explorer data are appropriate and consistent with our own findings; however, for other taxa for which we have more complete and/or recent information a different or finer division of status was used. Our system of evaluation uses the same number grading scale but also includes pluses and minuses to more fully define rarity and apparent risk of extinction. Examples of our grading system are as follows: A 1 would be comparable to the NatureServe grade of 1, usually with five or fewer known populations and significant threats; a 1+ would be at the upper range of these factors and 1- at the lower range. A 2 would be roughly comparable to the NatureServe Explorer grade of 2 with

6-20 existing sites and significant threats or impacts. A 3 would be comparable to the vulnerable designation with usually more than 20 sites or populations and some evidence of decline and/or threats.

Our grading system considered the number of sites and populations, as well as population size, habitat impacts and evidence of decline from past and recent site visits. Consequently, a form with greater decline or threats and small population sizes could be assigned a higher grade of rarity than site numbers alone would indicate. Through our field work and contact with collectors we also considered the extent of searching for the various taxa, recent search results and the likelihood of additional populations being found. Although we considered all key factors used by the USFWS, some or much of this information was limited, lacking or anecdotal for many species for which extensive surveys have not been conducted. We do not include those species or subspecies that are listed only in one state if they are more abundant and secure throughout their full range.

Taxonomic considerations

In addition to the species and subspecies included in Pearson et al. (2006) we also included some of the forms that some specialists do not consider valid subspecies. Historically, the criteria for describing tiger beetle forms has been quite variable and newer taxonomic approaches such at genetic analysis utilizing mtDNA or other genetic markers will be necessary to fully resolve many of the taxonomy challenges. It could be argued that while some taxa may eventually be confirmed not to represent valid subspecies, they may carry distinct genetic traits that contribute to the genetic diversity of the species, and as such are valuable to protect. Consequently, we believe it is important to include information on their rarity status regardless of the outcome of future taxonomic studies.

Historic and recent collection records

Our compilation of records from museum and individual collections was critical for reliably determining distribution and abundance of each taxon. For instances, these collecting records were instrumental in determining the extirpation of *C. hirticollis abrupta* Casey (Knisley and Fenster, 2005), the loss of *C. p. patruela* in Maryland (Mawdsley, 2005), and the loss of several species from historic sites in New York (Schlesinger and Novak, 2011). However, collection records may be fragmentary and present an incomplete or misleading picture of the historic and current range of a taxon. For example, because collecting efforts by early workers often were restricted by transportation and road access to many sites, large inaccessible areas were not surveyed. In more recent years, many records have been provided by collectors and amateurs who may be most interested in acquiring specimens for their collection and thus visit known localities rather than seeking out new sites. Another serious limitation is that increasingly, areas once open to collecting are becoming off limits due to landowners not allowing access and/or increasing legal restrictions to collecting insects in state and national parks and other public lands. Consequently, unless specimens can be identified by photographs it is now practically impossible to accurately determine the distribution of most taxa. Also, some forms are seldom collected and are considered rare because they are difficult to find or have highly ephemeral activity. For example, many of the southwestern tiger beetles will be active for only a few days or a week after significant rainfall. Detectability may also be a problem because many forms are highly restricted to small patches of seemingly identical habitat.

Examples of more complete surveys yielding significantly expanded distribution include: *Ci. highlandensis* which was known from only two sites when described by Choate (1984), but after extensive surveys from 1992-1996 it was found at 38 sites with the range extended 100 km to the north (Knisley and Hill, 2013). Similarly, when described, the only records for *C. p. huberi* W. N. Johnson were three small sites, but more extensive surveys by Willis (2000, 2001) found it at an additional 32 sites. The Federally Threatened *H. d. dorsalis* was initially known from only 17 sites within the Chesapeake Bay (Knisley et al., 1987) but after listing and subsequent extensive surveys supported by the USFWS, it was found at over 90 sites in Virginia and Maryland (Roble, 1996; Knisley et al., 1998; Knisley, 1999). The systematic surveys needed to establish the aforementioned species' actual distribution are representative of the data central to meeting the criteria for evaluation and possible listing as Threatened or Endangered by the USFWS which often provides funding for surveys.

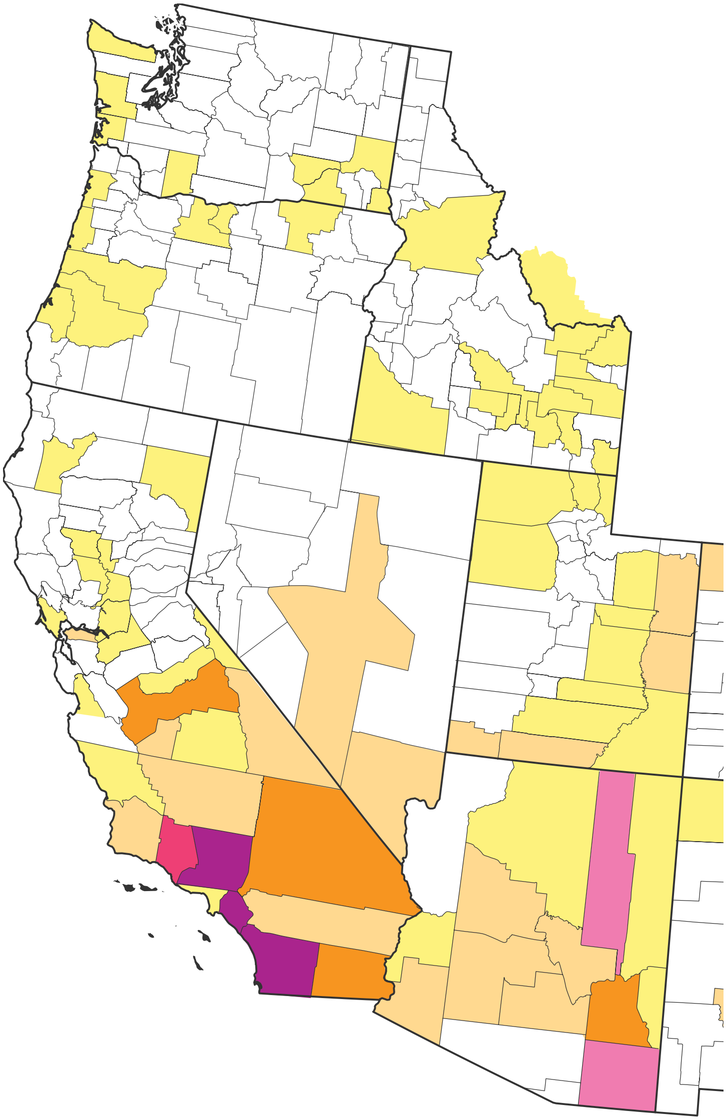
Results

Overview of rare species

The results of our study presented below include accounts of the three taxa considered to be extinct, four taxa currently listed as endangered or threatened and two candidates for listing by the USFWS and 61 other forms we determined are sufficiently rare to merit consideration for listing. The taxa we discuss are organized by state or geographic region. Forty-three of these are from the western U. S., including 18 from Arizona and New Mexico, 13 from California, and 12 from the other western states; another nine taxa occur in Texas (Map 1). Only nine taxa occur in the rest of the U. S., three in Midwestern states and six from the eastern third of the U. S. The high proportion of rare taxa in the west is not surprising since this U. S. region with the highest tiger beetle diversity and endemism (Willis, 1972). In the discussion below we provide for each taxon the grade which we assigned and the corresponding NatureServe grade in parentheses and a summary of relevant factors some included in Table 1 which we used in our determination. Also included are photos of representative taxa and maps showing the county level distribution for the western taxa.

Extinct taxa

The results of this study determined three U.S. tiger beetle taxa are extinct— *Cicindela chlorocephala smythi* E.D. Harris, *C. hirticollis abrupta* Casey, and *C. latesignata obliviosa* Casey. The only known collection record for *C. chlorocephala smythi* was a



Map 1. Distribution of rare tiger beetles in the western United States. Colors/grids indicate the total number of taxa (see legend) per county. This map is published in color in the online version.

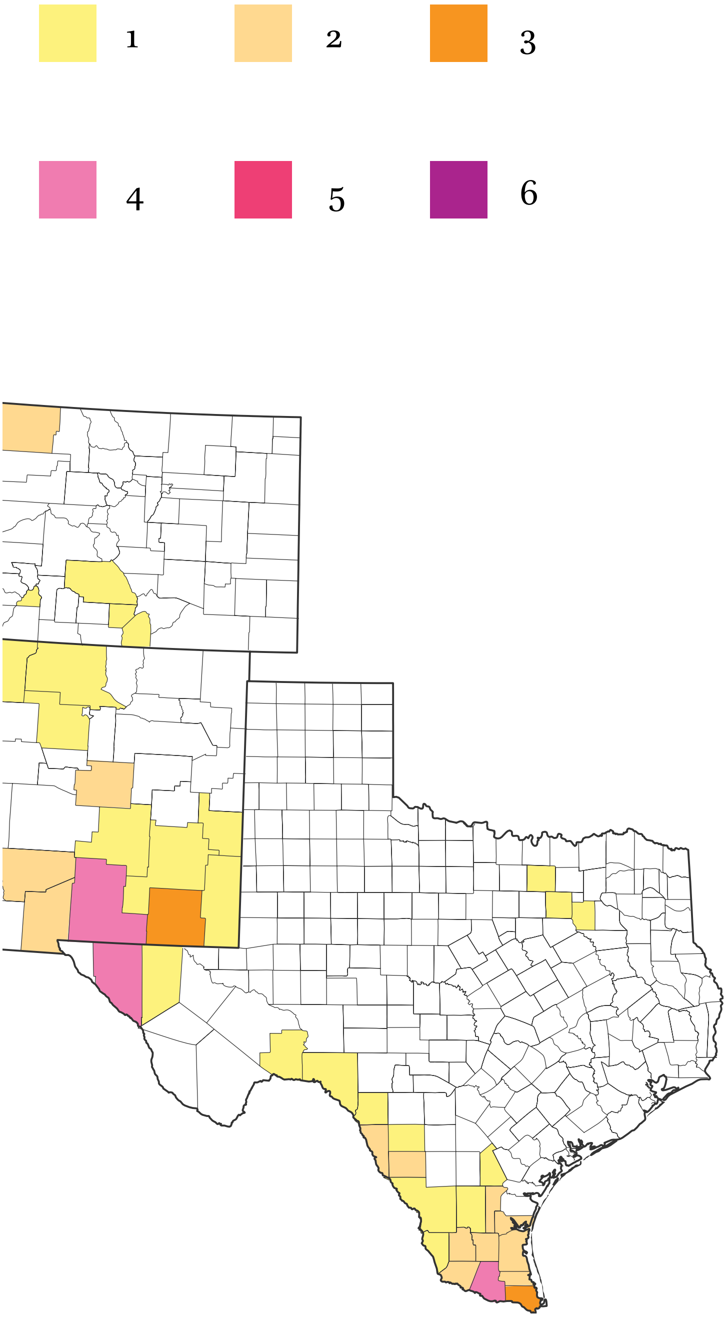

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Table 1. Relevant factors considered in determining rarity for all U. S. tiger beetles discussed in this paper. Endemism: HE = highly endemic, ME = moderately endemic; W= widespread.

Taxa	Our rarity grade	TNC grade	Habitat	Endemism	Historic and current counties	Pre-1990 sites	Post-1990 sites	Probability of new sites	Recent level of search	Threat factors
Arizona and New Mexico										
E. nevadica citata	1	3	playa, saline	HE	1	<5	<3	low	high	endemic, few sites, water level change
Ci. willistoni sulfontis	1	1	playa, saline	HE	1	<5	<3	low	high	endemic, few sites, water level change
H. fulgoris erronea	2+	1	playa, saline	HE	1	<10	<5	1ow	high	endemic, few sites, water level change
C. pimeriana	2	3	chalky, clay banks	HE	1	<10	<5	moderate	moderate	endemic, few sites, specific habitat
C. hirticollis coloradula	2+	1	riparian	HE	1	<5	2	moderate	high	endemic, water level changes?
C. hirticollis corpusculata	2	2	riparian	W	10	25	<10	high	moderate	river flow reductions, agriculture
H. praetextata praetextata	1–	2	riparian, saline	W	7	10-20	<5	low	moderate	riparian devpt, reduced flows, agric.
C. tranquebarica cibecuei	2	nr	riparian	ME	2	<5	<5	moderate	high	endemic, riparian impacts, orv. activity
E. nevadica tubensis	3	2	water edge, often saline	W	14	10-20	<10	high	moderate	riparian devpt, reduced flows, agric.
C. formosa rutilovirescens	2–	nr	sand dunes, blowoutw	ME	7	15	25	high	high	invasive vegetation
C. fulgida rumpii	2+	nr	playas, saline	HE	1	<5	<5	low	high	endemic, water level changes

(*Continued*)

Table 1. (*Cont.*)

Taxa	Our rarity grade	TNC grade	Habitat	Endemism	Historic and current counties	Pre-1990 sites	Post-1990 sites	Probability of new sites	Recent level of search	Threat factors
Ci. willistoni estancia	1–	1	playas, saline	HE	1	<5	<5	low	high	endemic, water level changes
Ci. willistoni funaroi	1	2	playa, saline	HE	1	<5	<5	low	high	endemic, water level changes
H. fulgoris albilata	1	3	playas, saline	HE	2	2	2	very low	high	endemic, water level changes
E, nevadica olmosa	2+	2	playa, saline	ME	4	7	<10	low	moderate	water level changes, grazing
Eu. togata fascinans	2	4	playas, saline	HE	4	<5	<5	low	moderate	endemic, water level changes
Ci p. petrophila	2–	3	limestone outcrops	HE	2	<5	<10	moderate	high	none known
Ci. politula barbarannae	3	3	limestone outcrops	W	4	<10	10-15	high	high	none known
CALIFORNIA										
H. gabbi	1–	4	coastal beaches, marshes	ME	4	11	4	low	moderate	coastal development, recreational use
C. latesignata latesignata	1–	1	coastal beaches	ME	3	16	4	low	moderate	coastal development, recreational use
Ci. hemorrhagica pacifica	1	5	cliff faces, back beach	ME	5	4	4?	low	moderate	coastal development, recreational use
C. hirticollis gravida	2–	2	ocean beaches	W	8	36	7-10	low	moderate	coastal development, recreational use
*Ci senilis frosti**	1–	1	coastal, inland marshes	ME	6	9	<5	low	high	coastal development, recreational use

(*Continued*)

Table 1. (*Cont.*)

Taxa	Our rarity grade	TNC grade	Habitat	Endemism	Historic and current counties	Pre-1990 sites	Post-1990 sites	Probability of new sites	Recent level of search	Threat factors
Ci. trifasciata sigmoidea	3+	3	coastal marshes, mudflats	ME	5	ca 10	8-10?	moderate	moderate	coastal development, recreational use
Ci. a. amargosae	2–	2	moist saline grasslands	ME	2	6	6	low	moderate	unknown
Cy lunalonga	1–	1	alkali,saline, grasslands	W	>25	17-20	13	low	high	agriculture, water changes, urban development
Cy. terricola continua	1–	3	alkali grasslands, meadows	ME	5	<6	0	moderate	moderate	water level reduction
Cy. t. susanagree	2–	nr	alkali wetlands, water edges	ME	2	20-25	10-15	moderate	moderate	water level reduction, agriculture
C. tranquebarica joaquinensis	1+	1	alkali sinks	HE	4	12	3	low	very high	endemic, agric., water level change
C. tranquebarica viridissima	1+	1	floodplain, orchards	ME	4	8-12	1-2	moderate	high	Urbaniz., other development
Omus submetallicus	1–	3	canyon woodlands	HE	1	2	2	moderate	high	future land use change
Colorado, Utah, Idaho										
C. formosa gibsoni	2	1	sand dunes	ME	1	<15	<15	moderate	high	dune succession, grazing, agriculture
C. scutellaris yampae	1–	1	sand dunes	HE	1	<10	<5	moderate	high	dune succession, grazing, agriculture

(*Continued*)

Table 1. (*Cont.*)

Taxa	Our rarity grade	TNC grade	Habitat	Endemism	Historic and current counties	Pre-1990 sites	Post-1990 sites	Probability of new sites	Recent level of search	Threat factors
C. theatina	2–	1	sand dunes	HE	3	5	<5	low	moderate	Unknown
H. praetextata pallidofemora	1	1	riparian, saline	ME	2	5?	3?	moderate	moderate	riparian devpt, reduced flows, agric.
C. decemnotata bonnevillensis	2	nr	Low sage, sand flats	HE	1	15-20	<15	moderate	moderate	Endemic, invasive veg
C. d. montevolans	2–	nr	Montane, sagebrush	ME	4	23	<20	moderate	moderate	Possible recreation
C. arenicola	2	1	sand dunes	ME	12	>20	<20	moderate	high	Agric., invasive sp.
C. waynei	1+	1	sand dunes	HE	1	1	1	very low	high	invasive vegetation, collectors
C. columbica	2	2	riparian	ME	8	10-15	<10	low	high	dams, water level changes
WASHINGTON, OREGON										
C. bellisima frechini	1	1	sandy coast beaches	HE	1	<5	<5	low	moderate	unknown
C. hirticollis siuslawensis	2	1	sandy coast beaches	NE	7	>20	18	moderate	moderate	recreation beach activity
Omus cazieri	2	2	mixed conifer forest	HE	1	<5	<5	high	high	future land use changes
Great Plains										
Cy. celeripes	3	3	grasslands	W	16	>25	14	high	moderate	agriculture, invasive vegetation
H. circumpicta. pembina	1	2	saline, playas	HE	2	<5	<5	low	high	succession, vegetation encroachment

(*Continued*)

Table 1. (*Cont.*)

Taxa	Our rarity grade	TNC grade	Habitat	Endemism	Historic and current counties	Pre-1990 sites	Post-1990 sites	Probability of new sites	Recent level of search	Threat factors
E. nevadica makosika	1	1	riparian saline	HE	1	2	2	high	low	cattle grazing
TEXAS										
Ci. obsoleta neojuvenalis	1+	1	grassland, scrub	HE	2?	1	1-3	low	high	endemic, urbanization, agriculture
Ci. nigrocoerulea subtropica	1+	2	moist patches, grassland	HE	2?	6	0-3	moderate	high	endemic, urbanization, agriculture
E. nevadica olmosa	1	2	coastal, saline creeks	ME	4	4	2	moderate	high	coastal development
Ci. cazieri	2+	2	limestone, mesquite	HE	2	6	<5	high	high	endemic, agriculture, possibly grazing
Amblycheila hoversoni	3+	3	mesquite woodlands	ME	14	14	14	high	high	unknown, possibly agric. dev.
Dromochorus velutinigrens	2+	3	grasslands, woodlands	ME	3	3	3	moderate	high	unknown, possibly agric. dev.
E. macra ampliata	2	4	riparian	HE?	3	10	<10	moderate	moderate	urban development, water level change
C. formosa pigmentosignata	2	5	open forests, sand blows	ME	14	20-30	<10	moderate	moderate	urban development, habitat conversion, succession
Tetracha impressa	2	4	wet, damp areas, nocturnal	HE	2	<5	<5	high	moderate	urban development, agriculture

(*Continued*)

Table 1. (*Cont.*)

Taxa	Our rarity grade	TNC grade	Habitat	Endemism	Historic and current counties	Pre-1990 sites	Post-1990 sites	Probability of new sites	Recent level of search	Threat factors
EASTERN										
Ci. floridana	1+	nr	pine rockland	HE	1	4	3	low	high	vegetation encroachment, urban development
Microthylax olivacea	1+	3	coral rock beaches	HE	1	8	0?	low	high	shoreline development
C. patruela patruela	3	3	moist saline grasslands	W	>25	>50	>40	high	moderate	land use changes, succession, fire suppression
C. p. consentanea	1–	2	pine barrens	ME	11	36	<10	moderate	moderate	fire suppression, succession, land use change
Ci marginipennis	2–	2	river gravel bars and edges	W	>15	20-30	>20	high	high	riparian devpt, reduced flows, agriculture
Ci. rufiventris hentzi	2	1	granite hills, woodlands	HE	4	15-20	10-20	moderate	unknown	urbanization, land use change

large series (80 specimens) taken on South Padre Island, Texas in 1913. Pearson et al. (2006) suggest this species may have been lost from the area by a series of large and destructive hurricanes from 1912 to 1919. Support for this hypothesis is evidence that hurricanes and shoreline erosion have eliminated sandy beach habitat and populations of *H. dorsalis* in the Chesapeake Bay and along the north Atlantic Coast (USFWS, 1993). Because no other U.S. records are known for this taxon, it is uncertain if the south Texas coast was part of its historic range or only a transitory site. The second taxon, *Cicindela hirticollis abrupta*, is a more recent extinction. Extensive surveys including all historic sites as well as potential sites throughout its historic range along the Feather and Sacramento Rivers in central California failed to locate any specimens (Knisley and Fenster, 2005). The presumed cause of its extinction was the loss and disruptions to point bar habitats along these rivers after construction of the Oroville and Shasta dams (Fenster and Knisley, 2006). Water level disruptions from the dams resulted in loss, reduction or prolonged inundation of point bars, changes in sand grain size, and vegetation encroachment. The other taxon considered extinct is, *C. latesignata obliviosa* Casey, but most workers do not consider this a valid subspecies.

Listed species

There is a significant range of rarity (numbers of sites and populations, area occupied) and threats for the four listed and two candidate tiger beetle taxa (Table 2). While we believe all are in need of listing, there are many other species equally or perhaps more worthy of listing based on the same criteria. The "least rare" of those USFWS listed taxa is *H. d. dorsalis*. This subspecies experienced an extensive range wide decline since the early 1900's, having been extirpated from all but one historic site from New Jersey to Massachusetts (Knisley et al., 1987). After listing, extensive surveys in the 1990s found it at over 90 sites within the Chesapeake Bay of Virginia with estimated adult numbers of over 60,000 (Knisley et al, 1998, Knisley and Hill, 1999). However, surveys within the past five years have found populations have been lost or declined significantly from many sites (Knisley, 2012a). In stark contrast *C. albissima* has only one population of <2000 adults that restricted to a small portion (<3 km^2) of the Coral

Table 2. Rarity indicators for United States listed and candidate tiger beetles.

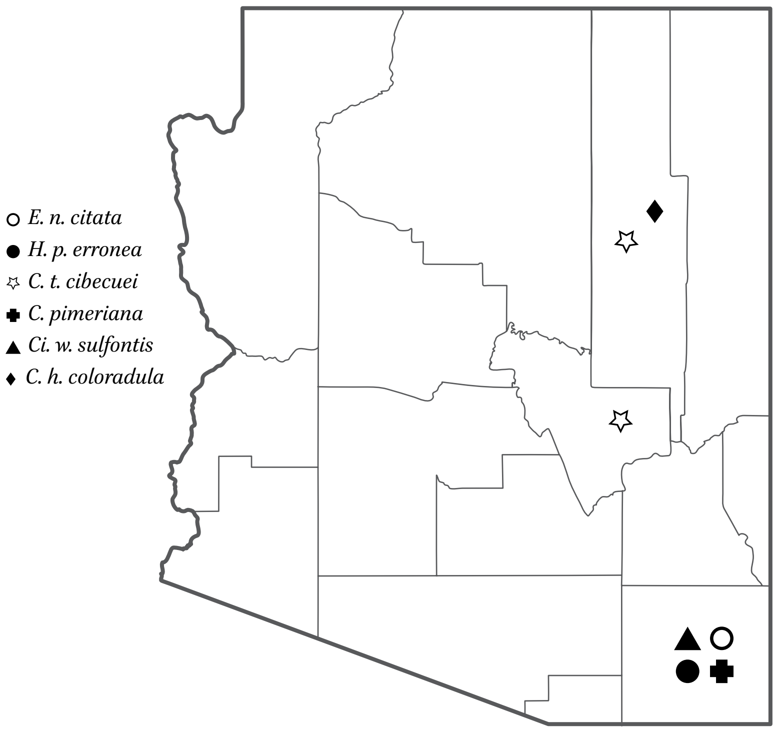
Taxa	No. of sites	No. of metapop	Recent total numbers	Rangewide threat level
H. d. dorsalis	70	unknown	55000	moderate
C. puritana	17	4	6500	high
E. nevadica lincolniana	3	1	315	high
C. ohlone	7	7	300-1000	high
C. albissima	1	1	1400	high
Ci. highlandensis	39	unknown	3000-4000	low-moderate

Pink Sand Dunes of southern Utah) (Gowan and Knisley, 2014) and *E. nevadica lincolniana* which currently occurs at only three small sites with < 500 total adults counted (S. Spomer, personal comm.). Additional threats to these taxa are the disruption of some of the habitat of *C. albissima* by recreational OHV use and the small amount of protected habitat for *E. nevadica lincoliana*. *Cicindela puritana* was lost from all but two sites along the Connecticut River and has experienced decline at sites within the Chesapeake Bay (Vogler et al., 1993; Knisley, 2012b). Similarly, *C. ohlone* has been lost from several sites in recent years and is now known from only seven sites within its very limited range and specialized grassland habitat of Santa Cruz County, California (Knisley and Arnold, 2013). In contrast to the above species that have experienced decline since listing by the USFWS, *Ci. highlandensis* has improved in recent years as a result of additional Florida sites being protected as well as implementation of fire and other management options to create additional suitable habitat (Knisley and Hill, 2013, Cornelisse, 2013; Cornelisse et al. 2013).

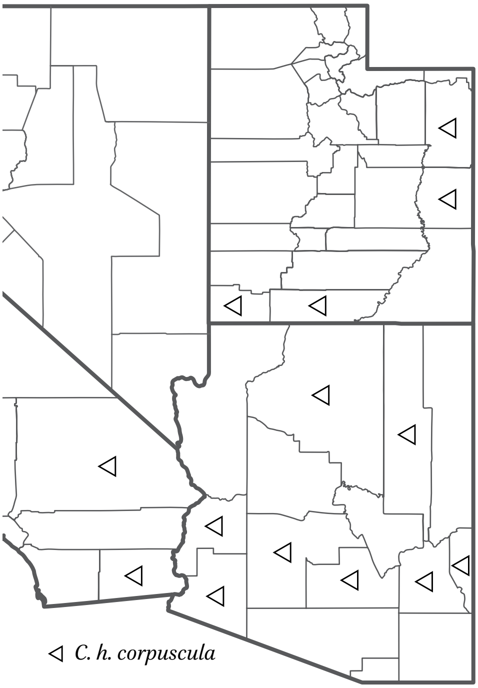
Species accounts

Arizona and New Mexico (Maps 1-6)

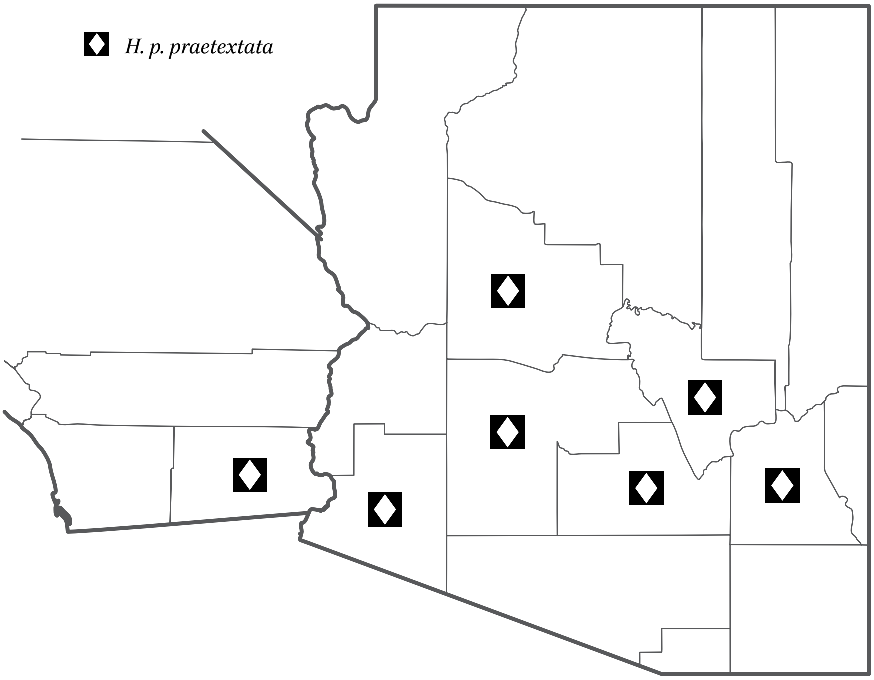
Both of these states have especially rich cicindelid faunas (40+ taxa in each state) and correspondingly a large number of rare species. Most of the nine rare taxa in Arizona



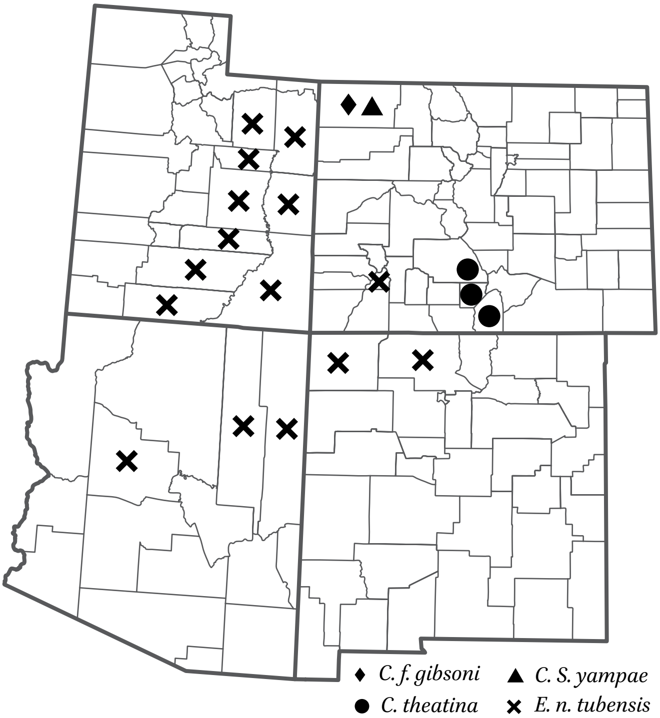
Map 2. Distribution of rare tiger beetles in Arizona.



Map 3. Distribution of *Cicindela hirticollis corpusculata*.



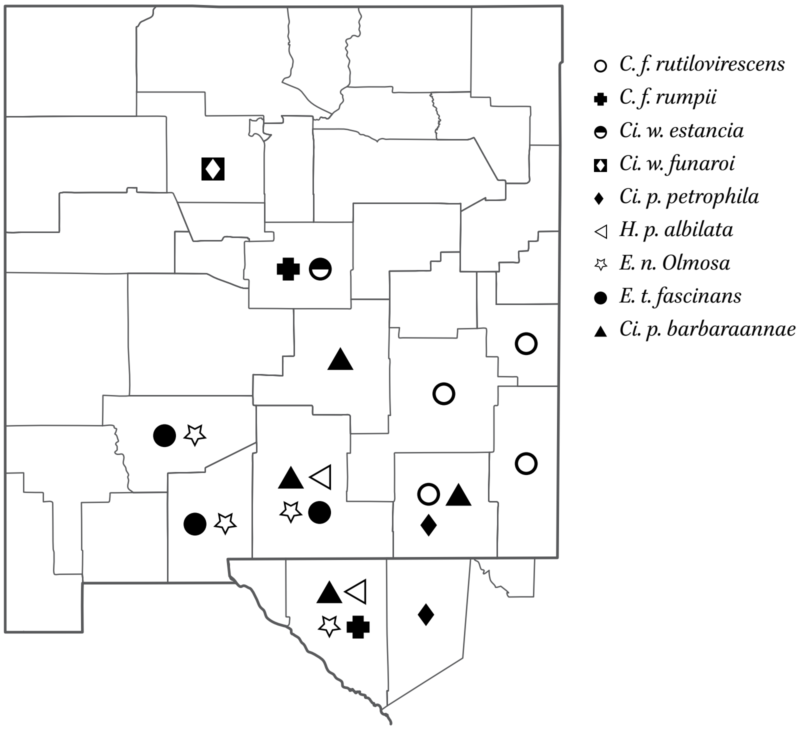
Map 4. Distribution of *Habrosceliomorpha praetextata praetextata*.



Map 5. Distribution of *Ellipsoptera nevadica tubensis, Cicindela theatina, C. formosa gibsoni, and C. scutellaris yampae*.

(Maps 2, 3, 4, 5) and ten in New Mexico (Map 6) are endemics confined to highly restricted microhabitat types that are susceptible to water table lowering, river flow changes, and other human impacts.

Ellipsoptera nevadica citata Rumpp, *Cicindelidia willistoni sulfontis* Rumpp, and *Habrosceliomorpha fulgoris erronea* Vaurie are all endemic forms restricted to the area in and around the Willcox Playa in southeastern Arizona (Rumpp, 1977). *Ellipsoptera n. citata* (Fig. 1A) 1 (3), listed as S1 in Arizona, is undoubtedly the rarest of the three and has been infrequently collected and thus is rare in collections. During seven summers (1979 to 1987) when the first author was studying tiger beetles in the Willcox area (Knisley, 1987), *E. n. citata* was found only at three locations and less than six times, always in very low (<20 individuals) numbers. This is due in part to its ephemeral adult active period; adults were active in muddy water edge sites for only a few days after significant rainfall. The only known site with a large population was along the edge of the playa; two smaller sites were along the edge of permanent ponds south of Willcox. Many specimens from the type series were collected from one of these pond edge sites (Rumpp, 1977). Subsequently, these pond edge sites have experienced increased vegetation encroachment and other changes that have eliminated these as suitable habitats. Although the lack of records for this species may be due, in part to its ephemeral activity, the limited availability of its preferred habitat is important evidence for its rarity.



Map 6. Distribution of rare tiger beetles in New Mexico and west Texas.

Cicindelidia willistoni sulfontis (Fig. 1B) 1 (1), also listed as S1 in Arizona, was studied during the same period indicated above for *E. n. citata*. During that time adults were relatively common and present in all years at three separate areas, all within a few km^2 area along the southeastern and south edges of the Willcox Playa. The only large site with a consistent presence of adults and relatively abundant larvae was along the northeastern edge of the playa floor where water accumulated during the summer monsoons. A large population of larvae was present and studied during this period (Knisley and Pearson, 1981). Rarely, a few adults were found south and east along the edges of small temporary ponds close to the playa edge. Rumpp (1977) had nearly 100 specimens in the type series collected on one date in 1969 from the playa site, but information from collectors visiting that site in recent years indicates most have found few or no individuals.

Habrosceliomorpha fulgoris erronea (Fig. 1C) 2+ (1), listed as S3 in Arizona, is also endemic to the Willcox Playa and has been found at 10-15 sites, primarily the edges of temporary and permanent ponds within a few km of the edge of the playa. Many of these sites are apparently used only by adults for foraging and do not support larvae since most dry up after the summer monsoon period, and as a result there is little prey to support larval development. The only site where the first author found and studied a population of larvae was along the playa edge where it co-occurred with *Ci. w. sulfontis* (Knisley, 1987). At this site the water table is near the surface and provides permanent

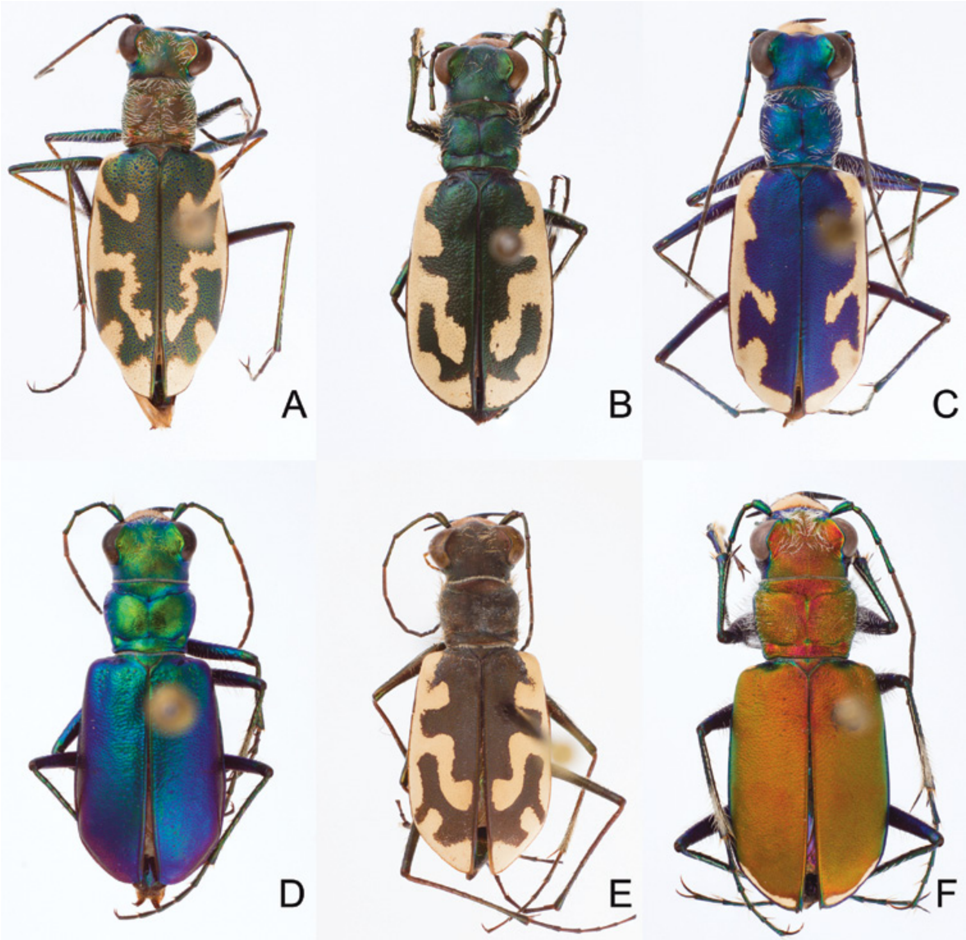


Figure 1. Dorsal view of rare tiger beetles. A. *Ellipsoptera nevadica citata*, B. *Cicindelidia willistoni sulfontis*, C. *Habrosceliomorpha fulgoris erronea*, D. *Cicindela pimeriana*, E. *Cicindela hirticollis* corpusculata, F. *Cicindela formosa rutilovirescens*. This figure is published in color in the online version.

moisture for larvae throughout the year. Information from collectors and several visits by us in recent years indicated that like *Ci. willistoni sulfontis*, *H. fulgoris erronea* is much less common than several decades ago. These three playa subspecies may be negatively impacted by a lowering of the water table due to irrigation for orchards and other agricultural crops that have expanded greatly in the surrounding valley since the late 1970s.

Cicindela pimeriana LeConte 2 (3) (Fig. 1D) listed as S3 in Arizona is restricted to a few sites in Cochise County of southeastern Arizona and possibly into Mexico (Rumpp, 1977). It is a solitary species that has been found most often near the Willcox Playa on chalky, clay banks and in low numbers. We have seven sites from this area and another two from further south in the San Bernadino Valley near the Mexican border. Extensive surveys for this species have not been done, and we have no evidence of habitat loss, but we include it here because of its limited range, few sites, and apparently very specific habitat requirements.

Cicindela hirticollis coloradula Graves 2+ (1) has a limited historic range, known only from along the Little Colorado River upriver from the Grand Canyon in northeastern Arizona. All records are from accessible areas of the river at Holbrook, Winslow and Joseph City, Navajo County (Graves et al., 1988). Additional populations along the river may exist and extend the known range, but access is limited and apparently little searching has been done beyond the known sites. A population collected from near Canyon de Chelly, Apache County in the 1980s seems to match this subspecies although confirmation is needed since that population is quite disjunct (T. Schultz, personal communication).

Cicindela hirticollis corpuscula Rumpp (Fig. 1E, Map 3) 2 (2) is another riparian subspecies with an extensive historic range along the Virgin, Green, and lower Colorado Rivers in Utah, Arizona, southeastern California, and far southern Nevada. Many of the historic records are from the Phoenix and Yuma areas, but we unaware of any recent records for most of these historic sites along the length of the Colorado or Gila Rivers. Because of the extensive development and water flow decline and disruptions, it may be extirpated from these areas (Pearson et al., 2006). The only recent records we have (after 1970) are two sites along the Virgin River in Clark County, Nevada, two along the Colorado River near Moab, Utah, and two from the Green River in Utah. We suspect that there are additional sites along the Colorado and Green Rivers in Utah; however, much of this area is either unsurveyed or not readily accessible. Regardless, it is obvious that this form has disappeared from much of its historic range and continues to be impacted by dam construction and other modifications of water flow in these southwestern rivers.

Habrosceliomorpha praetextata praetextata LeConte (Map 4) 1- (2) has an historic range in sandy, often saline riparian habitats in the lower Colorado River system including the Gila and Salt Rivers of Arizona and a disjunct occurrence along the Salton Sea of southern California (Pearson et al,. 2006). This latter location is apparently a result of a population becoming established when the Colorado River flooded in the early 1900s and flowed for a number of years to form the Salton Sea. Records extend from as far east as Safford, Arizona (Graham County) along the Gila River, north to the Phoenix area and at numerous sites along the Colorado River between the Arizona-California border, extending as far north as Blythe, California. As is the case with *C. h. corpusculata*, which shares much of its range, many historic records (over 35) for *H. p. praetextata* and most prior to 1970 are primarily from the Phoenix and Yuma areas. Collection records and limited surveys indicate this species has disappeared from most of the recorded sites in Arizona and California over the past 30 years due to dams and water diversions that have disrupted water flow in their riparian habitats (Pearson et al., 2006). The third author collected a small number of specimens along the Gila River near Stafford, Arizona in 1987; however subsequent visits to that site failed to yield any specimens probably due to the increased development activity along the river. In more recent years the species has been found at Gillespie Dam west of Phoenix and the Salton Sea, and in 2013 it was rediscovered at a site in west Phoenix along a section of the Gila River that was recently restored to increase more natural water flow (Pearson, personal communication). Although systematic surveys throughout its range have not been conducted there are unlikely to be many new sites found because of the disruptions to the river systems where it historically occurred.

Cicindela tranquebarica cibecuei Duncan 2 (not ranked) is an endemic riparian form that, based on our records, is known from < 10 sites, most along Cibecuei and Carrizo Creeks in Gila and Navajo Counties in east central Arizona; it is listed as S1 by the state. Schultz and Hadley (1987) studied the microhabitat of this subspecies at several sites along Carrizo Creek, so it may be found in a more extensive area than reported in the literature. Regardless, its range is probably restricted to that area of central Arizona since other subspecies of *C. tranquebarica* are found elsewhere in Arizona. Riparian habitats where it might occur in this area are also being seriously impacted by Off-Highway vehicle activity (Schultz, 1988).

Ellipsoptera nevadica tubensis Cazier (Map 5) 3 (2) is a subspecies with a fairly broad range in the four corners area northward through the eastern third of Utah (Pearson et al., 2006). It is primarily a water edge species inhabiting sandy river habitats or other sites with permanent water. The population at the Tuba City type locality has apparently been extirpated due to the site being destroyed by grading and drainage. We have records for at least six current sites, most in southeastern Utah and northeast Arizona. There are probably additional extant sites and suitable habitat throughout its range but systematic surveys are needed to determine if additional sites support populations.

Cicindela formosa rutilovirescens Rumpp (Fig. 1F) 2- (not rated) occurs in the area known as the Mescelaro Sand Dunes of southeastern New Mexico and along the border in west Texas. In a compilation of historic records as well as surveys for new sites to determine the distribution and abundance of New Mexico tiger beetles, Knisley et al. (2001) found that most records for this subspecies were from the extensive dunes along Highway 380, 33-42 miles east of Roswell, Chaves County. The more recent surveys found 15 new sites in Lea, Eddy and Roosevelt County, New Mexico and Cochrane, Yoakum, and Terry Counties, Texas. No individuals were found at many other dune sites with apparently suitable habitat throughout the area, possibly due to high vegetation density or other unfavorable habitat factors. At the sites where this subspecies has been found, adults occurred at low densities, thus adding to the difficulty in detection. A few sites are protected within the Mather Research Natural Area, now classified as a National Natural Area, and the BLM's Mescelaro Sands Area of Critical Environmental Concern south of U.S. 380. Most other sites are ranch-lands under private ownership, although grazing does not appear to have negative impacts on the populations.

The primary threat to *Cicindela formosa rutilovirescens* is vegetation encroachment related to the use of Tibithiuron for the control shinnery oak, *Quercus harvardii* which is a common practice within its range. For example, two sites that utilized this method for 5-6 years became dominated by bluestem grass, sunflower, and other forbs (Peterson and Boyd, 1998). This seems to have caused the reduction in sufficient open areas needed by tiger beetles. At these sites, adults of *C. f. rutilovirescens* were found in nearby areas that were uncontrolled for shinnery which, under normal conditions, have open areas sufficient for tiger beetles. Studies of the sand dune lizard, *Sceloporus* *arenicolous*, which frequently co-occurs with *C. f. rutilovirescens*, showed their numbers decreased 70-94% as a result of Tibuthiuron treatment (Painter et al., 1999). Alternatively, factors such as moderate OHV activity and oil and gas exploration which reduce vegetation density and create open patches of habitat may benefit this subspecies. At one site we found adults more common along a pipe line right-of-way than in adjacent more densely vegetated areas. While there is still a large area of potential habitat, some of which remains unsurveyed in the Mescelaro sands, future impacts related to vegetation encroachment may be a threat to this tiger beetle's continued existence.

Cicindela fulgida Say. Five subspecies of this saline habitat species occur in New Mexico, three which are endemic to separate playa systems. However, the taxonomy of this species, particularly the validity of several described subspecies and thus the distribution of the forms is in need of further study. Two subspecies described by Knudsen (1985) were considered by Freitag (1999) to be synonymous with *C. f. pseudosenilis* Horn and not valid subspecies by Pearson et al. (20060. Although dubious these two forms are localized and rare, and their habitats threatened.

Cicindela fulgida rumpii Knudsen (Fig. 2A) 2+ (not rated) and *Cicindelidia willistoni estancia* Rumpp (Fig. 2B) A- (1) are endemic to the Estancia Basin playa system east of Willard, Torrance County, New Mexico (Rumpp, 1962). Nearly all records for both subspecies are from near the easily accessible rest area along Highway 60; however, this is most likely a collecting artifact as the playas extend well north and west, most of which are not easily accessible. Adults of both species tend to be present in low numbers, most often after recent rains. *Cicindela f. rumpii* is most often encountered among sparse vegetation in the saline soils along the playa edges while *Ci. w. estancia* is usually found on the open unvegetated wet playa. Populations of apparently the same two subspecies but with more reduced maculations are found in a small disjunct playa (Pinos Wells) ca 45 km to the eastsoutheast. We found a few specimens of *Ci. w. estancia* at another small disjunct playa 25 miles east of the main playa, just south of Encino. Most of the Estancia Basin is under private ownership, although the playa near Pinos Wells lies on land administered by the Bureau of Land Management. These playas are open to cattle grazing which is causing some pollution and trampling, but the significance of this impact is uncertain. Additional surveys are needed to establish how abundant and widespread these species are throughout this playa system.

Cicindelidia willistoni funaroi Rotger 1 (2) has a localized distribution in saline habitats in Sandoval County, New Mexico. Rotger (1972) described it and identified the type locality as a saline meadow near mineral springs along the Rio Salado. Our study found 21 records, all at a few sites within a few miles north or west of San Ysidro, Sandoval County, most of which are associated with the Rio Salado floodplain. Interestingly, the saline habitat along the river is "semi-fluvial", consisting of a poorly drained area along the wide low floodplain. We found a small number of specimens 2.4 miles west of town in September 2000 but did not find any at the type locality north of town, apparently because vegetation encroachment had eliminated most of the patches of bare ground necessary for adults and larvae. We also noticed agricultural activity in the area that may be reducing surface and ground water. It seemed apparent that this area is being impacted by other factors such as withdrawal

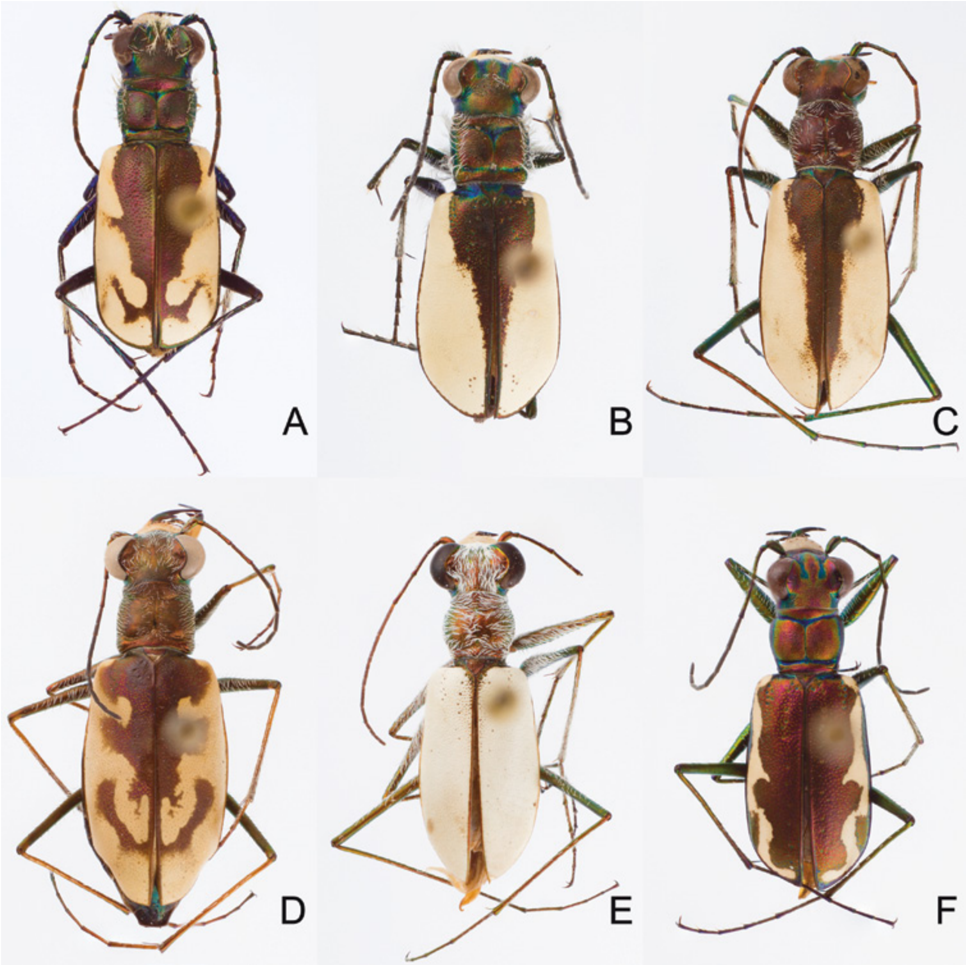


Figure 2. Dorsal view of rare tiger beetles. A. *Cicindela fulgida rumpii*, B. *Cicindelidia willistoni estancia*, C. *Habrosceliomorpha praetextata albilata*, D. *Ellipsoptera nevadica olmosa*, E. *Cicindela togata fascinans*, F. *Cicindelidia politula barbaraanae*. This figure is published in color in the online version.

of upstream water for agriculture and other purposes. There are still saline deposits, but most of the area is quite heavily vegetated and more suitable for *C. fulgida* Say and *C. tranquebarica* Herbst rather than *Ci. willistoni funaroi*. Other potential sites along the Rio Salado are privately owned and used for cattle grazing. Although there is some question about the validity of this subspecies, there seems little doubt that it is localized and rare.

Habrosceliomorpha fulgoris albilata Acciavatti (Fig. 2C) 1 (3) is endemic to the Salt Basin of west Texas which includes a small extension into extreme southeast New Mexico (Pearson et al., 2006). The majority of the records, including those in the type series, are from the playa 5-6 miles east of Salt Flat, Hudspeth Co., Texas. Two additional records are from a site ca 25 km north of Salt Flat on the Texas/New Mexico border. Several specimens collected in Dawson County, Texas, over 350 km to the northeast in the Texas Panhandle, match this form. These are probably dispersing individuals (Acciavatti, 1980) or possibly indicate an erroneous record. Surveys we conducted for this subspecies in Texas and New Mexico from 2001 to 2006 indicated it exists at only three sites which probably represent a single population in the Salt Flat area. Based on collecting data it appears that this subspecies is now less common than it was in the 1970s and 80s. Like other southwestern playa areas, the water table in this area is likely being lowered due to agricultural irrigation wells which are abundant in this area. Another potentially significant threat to this subspecies is a recent proposal for a large underground water storage project designed to provide water to El Paso by pumping from underground wells in the Salt Flat area and depositing salt water into part of the playa system. Because of its restriction to the playa habitat there are almost certainly no additional populations of this subspecies. Numerous records from 11 sites in Dona Ana, Otero and Sierra Counties are probably intergrade populations of *H. f. fulgoris* x *H. f. albilata* (Acciavatti, 1980; Knisley et al., 2001).

Ellipsoptera nevadica olmosa Vaurie (Fig. 2D) 2+ is another form inhabiting the Estancia Basin but is also in additional playas in southern New Mexico and far west Texas. As indicated below, we consider the western populations to be distinct from those in southeast Texas based on morphological characters and geographic distribution. Discounting a few dubious records, in New Mexico this subspecies is restricted to two separate salt basins—the Estancia (Torrance County) and Tularosa Basins (Dona Ana, Otero, and Sierra Counties in New Mexico and Hudspeth County in Texas). We reported records for 12 sites, including eight that are apparently new, during surveys conducted in 2000 (Knisley et al., 2001). Six of the new sites were in the White Sands area and two from Pinos Wells and near Encino which extended its range 25 miles east in the Estancia Basin. The largest number of adults (>50) were found along the playa edge, many under cowpies at Pinos Wells. The Hudspeth County population is restricted to the Salt Flat playa but it has rarely been encountered in recent years.

Cicindela togata fascinans Casey (Fig. 2E) 2 (4). A study of *C. togata* currently underway (R. Acciavatti, personal comm.) has preliminarily determined that the populations from the Tularosa Basin represent a distinct subspecies. Other populations from southern New Mexico and the Estancia Basin are probably either *C. t. globicollis* or hybrids of these two subspecies. Most of the records for this new form are from Salt Flat, Texas where adults have been found to be relatively common, even in recent years (Knisley et al., 2001); however, the future of this site is uncertain due to the proposed water project (see discussion under *Habrosceliomorpha fulgoris albilata*). Relatively few other specimens have been found at the several playa or saline sites at White Sands Missile Range and White Sands National Monument (Knisley et al. 2001).

Cicindelidia politula petrophila Sumlin 2- (3) and *Ci. p. barbarannae* Sumlin C (3) are subspecies occurring on limestone deposits in montane areas of west Texas and southern New Mexico. Both were listed as Category 2 species (USFWS 1989) because of limited distribution and few known sites. Based on additional records from collectors and extensive surveys since 2000 at Guadalupe Mountains National Park and southern New Mexico, we have recorded *C. p. petrophila* at eight sites along various trails in the Park and have identified more potential, but as of yet unsurveyed habitat. Even though all sites where these taxa were present had low numbers of adults (5-60), they are well protected within the Park and exhibited no evidence of negative impacts.

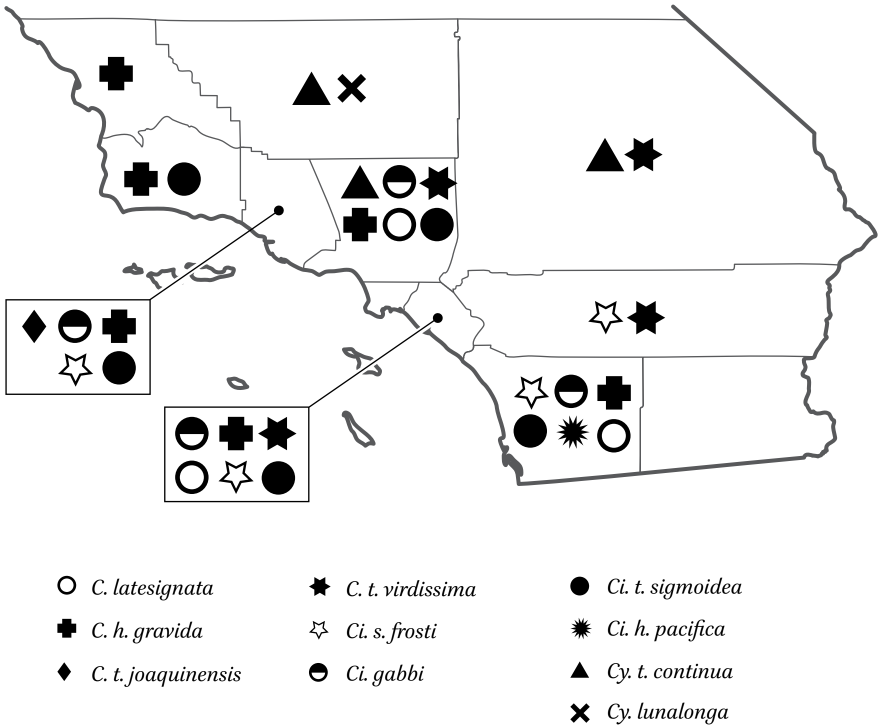
Cicindelidia politula barbarannae (Fig. 2F) 3 (3) is much more widely distributed than *C. p. petrophila*. We have records for at least 15 sites in west Texas and southern New Mexico that are located south, west and north of the range of *Ci. p. petrophila*, none of which are within Guadalupe Mountains National Park (Knisley et al. 2001, Pearson et al. 2006). Gage (1988) reported this subspecies at two additional sites in west Texas which extend the range 75 and 120 miles east of the type locality in west Texas. While some of these sites are on grazing lands, there appears to be little apparent impact from this or other activities at most sites where the subspecies occurs. Another related form, *Ci. p. viridimonticola* Gage (Fig. 3A) was described from one extremely small patch of habitat in southern New Mexico (Gage 1988). However, results of recent and extensive surveys found this form co-occurring at sites in southern New Mexico and west Texas with *Ci. p. barbarannae* and *Ci. p. petrophila* along with other color and maculation variations. As a result it seems apparent that *Ci. p. viridimonticola* is not a valid subspecies. Additional surveys and genetic analysis will be needed to resolve the taxonomy of these and other forms in the *Ci. politula* group.

California (Maps 7-8)

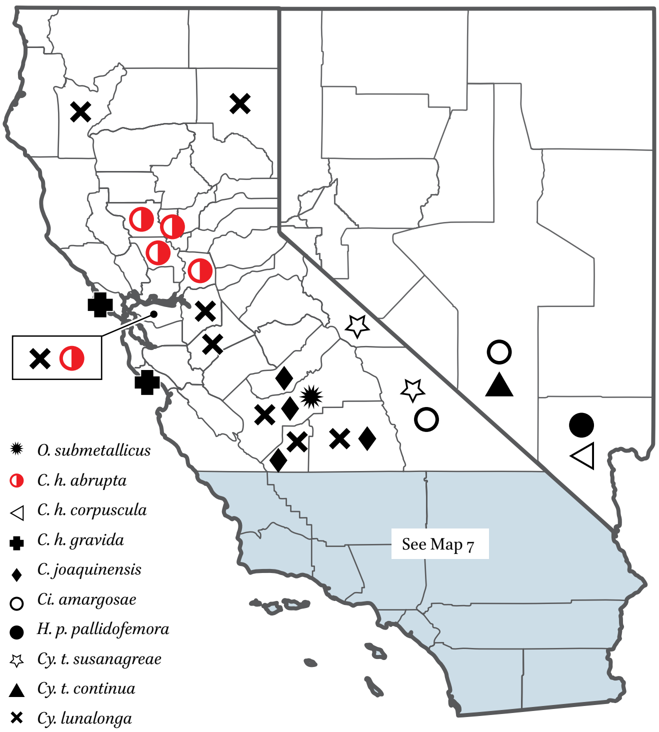
In one of the earliest studies of threatened and endangered tiger beetles, Nagano (1982) documented the rarity of tiger beetles occurring in Southern California coastal habitats and the impacts of coastal development and other human activities. He concluded that four of these, *H. gabbii* Horn, *Ci. senilis frosti* Varas-Arangua, *C. latesignata* LeConte, and *C. hirticollis gravida* LeConte, were sufficiently rare that they should be listed as Threatened species by the USFWS. Results of our study—over 30 years later—generally support his assessment for all of these forms except *C. h. gravida* which has more viable populations and ranges much further north than the others. In addition, we include nine additional California forms that merit consideration as rare.

Habrosceliomorpha gabbii G.H. Horn (Fig. 3B) 1- (not rated) has an historic range along the southern California coast and south into Mexico, primarily on mudflat and estuary habitats. We have records for 13 sites in, Los Angeles, Orange, San Diego and Ventura Counties and additional sites south into Mexico. Although Nagano (1982) questioned the validity of the Ventura record and later failed to find it during his survey at Point Mugu Naval Air Station, it was more recently found to be relatively common there (Young, 2005). We determined it is no longer present at most of the historic sites including all of those cited by Nagano (1982) in Los Angeles County. Extant populations are still present at two sites in San Diego County, one in Orange County, and one in Ventura County all of which are parks or military facilities which afford a certain level of protection. We are uncertain of the current status of this species in Mexico since most of our records there are over 25 years old.

Cicindela latesignata 1- (1) (Fig. 3C) is an inhabitant of sandy coastal beaches with 24 known historic sites along the southern California coast—6 sites in Orange, 4 in



Map 7. Distribution of rare tiger beetles in southern California.



Map 8. Distribution of rare tiger beetles in central and northern California.

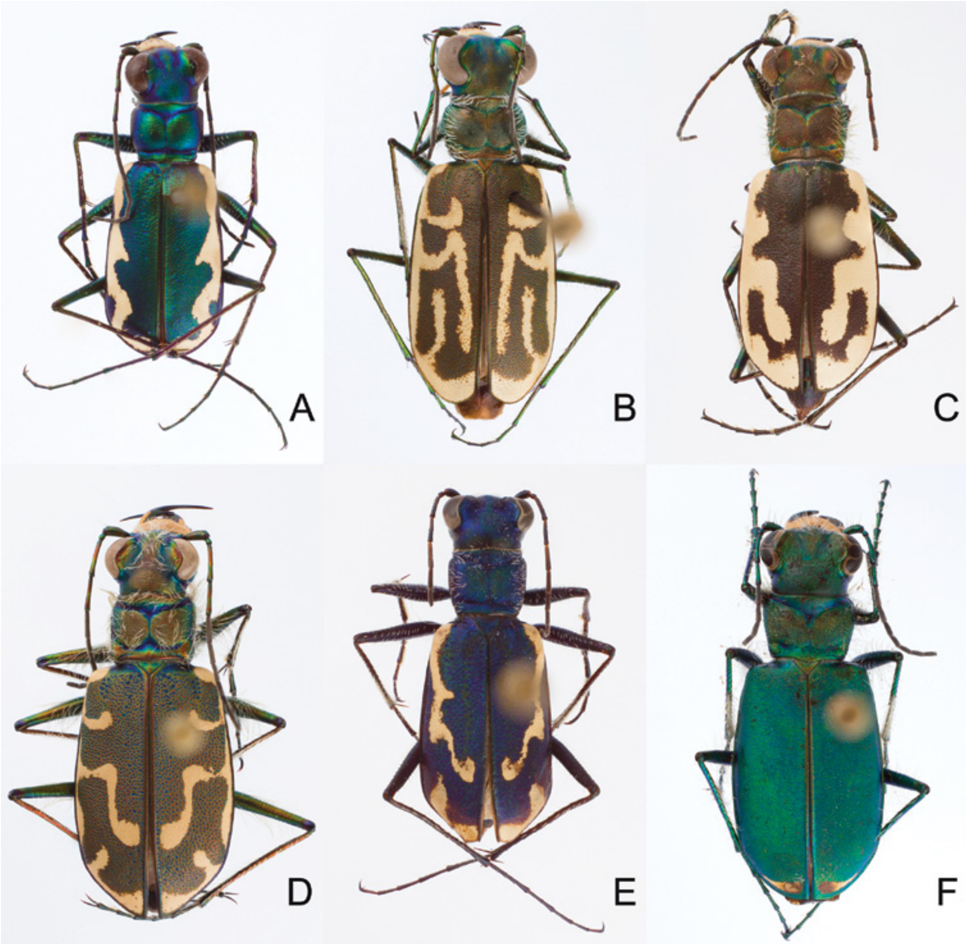


Figure 3. Dorsal view of rare tiger beetles. A. *Cicindelidia politula viridimonticola*, B. *Habrosceliomorpha gabbii*, C. *Cicindela latesignata*, D. *Cicindela hirticollis gravida*, E. *Cylindera terricola continua*, F. *Cicindela tranquebarica joaquinensis*. This figure is published in color in the online version.

Los Angeles, and 14 in San Diego counties. It also ranges far southward along the coast into northern Mexico. Results of our recent surveys and collection records confirm it is present at only four sites in San Diego County, including well-established populations at two protected sites—Borderfield State Park and Tijuana Slough National Wildlife Refuge. Specimens from La Jolla to the San Diego/Orange County line have noticeably wider maculations and were considered a distinct subspecies, *C. l. obliviosa* by Rumpp (1979) and Nagano (1982), the latter author reporting it from five historic sites; however, more recent treatments of tiger beetles do not consider it to be a valid subspecies (Freitag, 1999; Pearson et al., 2006).

Cicindelidia hemorrhagica hemorrhagica Leconte is a widespread subspecies ranging from Arizona, Nevada, and California northward to Washington. Very localized populations in northern San Diego County exhibit metallic blue dorsal coloration with reduced maculation and were described as *Cicindelidia hemorrhagica pacifica* by Schaupp (1884) 1 (5). Nagano (1982) reported this form from Carlsbad to LaJolla in San Diego County where adults and larvae were restricted to sandy cliff faces and adjacent beaches which back the narrow sea beach. He found numbers declined when its prey insects were reduced by removing kelp wrack along the shoreline. Interestingly, Nagano found the more widespread *Ci. h. hemorrhagica* was also common in this area but not in the sandy cliff habitats. More study is needed to better understand the taxonomic status and distribution of these forms in San Diego County.

Cicindela hirticollis gravida LeConte (Fig. 3D) 2- (2) has an extensive range along the California coast from Point Reyes in Marin County to San Diego County southward into Mexico (Pearson et al., 2006). We documented it from over 40 sites within this range, most prior to 1980. It is not surprising that given the rapid growth and development of California's coastal areas, this subspecies has been extirpated from most of them. Nagano (1982) reported that it was gone from 19 historic sites. Our work suggests that there are probably viable populations currently present at 12-15 sites, ten of these at parks, preserves or military facilities, thus receiving some level of protection. Most of these extant populations are in southern California with one or more sites each in San Luis Obispo, Ventura, Santa Barbara and San Diego Counties. The far northern Marin County population was considered an intergrade of *C. h. gravida* and *C. h. abrupta* (Graves et al., 1988) but a recent mtDNA analysis revealed that this population was genetically distinct from all other U. S. forms of *C. hirticollis* (Knisley, 2004; D. Duran, personal communication); therefore its actual taxonomic status remains uncertain.

Cicindelidia senilis frosti 1- (1) was described from Los Angeles County and has been recorded from Orange, Riverside, San Diego and San Bernardino Counties (Pearson et al., 2006). Because it is distinguished from the nominate form only by its green or green-brown color and a distribution restricted to southern California, some tiger beetle researchers do not consider this form to be a valid subspecies. Nagano (1982) and more recently Young (2005) referred to the population at Point Mugu as *Ci. s. frosti*, however, these may be intergrades with the nominate form since they are brown to brown-green unlike the more distinct green of *C. s. frosti* and in an area where the range of both subspecies intersects. The habitat of this taxon includes coastal salt marshes, tidal mud flats, and inland salt marshes (Pearson et al. 2006). Overall, we found 11 historic sites within the four-county range, most of which have been impacted or destroyed by coastal development; at most there may be only one or two extant sites remaining in San Diego County. One of the more recent records was a large population with bright green adults at an inland salt marsh near Lake Elsinore (Kamoun, 1996); however when we contacted Kamoun to get details of the specific location, our subsequent surveys there in 2010 did not produce any specimens and the habitat was apparently destroyed by development. We could also not find it at DelMar, another more recent site mentioned by Kamoun (1996) or at the Jacumba site mentioned in Pearson et al. (2006). While the taxonomy of this form is uncertain, there is no question of its extreme rarity. *Ci. s. senilis* Horn is graded as a 1 in NatureServe Explorer but we do not consider it rare based on our knowledge of more than 15 known sites, some with very large populations and the likelihood of additional sites being found.

Cicindelidia trifasciata sigmoidea Leconte 3+ (Fig. 6B) is found primarily on mudflats in coastal southern California from Morro Bay in San Luis Obispo County south to San Diego County and along both coasts of the Gulf of California. Disjunct records from the Salton Sea area and western Arizona probably represent dispersing individuals since this species is well known to be a long distance disperser (Pearson et al., 2006). Nagano (1982) reported it was present at only eight of the 25 U. S. historic sites. We found recent records for ten sites, including four in San Diego Counties, three in Los Angeles County, two in Orange, and one in Ventura, at least five of these are protected and with a substantial amount of habitat present.

Cicindelidia amargosae Dahl includes two subspecies that occur along the margins of salt encrusted desert streams, ponds and salt flats with sparse grasses (Pearson et al. 2006). *Cicindelidia a. amargosae* 2- (2) is restricted to the Death Valley area of California and adjacent Nevada where a small number of robust populations occur while *Ci. a. nyensis* Rumpp (4) which we do not consider rare at this time occurs in a narrow band of the western edge of the Great Basin from northern Nevada and California into southeastern Oregon (Pearson et al. 2006). Populations to the east in the Amargosa Valley were considered intergrades (Pearson et al. 2006) although Kippenhan (2005) found that the variation in dorsal coloration used to distinguish the two subspecies was not consistent with their reported distribution. Beyond the Death Valley sites, there are at least ten sites for *Ci. a. amargosae*, several large and in areas that are unlikely to be impacted by development or other human activities.

Cylindera lunalonga Schaupp 1- (1) was recently elevated to a full species based on mtDNA and morphology (Woodcock et al., 2006; Kippenhan and Knisley, 2009) at which time it was known from only one location (Lassen County) and thus considered sufficiently rare that it should be listed by USFWS. Historically, it was known from various wetland sites in the San Joaquin Valley and several montane sites in the Sierra Nevada. While extensive recent searches produced no other extant sites in the Sierra Nevada, the species was rediscovered at 11 sites in the San Joaquin Valley, most west of Stockton (Kippenhan et al., 2012). Interestingly, all of these sites were along irrigation ditches and canals at the edges of agriculture fields indicating this species has adapted to the permanent water availability in agriculture habitats and is well established in this area. More recently, the range has been extended to the east at several similar irrigation sites into Contra Costa County (D. Katz, personal communication).

Cylindera terricola continua Pearson, Knisley and Kazilek (Fig. 3E) 1- (3) was most recently treated as a valid subspecies by Pearson et al. (2006) while Kippenhan (2007) clarified its taxonomic standing. The type locality is Baldwin Lake near Pine Knot, San Bernadino Mountains, California with a range that includes Kern, Los Angeles, western Ventura, and San Bernadino counties in California northeast to Nye County, Nevada (Kippenhan, 2007). Our numerous searches at the type locality and at all historic and additional California sites in 2002 and 2003 produced no specimens. The only known extant population is in Nye County, Nevada where it occurs at only one relatively small and localized site; individuals in that population are distinct from the other populations by a bright blue elytral coloration.

Cylindera terricola susanagreae Kippenhan 2- (not rated) was recently described as a distinct subspecies endemic to the Owens River and associated valleys of east central California where we have existing records for 16 sites from the Fish Slough area north of Bishop, Mono County south to Owens Lake, Inyo County (Kippenhan, 2007). Its habitat is primarily water edges or moist soil often with evidence of saline deposits. Many of the collection records are prior to the 1990s and although it has been collected recently at a number of sites, it has apparently disappeared from some of its range and declined in abundance at some of the previously reliable collecting sites. It is possible that some of the decline is related to reduced ground and surface water in the Owens Valley.

Cicindela tranquebarica joaquinensis Knisley and Haines (Fig. 3F) 1+ (1) was recently described from three sites in the San Joaquin Valley (Tulare and Kings counties) of California as part of a study of its conservation status (Knisley and Haines, 2007). Follow up surveys of over 100 sites including six historic ones found three additional sites (Knisley and Haines, 2010a). At that time only four sites had apparent viable populations with abundant larvae and peak index counts of adults ranging from 20 to 75. Two of these sites experienced a significant decline in adult numbers after much of the vegetation was denuded by a combined year long drought and overgrazing. As of 2014 after the complete plowing of one of the best sites, there is only one confirmed site with a healthy population and an adequate amount of suitable habitat. An additional site in Madera County that previously supported a viable population has been inaccessible and of unknown status. All of the sites where this subspecies has been found are privately owned, used for cattle grazing, unprotected and at risk, especially since there is a recent history of land in this area being converted from rangeland to other uses. Because of the extensive survey work it is unlikely that additional viable sites will be found.

Cicindela tranquebarica viridissima Fall (Fig. 4A) 1+ (1) We found over 20 records for eight different sites throughout an historic range that includes Los Angeles, Orange, Riverside and San Bernadino counties. Its apparent rarity is suggested by the fact that it was listed as a category 2 taxon by USFWS (Federal Register 1984). Similar to other western subspecies of *C. tranquebarica*, it is typically found in sandy soils in various habitats, especially floodplains or where there is a permanent or periodic water supply. Museum records indicated Rumpp collected large numbers of specimens in the 1950s from what is now Anaheim Stadium, but this site, like most other historic sites, has been lost to urbanization and related developments. Information from Rumpp (1979) included in Nagano (1982) suggested it had been lost from most sites and survived only in the Santa Ana river basin, but our more recent information indicates these sites have been eliminated or disturbed with the apparent loss of the subspecies there. Over the years, many workers have searched for it at several historic and other sites within its known range, but additional populations have not been located. Currently, we know of only one extant population—in an orange orchard in southwest Riverside County. This site has periodically irrigated sandy soil which apparently provides suitable conditions for a viable population. Its presence in this orchard habitat suggests it may also exist in similar habitats where a water supply or soil moisture is present.

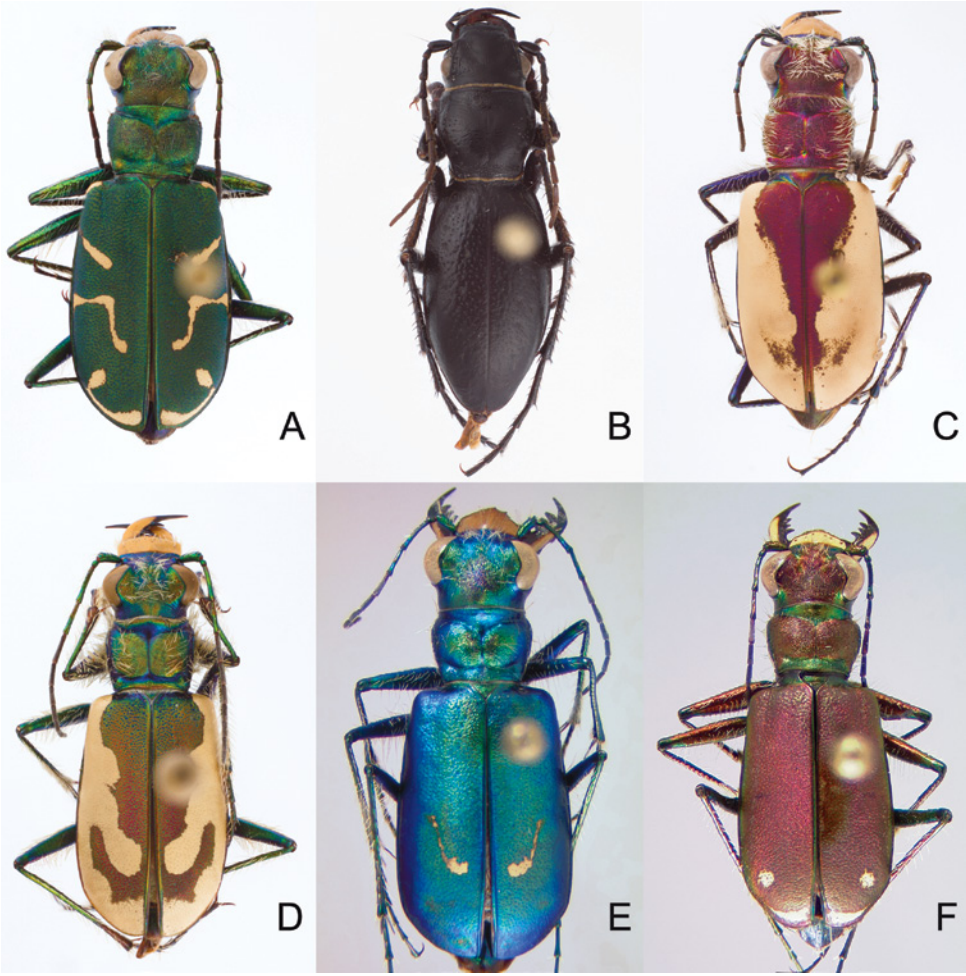


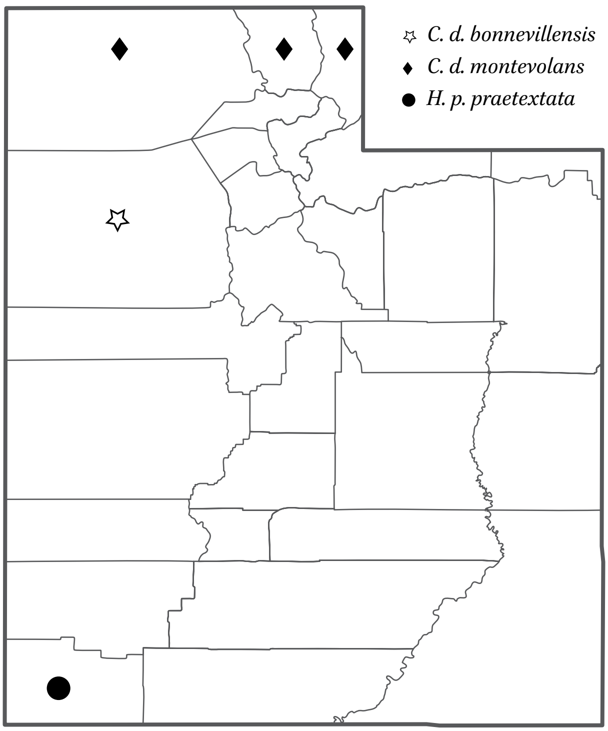
Figure 4. Dorsal view of rare tiger beetles. A. *Cicindela tranquebarica viridissima*, B. *Omus submetallicus*, C. *Cicindela formosa gibsoni*, D. *Cicindela theatina*, E. *Cicindela decemnotata bonnevillensis,* F. *Cicindela decemnotata montevolans*. This figure is published in color in the online version.

Omus submetallicus Cazier 1- (3) (Fig. 4B) has an extremely localized range at the mouth of Warthan Canyon, eastern Fresno County, California (Pearson et al., 2006). Its habitat is conifer woodland that is more xeric than that of other *Omus* species. A recent study of its distribution and abundance confirmed its limited range but found adults and larvae to be relatively abundant and well established within this range (Knisley and Haines, 2010b). All known sites are private lands in rugged terrain, relatively inaccessible, and thus afforded some level of protection. These sites are all used for cattle grazing but there is no evidence of this having a significant impact on the species or its habitat. However, we do not consider it secure because of the limited range, and the reasonable possibility of a change in land use, such as deforestation, conversion to housing or other developments.

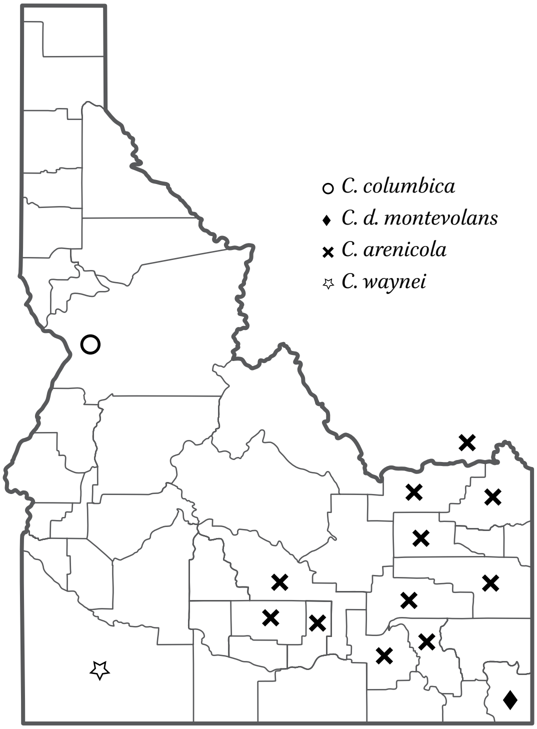
Colorado, Utah, Idaho (Maps 5, 9, and 10)

Cicindela formosa gibsoni Brown (Fig. 4C) 2 (1) co-occurs at most or all sites with *C. s. yampae* in the Moffat County sand dunes, but has been collected at more sites (>22) and in much larger numbers (Kippenhan, 1994). Indeed, our surveys at numerous sites in the past few years indicate it remains abundant and widespread, perhaps because it can utilize a wider array of dunes habitats, and may be less impacted by vegetation encroachment than *C. s. yampae*. Further west near the Utah state line it intergrades with *C. f. formosa* Say (Pearson et al., 2006). Interestingly, this same subspecies occurs in sand dunes in southwestern Saskatchewan and has recently been found in southwestern Montana (Hendricks and Lesica, 2007). These widely separated populations have been considered the same subspecies because of a similarity in dorsal maculation pattern. However, this similarity could be a result of convergent evolution related to background matching or thermoregulation, so additional genetic studies are needed to resolve the taxonomy of these forms.

Cicindela scutellaris yampae 1- (1) is endemic to the Yampa River sand dunes in Moffatt County, Colorado (Kippenhan, 1994). Our records indicate adults have been collected from less than eight sites and most often in small numbers. Recent searches by collectors suggest it is less common now than prior to the 1990s. There has been an observed increase in grazing and agricultural crops in Moffatt County but the most important negative impact may be the reduction of open dune areas due to vegetation



Map 9. Distribution of rare tiger beetles in Utah.



Map 10. Distribution of rare tiger beetles in Idaho.

encroachment, especially cheat grass which we found at many of the dune sites. While collectors have consistently found the co-occurring *C. f. gibsoni* over the years and recently, *C. s. yampae* is infrequently collected.

Cicindela theatina Rotger 2- (1) (Fig. 4D) is a sand dune endemic restricted to the Great Sand Dunes ecosystem of Colorado. This species has been relatively well studied by Pineda and Kondratieff (2003) who found it was restricted to suitable habitat within a 290 km^2 area of the Great Sand Dunes National Park. Suitable habitat included active dunes, blowouts and other open sand areas with limited vegetation cover. The actual area occupied by the species was only 28.6 km^2, but there were no estimates of population size provided. There is evidence that some of the few populations outside the park have been lost due to conversion of habitat to agricultural lands and the possibility that depletion of ground water in the San Luis Valley could impact hydrology and dune characteristics, eventually having negative impacts. The presence of this species within a national park affords it protection from many of the human impacts that have negatively affected other sand dune tiger beetles.

Habrosceliomorpha praetextata pallidofemora Acciavatti 1(1) is a riparian form found on sand and mud flats along the Virgin River from extreme southwestern Utah to southeastern Nevada above Lake Meade (Acciavatti, 1980). All records, including the type series, are from only sites at St. George, Washington County, Utah and along the river from Mesquite to Riverside, Clark County, Nevada. Between these two locations, the river flows rapidly through the Virgin River gorge resulting in gravelly substrate along the river edge and unsuitable habitat. Several searches in the Mesquite-Riverside section of the river in most recent years produced no specimens probably due to a number of possible negative impacts—severe floods which scoured much of the floodplain, increased cattle grazing along the river; and the impact on the river's water flow due to the explosive population and recreational growth of Mesquite, Nevada over the last 20 years. Our recent survey of a site it once occupied in St George found little of the sandy floodplain habitat that was present in the early 1990s. Most recently in 2013 and 2014, the second author and several other workers have rediscovered this subspecies along the Virgin River near Riverside.

Cicindela decemnotata was not considered a rare species in NatureServe Explorer, but a recent taxonomic study described three new subspecies and reviewed their biology, distribution and conservation status (Knisley et al., 2012). The two subspecies from Utah have limited geographic ranges, specific habitats and relatively few known collection sites. *Cicindela d. bonnevillensis* Knisley and Kippenhan (Fig. 4E) 2 (not rated) occupies low elevation, often saline soil sites in Utah's west desert along what was the western border of the ancient Lake Bonneville. Recent survey work found it at less than 20 sites within a 24 x 80 km^2 area of Tooele County; all but three of these are from Dugway Proving Ground (Knisley et al., 2012). Most other records are from a salt flat site near Delle, along I-80. Many of the sites at Dugway Proving Ground are along little used roads and other disturbed areas of bare ground. Rather than having a negative impact on the subspecies, these disturbances from vehicle use and training activities have apparently benefited it by reducing vegetation and creating open areas of habitat needed by adults and larvae (Knisley, 2010, Knisley et al., 2012). Index counts over several years at Dugway Proving Ground sites found adults occurred at low densities with total numbers ranging from 2 to 60 per site; only six sites had more than 20 adults. There may be additional potential habitat at Dugway and elsewhere in Tooele County, but like the other subspecies of *C. decemnotata*, *C. d. bonnevillensis* is restricted to limited patches of otherwise seemingly similar habitat and occurs at low densities. It is also ephemeral with adult activity declining as the soil dries out.

Cicindela decemnotata montevolans Knisley and Kippenhan (Fig. 4F) 2- (not rated) is known only from high elevation sites of the Bear River Mountain Range in Cache, Box Elder, and Rich Counties of northeastern Utah, and the adjacent Bear Lake County, southeastern Idaho (Knisley et al., 2012). The known records in Cache County are within a 16-32 km^2 area, usually along trails or paths through areas of sagebrush around the Bear Lake summit (Knisley et al., 2012). Other forms of *C. decemnotata* have a more typical spring-fall activity pattern, but apparently because of its high altitude distribution, the adults of this subspecies are active from late May into summer and again in late August to September. Although it has a limited range, there is a relatively large amount of potential sagebrush habitat available and adults may sometimes be found in abundance. It presence in the area of ORV and snowmobile trails may be beneficial by creating and maintaining the open areas needed by adults and larvae.

Cicindela arenicola Rumpp (Fig. 4D) 2 (1) is a sand dunes species largely restricted to eastern and south central Idaho with the greatest concentration in the St. Anthony dunes (10,600 acres). Adults have been recorded from several other smaller and more isolated dunes. Recently, its range was extended into sand dunes in Montana near the Idaho border (Winton et al., 2010). Anderson (1988, 1989) conducted extensive surveys and biological studies, finding it at many sites from eight Idaho Counties, and estimating there might be as many as one million adults throughout its range. Subsequent surveys found it at 30 additional sites and in four new counties although most of these sites supported only small numbers (Logan, 1995). The species has apparently been extirpated from the Heyburn Dunes possibly from planting vegetation to reduce erosion (Anderson, 1988, Makela, 1994). Many other sites are impacted by ORV activity, increased vegetation growth, especially invasive species, and/or cattle grazing (Makela, 1994, Logan, 1995). Bauer (1991) reported that cattle grazing could have a negative effect on larvae, especially early instars. Bouffart et al. (2009) provided information on how herbicide treatment of invasive vegetation might be a valuable tool for improving habitat for this species. Because of its presence at many sites Anderson (1988) and Logan (1995) did not consider the species to be in eminent danger of extinction although continued ORV and invasive vegetation impacts may now be reducing populations and increasing its risk.

Cicindela waynei Leffler (Fig. 6A) 1+ (1) was considered a variant or subspecies of *C. arenicola* until recently described as a distinct species by Leffler (2001) because of several morphological characters, including a distinct mandibular tooth in males. Recent genetic study supported it as a separate species (Goldberg et al., 2011) although the genetic results have been interpreted by some as evidence that it was not a valid species (D. Duran, personal communication). In any event *C. waynei* is one of the most imperiled U. S. tiger beetles because of its highly localized distribution within the Bruneau sand dunes of southwestern Idaho and small population size. Recent surveys indicate the population declined in both numbers and area occupied, and a small satellite population east of the main population on BLM lands has apparently been extirpated (Bosworth, 2010). Monitoring of the species over the years has focused primarily on area occupied by larvae and their numbers in established plots; numbers of adults have not been reported. Studies have found it is seriously threatened by various impacts, including human recreational activities, livestock grazing, and especially invasive vegetation (Goldberg et al., 2011). The most important of these threats is invasive vegetation, especially cheat grass which stabilizes the dune and reduces the bare ground needed by adults and larvae (Baker et al., 1997). Larvae were found to be absent from most of the 14 patches they previously occupied, most of these losses attributed to cheat grass effects. At present the small size and localized distribution of this species coupled with continued impacts of the habitat from invasive vegetation make it one of the most at risk of U. S. tiger beetles. It is likely that its status could be improved by vegetation control by herbicides or other methods (Bouffard et al, 2009; Bosworth, 2010). There may also be a loss of adults from overcollection (Shook and Clark 1988, Makela, 1994) although like many tiger beetles the loss of adults in a

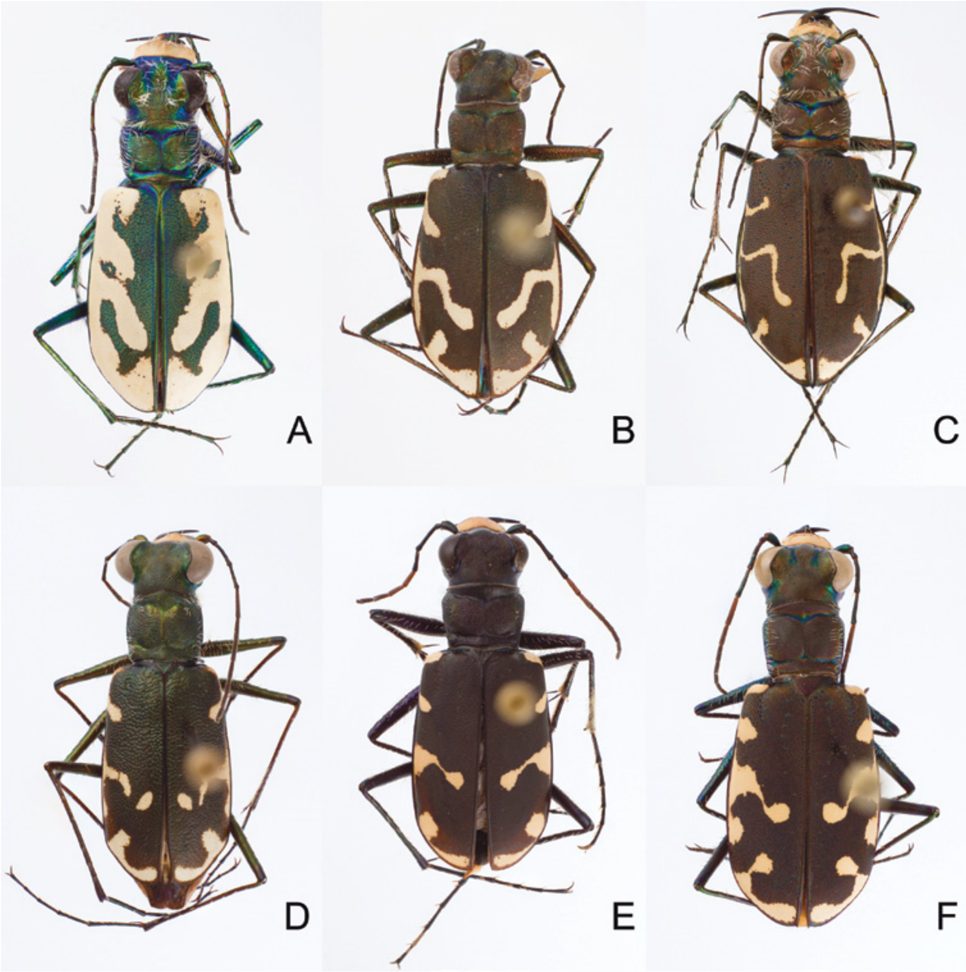


Figure 5. Dorsal view of rare tiger beetles. A. *Cicindela arenicola*, B. *Cicindela columbica* C. *Cicindela hirticollis siuslawensis*, D. *Microthylax olivacea*, E. *Cicindela patruela consentanea*, F. *Cicindelidia rufiventris hentzi*. This figure is published in color in the online version.

diverse habitat where they are widely distributed may be insignificant compared to habitat impacts.

Cicindela columbica Casey (Fig. 5B) 2 (2) was historically found along sandy riverine beaches along the Columbia, Snake and Salmon Rivers of eastern Washington, northeastern Oregon, and northwestern Idaho, but is now known from only the Salmon River in Idaho (Pearson et al,. 2006). Hatch (1971) first reported on the absence of this species from Oregon sites along the Columbia River where he previously had found it. Shook (1981) reviewed the historic loss of this species from the Columbia River after flooding from dam construction and results of unsuccessful searches for it in Washington by various workers. The last collection of this species that we are aware of from Washington was along the Snake River in Whitman County (Willis and Stamatov, 1971). As a result of this decline in range, *C. columbica* was listed as a Category 2

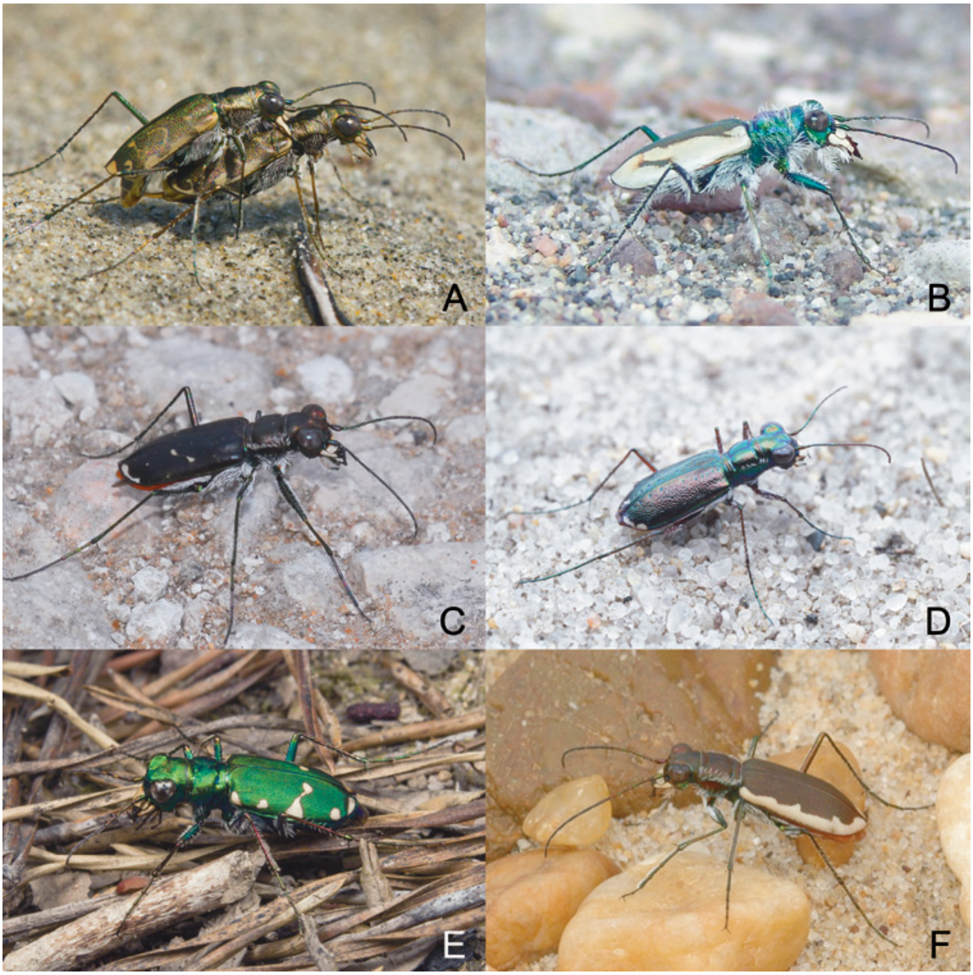
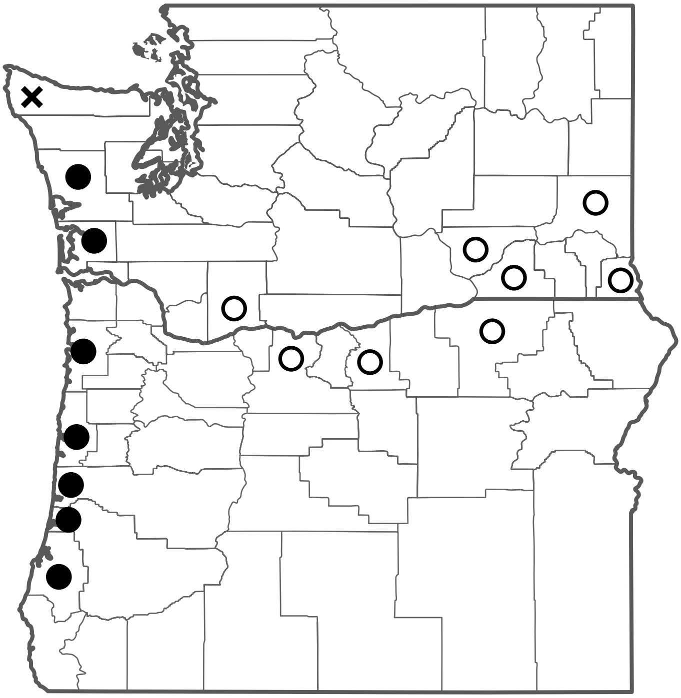


Figure 6. Photographs of live tiger beetles in their natural environment. A. *Cicindelidia trifasciata sigmoidea*, B. *Cicindela waynei*, C. *Cicindelidia cazieri*, D. *Cicindelidia floridana*, E. *Cicindela patruela*, F. *Cicindelidia marginipennis*. This figure is published in color in the online version.

species by the USFWS (Federal Register 1989), but this designation was later changed since some of the existing habitat was protected as federal lands. The results of Shook's (1981) boat surveys of potential habitat along the Lower Snake and Salmon Rivers found adults at 14 sites along a <30 mile stretch of the Salmon River. Many sites were in close proximity so the number of populations was much less than the number of sites, and possibly only one metapopulation. Although some of the sites are protected and difficult to access, the species still remains at risk because of its limited range and the dynamic nature of its riparian habitat.

Washington and Oregon (Map 11)

Cicindela bellisima frechini Leffler 1 (1) was described by Leffler (1979) who found it restricted to the area of Neah and Mukkah Bays, Clallam County, northwestern



Map 11. Distribution of rare tiger beetles in Washington and Oregon.

Washington. Searches since the original description suggest this subspecies remains relatively abundant but apparently restricted to a small area of suitable dune habitat within this same area. However, no systematic surveys have ever been conducted, but evidence suggests few additional sites or habitat are likely to be found.

Cicindela hirticollis siuslawensis Graves (Fig. 5C) 2 (1) has an historic range from central Washington to Humboldt County, California on coastal sandy beaches, usually at the mouths of rivers (Graves et al., 1988). We found historic records for 12 sites in four counties in Oregon (Coos, Lane, Lincoln, Tillamook) and two counties in Washington (Grays Harbor, Pacific). Surveys in recent years by the third author as well as other individuals, found it absent from many of these historic sites with many experiencing significant human beach activity and some ORV use. Records indicate it has been found fairly consistently at a site near Bandon, Coos County, Oregon. A recent more thorough survey of much of the Oregon coast found adults present at 17 of 49 sites in four counties from Sutton Creek to Port Orford (Mazzacano et al., 2010). Some of these are protected or not readily accessible. Paulson (2012) reported finding another large population at a new protected site (for snowy plovers) in Pacific County, Washington. The finding of these new sites, many protected or relatively inaccessible significantly improves the status of this subspecies.

Omus cazieri van den Berghe 2 (2) is currently known only from the north slope of Mt Ashland, Oregon, in a mixed conifer forest dominated by Douglas Fir (Pearson et al., 2006). Southern Oregon has been poorly collected for tiger beetles and even though there are few collection sites for this species, we do not believe this is representative of its true distribution. Despite this, it has been taken in abundance by various workers over the years indicating populations are apparently large and stable in this area. To our knowledge there are no significant factors impacting its habitat.

Midwest

Cylindera celeripes (LeConte) occurs in a narrow band of the eastern and southern Great Plains from western Iowa south to north Texas (Pearson et al., 2006). A recent study of its biology and conservation by MacRae and Brown (2011) found it has declined or been lost from many historic sites in Nebraska, Iowa and Kansas because of conversion of its prairie/grassland habitats to agriculture or urban uses. They confirmed extant populations, some robust at three counties in Iowa, two in Oklahoma, two in Missouri, and probably other occurrences in these states, Arkansas and north Texas. It has been found over the years at the type locality of Fort Riley, Kansas although the area there is small. It may also occur at other sites in eastern Kansas. The workers concluded from their study that given the current distribution and the likelihood of additional populations being found it would not qualify as a threatened or endangered species. They suggest that management of existing and potential habitats by prescribed burns to maintain and create open patches of habitat and foster grassland habitats would greatly improve its status.'

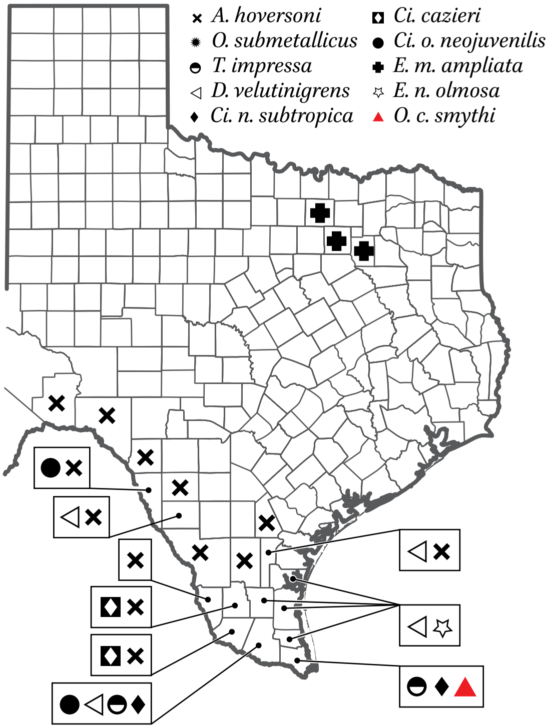
Habrosceliomorpha circumpicta pembina W. N. Johnson 1 (2) was described from specimens collected at Pembina in Pembina County, North Dakota where it was isolated by over 800 km from the nearest populations of the subspecies, *H. c. johnsoni* Fitch (Johnson, 1993). We have records for four sites, all localized in Pembina and adjacent Grand Forks Counties in the northeastern corner of North Dakota. Several hundred specimens were collected at the type locality in 1984 and 1985, thus indicating a large population there at the time. Information from several collector visits to the area in the past few years have found few or no specimens at several sites and some evidence that vegetation encroachment and development impacts are reducing the suitable habitat.

Ellipsoptera nevadica makosika Spomer A (1) is a recently described subspecies known only from two sites along an intermittent saline stream bed in the Badlands region, Pennington County, South Dakota. Spomer (2004) found it associated with saline mud that apparently resulted from overlying Pierre shale, a fairly restricted geologic formation. He suggested the habitat could be impacted by cattle trampling which was common at the sites. Several collector records indicate a relatively large population in and near the type locality. Thorough surveys have not been conducted but if the species is limited to Pierre shale formation as indicated, it is likely to have a very limited range and could be at risk from water level changes and impacts from grazing.

Texas (Map 12)

South Texas is a biological hotspot for many taxa, including tiger beetles, with at least 20 species known from this area, a number of which are rare due to the loss of natural habitat from rapid population growth and expanded agricultural development. We determined four taxa that are especially rare—*Cicindelidia obsoleta neojuvenalis* Vogt, *Ci. nigrocorulea subtropica* Vogt, *Ellipsoptera nevadica olmosa* Vaurie, *and Ci. cazieri* Vogt—all of which are restricted to south Texas (some may be in Mexico) and reported from five or fewer sites. Adults of *Ellipsoptera n. olmosa* are active in early summer and fall while the others are active only in the fall and early winter.

Cicindelidia obsoleta neojuvenalis 1+ (1) was described by Vogt (1949) from a small series of specimens collected from five miles southwest of Mission, Hidalgo County, and these remain the only confirmed specimens of this taxon. Vogt reported it to be "associated with mesquite forestland along the alluvial floodplain of the Rio Grande, occurring along lonely roadways, edges of cultivated fields and in clearings" and that it was not common. This suggests he probably found it at other sites but provides no other locality information. Since it has long been known to be rare and absent from collections, workers have searched for it extensively in the area of the few historic sites and elsewhere in south Texas. Over the past few decades, we have made 12-15 trips to the apparent type locality and searched at 15-20 other potential sites in several south Texas counties. Since this is a large tiger beetle like other *Ci. obsoleta* subspecies and associated with grassland habitats, relatively large patches of habitat are probably needed to sustain viable populations. Because much of the natural habitat in south Texas has been lost, there are likely to be few areas to support this species. Much of the



Map 12. Distribution of rare tiger beetles in Texas.

area west of Hidalgo County is private ranchland and has not been well surveyed but could have additional populations.

Recently specimens from two other sites in South Texas that are morphologically similar to, and may be identical with *Ci. o. neojuvenalis* have been found. At one of these sites near Eagle Pass, over 350 km northwest of the type locality, a large series collected by the third author appear to match *Ci. o. neojuvenalis* (Mawdsley, unpublished data). A single specimen from near Falfurrius, Brooks County is also similar but closer to the range of *Ci. o. vulturina* in central to eastern Texas. While the occurrence of this subspecies near the border in Mexico seems likely, Cazier (1954) did not report it in his paper on Mexican tiger beetles and Murray (1979) indicated that specimens from Tamaulipas were different and possibly a yet undescribed subspecies. Further taxonomic studies including genetic analysis are needed to resolve the status of the various *Ci. obsoleta* subspecies.

Cicindelidia nigrocuerulea subtropica 1+ (2) was also described by Vogt (1949) from three Hidalgo County locations, one apparently the same as the *Ci. o. neojuvenalis* site, the others at Mercedes and near Mission. He found the subspecies in open areas along little used roadways in second growth mesquite habitats of maintained floodways. More recently, Gage and Sumlin (1986) provided a more complete description of this subspecies with a dorsal habitus illustration and new collection information. They reported it from the type locality and at two additional sites on ten dates between 1979 and 1984. Adults were found to be highly ephemeral and active for only a few days after rain when the soil was wet, a factor that probably contributes to the lack of collection records. We searched for this beetle at 12-15 sites in Hidalgo County, and found it once at the type locality and at three other sites in the Mission area, always in small numbers (5-10 individuals). Habitats at these sites included a wet area along the edge of a citrus field, a wet area along a drainage ditch, around the edge of a small pond, and damp bare areas in a grassland. One of the sites was subsequently lost to urban development and no individuals have been found there or at the other sites in the past 10 years. Many others workers have searched unsuccessfully for this form in the past few decades. Although records for this beetle are limited to Hidalgo and Cameron Counties, it may be more widespread in the Rio Grande Valley as suggested by Gage and Sumlin (1986). Searching west of the known sites may offer the best chance for finding new sites. *Cicindelidia n. subtropica* is widely separated (>700 km) from the closest record for the nominate subspecies in Reeves County, Texas. Like some of the other south Texas tiger beetles, it apparently ranges south into Mexico (Boyd et al., 1982). The third author has collected it in Tamaulipas.

Ellipsoptera nevadica olmosa Vaurie A (2) was described from specimens collected along Los Olmos Creek, Kenedy Co., Texas (designated as the type locality) and from two sites in southern New Mexico (Dona Ana County) (Vaurie 1951). More recently it has been found in the Salt Flat area of West Texas. Despite the wide separation of the south Texas and western populations, they have similar maculation patterns, the only character used in distinguishing them from other *E. nevadica* subspecies. It is unusual that such two widely separated forms without intervening populations would be the same subspecies, and in fact, a recent study found several morphological characters which distinguish them and suggests the Texas and New Mexico population are separate subspecies (Knisley et al., 2001). The patterns of adult seasonal activity are also different with adults in south Texas being more common in the fall than early summer (most records in September and October) but only from June to August in New Mexico. For the purposes of this paper, we consider them different forms. The habitat in both Texas and New Mexico is wet, muddy edges of salt flats, saline ponds and streams. We have records for five sites in south Texas, most are along Los Olmos Creek in Kleberg and Kenedy Counties (12 records) and Port Mansfield, Willacy County (8 records) near the coast. Gaumer and Murray (1972) collected it from Laguna Salado near Falfurrius, Brooks County, but we could not find it there during recent searches possibly because the apparent habitat has been disturbed by drainage modifications and housing developments. Records indicate the populations at these sites are small, and while additional sites may occur within its south Texas range, we consider it very rare.

Cicindelidia cazieri 2+ (2) (Fig. 6C) was the third South Texas taxon described by Vogt (1949). He found it to be common along roadsides about 10 miles north of Rio Grande City, Starr County. Most records we have (20 of the 28) are within 10 km of the type locality. Pearson et al. (2006) report it from Jim Hogg Counties which is approximately 25 km north, but our surveys in that area produced only *Ci. p. politula*. To the west in Webb and Dimmitt Counties only *Ci. schauppi* G. H. Horn has been found. The habitat for this species, like that of its close relatives, *Ci. politula* LeConte and *Ci. schauppi*, is limestone outcrops with rock and gravel substrates in scrub or sparse grasslands. When conditions are ideal (after rainfall) adults may be present in relatively large numbers. It is likely that *Ci. cazieri* occurs at many more sites in Starr County, but most of this area is private ranch land with few roads and thus not very accessible, especially since landowners are not receptive to outsiders on their land. Consequently, the species may receive de facto protection in rangelands but would be subject to habitat loss if these lands are converted to crops. We have no records for Mexico, but it may occur there since limestone outcrops extend south of the border.

Amblycheila hoversoni Gage 3+ (3) is a large, flightless nocturnal species described by Gage (1991) from Live Oak County, Texas. He lists it from 19 sites in 11 counties in south and southwest Texas. We have records for three other counties. It is found most commonly in undisturbed thorn tree woodlands with well drained caliche soils, and less abundant in more open habitats further west (Pearson et al., 2006). Because some of its range is in an area of extensive agriculture and urban development, some populations have probably been lost because of habitat disturbance or loss. However, it occurs over a relatively large area in a variety of habitats, so there are likely to be additional undiscovered populations. Most of the sites are private ranch lands where they may be protected from development and are probably only minimally affected by cattle grazing. This species is likely to range south into Mexico, but has not been found there yet.

Dromochorus velutinigrens W. N. Johnson 2+ (3) was described by Johnson (1992) from near Riviera, Kleberg County, Texas. The range maps in Pearson et al. (2006) show it from eight sites in seven counties, including Willacy, Kleberg and Cameron where it has been most recently collected. A variety of habitat types have been reported for this species, including sandy paths and roads in grassy areas of open forest and coastal savannas as well as salt flats, salt marshes, coastal prairies and clay dunes (Pearson et al., 2006). Gage (1992) indicated that coastal sites may be periodically inundated by high water. Little is known about its biology but like other *Dromochorus*, it is flightless and usually found moving quickly through open patches of grassy vegetation, thus making it difficult to detect. Although many workers have failed to find specimens at the type locality, we are aware of it being collected in that areas in the past two years. Gage (1991) provided an additional description for this species and suggested it may be more widespread across south Texas. We concur and attribute a lack of records to its ephemeral activity and difficulty in detecting it in the variable habitats where it occurs. Even though Boyd et al. (1982) list *D. belfragei* from Tamaulipas, Mexico, it is probable that this record is actually *D. velutinigrens*.

Ellipsoptera macra ampliata Vaurie 2 (4) is a riparian species found on sand bar habitats. Unlike other subspecies of *E. macra*, it has a restricted range being found only in north central Texas (Pearson et al., 2006). Vaurie reported it from 3 counties plus another adjacent county with an apparent intergrade population of *E. m. ampliata* x *C. m. fluviatilis*. We have records for ten sites, most of which are from a short section of the Brazos River. We could not confirm if records from four other counties to the southeast along the Trinity River were this subspecies. The subspecies has been found in recent years at several of the historic sites which supported large populations (based on numbers in collections and our site visits) in earlier years. We have no evidence of loss of sites or impacts to the riverine habitat although this has not been well studied.

Cicindela formosa pigmentosignata Horn 2 (5) occurs in open sandy areas of pine forests habitats of east central Texas extending into small areas of adjacent Louisiana and Arkansas (Pearson et al., 2006). We have records for 22 sites, most in Texas and most prior to 1980. Information from collectors who have looked for it in recent years confirms it to be no longer present at five or more sites where it previously occurred. In addition to these lost sites there are probably others that have also been lost due to conversion of the habitat to other uses which is occurring in this area. Based on this limited information we believe this subspecies has experienced significant decline in the past few decades and should be included as a rare subspecies.

Tetracha impressa Chevrolat 2 (2) ranges from far South Texas to northeastern Mexico (Naviaux 2007). In the United States, this flightless, nocturnal species has been reported to be common around lights at night near a river in the area of Brownsville (McGown and Shank, 1975; Freitag, 1999). We found only eight records for it, all in Cameron and Hidalgo Counties. There appears to be no accurate information on its habitat, but apparently it would be most common in riparian or wetland areas. Although more extensive collecting in south Texas counties is needed to determine its true distribution, the few existing records suggest that in the U. S. it is probably limited to few areas in far south Texas.

Eastern

Cicindelidia floridana Cartwright (Fig. 6D) 1+ (not rated) was recently rediscovered in south Florida and elevated to full species status on the basis of several morphological characters, habitat and seasonality (Brzoska et al., 2011). Unlike its sister species in the

Ci. abdominalis group which occur in sandy scrub or barren habitats, this species is found in pine rockland habitat with patches of sandy substrate. The type locality has been lost to urbanization and the species is now restricted to three small contiguous sites in the Richmond Heights area of south Miami. Highest counts at each of the three sites ranged from 2 to 45 adults and although some areas of these relatively small sites were not surveyed, suitable and occupied habitat was limited to a few scattered patches of more open sand within very densely vegetated and unsuitable habitat. Extensive surveys were conducted in both scrub habitats and most of the pine rockland sites in Miami-Dade, Ft. Lauderdale and Palm Beach Counties (Knisley, 2008). Most were unsuitable probably because they were too densely vegetated or the substrates were mostly oolitic limestone rock with few or no sand patches. The existing sites are protected and managed by the use of controlled burns but the burns have been much too infrequent to maintain the open areas needed by this species.

Microthalax olivacea Chaudoir (Fig. 5D) 1+ (3) was early described from Cuba (Chaudoir 1854), but first reported in the United States from a specimen collected in a light trap on Grassy Key in the Florida Keys (Woodruff and Graves, 1963). Since its discovery it has been reported from seven Florida Keys, Monroe County (Allens, Crawl, Grassy, Indian, Long, Lower Matecumbe, Summerland Keys) and Stock and Perrin Islands. Its habitat is coral rock and sand beaches. Woodruff and Graves (1963) suggested it was a strong flier that may have been introduced from Cuba by hurricane winds, and became well established in the Keys. The most recent records we have are in 1980 and 1994. Our visit to several known sites in 2013 indicated little or no habitat remained as a result of shoreline development. Thorough surveys including light trapping are needed to determine if this species still exists in the Florida Keys.

Cicindela patruela Dejean includes three named subspecies, although one of these *C. p. huberi* is not recognized as a valid subspecies in recent treatments of the group (Freitag, 1999; Pearson et al., 2006). Although initially considered localized, Willis (2000, 2001) found it common and more widespread. *Cicindela patruela patruela* Dejean 3 (3) (Fig. 6E) is widely distributed from Maine south to northern Georgia and west to Minnesota (Pearson et al., 2006). It is included on several state lists as a species of concern and considered as imperiled by NatureServe Explorer. Reported habitats include pine and/or oak barrens and upland mixed forest lands on sandy soil where it is has a patchy distribution in forest openings where eroded sandstone has accumulated (Acciavatti et al., 1992, Knisley and Schultz, 1997). We have historic records of nearly 100 sites throughout this range, but it is also known to have been lost from many of these and elsewhere is usually present as small localized populations (Willis, 2001, Mawdsley, 2007). Willis (2001) suggested that all subspecies were at risk because of limited dispersal ability and a restriction to specific aged sandy habitats that were scarce and declining. Mawdsley (2005) documented its extirpation from all historic barrens sites in Maryland. In West Virginia, it was reported from nine counties and locally abundant at some sites (Acciavatti et al., 1992). We are aware of over 40 sites where it has been found in recent years although many have small populations. More thorough surveys throughout its range will undoubtedly produce more sites and viable populations; thus overall we do not consider it as rare as indicated by NatureServe.

Cicindela patruela consentanea Dejean (Fig. 5E) 1- (2) historically occurred in pine barrens from Long Island to the Delmarva Peninsula (Kaulbers and Freitag, 1993), including 36 sites in seven New Jersey counties (Boyd, 1978). A recent study of its biology and conservation by Mawdsley (2007) found it was likely extirpated from most of the historic sites. He found populations at only four sites, all within state forest or wildlife management areas where there was at least some level of protection. At these sites it occurred along sandy trails and firebreaks in barrens dominated by *Pinus rigida* and oaks. At several sites it may have benefited from prescribed fire management, a method of management that could be successful in improving habitats and creating new sites for this subspecies. Mawdsley suggested more survey effort in the Pine Barrens would undoubtedly yield additional sites, but overall this subspecies is likely to be rare. More recent information indicates it may now be found only in Burlington and Ocean Counties where there are two large populations and several smaller ones (D. Duran, personal communication).

Cicindelidia marginipennis Dejean 2- (2) (Fig. 6F) is found on cobblestone river island or edge habitats over a relatively broad area from New Brunswick, Canada south to Alabama and west to Indiana and Kentucky. Throughout this region it is found at scattered localities along at least eight river systems and most apparently with small populations. These include the Connecticut River in New Hampshire and Vermont, the Delaware along the New Jersey/ Pennsylvania border (although this population may now be extinct), the Ohio in West Virginia, Sciota and Paint Creek in Ohio, the Whitewater in Indiana and the Cahaba and Coosa in Alabama. Some workers believe the Alabama populations represent a distinct subspecies. In recent years new populations have been found in New Brunswick (Sabine 2004), Maine (Ward and Mays 2010), western New York (Schlesinger and Novak 2011), Kentucky (Laudermilk et al., 2010), and western Pennsylvania (B. Coulter, personal communication). Other historic sites are known to have been lost due to impacts from dams and other disruptions of river flow. Some of the extant populations are in more remote areas and/or not currently experiencing habitat impacts, so rangewide the species is less at risk than before these new locations were found.

Cicindelidia rufiventris hentzii Dejean (Fig. 5F) 2 (1) is endemic to opens areas of granite rock ledges and quarries of hills in the area near Boston and northeastern Massachusetts (Pearson et al., 2006). There are older records for at least 20 localities and four counties in this area (Middlesex, Norfolk, Gloucester, Essex) (Wilson, 1971). Valenti (1996) suggested that this subspecies should continue to thrive because large populations are protected within the Middlesex Fells and Blue Hills reservations, although the number of sites and distribution are limited. He also reported finding intergrade populations of *Ci. r. hentzii* and *Ci. r. rufiventris* from Plymouth County, bordering Norfolk County to the southeast.

Discussion

The above accounts of 61 extant potentially threatened tiger beetle species and subspecies plus the four listed and two candidates, represent nearly a third of the 220 named forms of U. S. tiger beetles. Most of the unlisted forms are endemic subspecies with very restricted distributions in the western U. S. and although there is uncertainty about the validity of some of the subspecies, we consider them to be important in contributing to the genetic diversity of the species. The large number of named subspecies including information on their distribution and abundance that is important for determining rarity is in part a function of the popularity of tiger beetles, especially by non-professional entomologists. Among the many forms we include, several stand out as being critically imperiled and most worthy of immediate protection based on completed studies of their conservation status. Both *C. tranquebarica joaquinensis* and *Ci. floridana* have been extensively surveyed to confirm their very limited distribution, small populations and currently existing threats to their survival. Consequently, we recommend these two taxa should be immediately considered for listing by the USFWS.

As is the case with most animals and plants, the primary threats to tiger beetles are loss and/or disruptions to their habitats from human activities. This has resulted in the loss of many sites for many of the taxa and is an especially serious threat to the many that are limited to few sites. Probably the second most important factor impacting tiger beetles is encroachment of vegetation from natural succession or invasive plants. Knisley (2011) reviewed the significance of this factor and how natural or man-made disturbance factors may counter this factor by creating open areas of habitat needed by tiger beetles.

The effects of small population size including genetic decline, the Allee effect and related factors may be important as populations continue to decline, although little is known about this effect for tiger beetles. Many tiger beetle species are well known to be a colonizing species that experience dramatic fluctuations in population size, local extinctions, bottlenecks, recolonization and probably a significant loss of genetic diversity. However, our field work has found that small populations (<50-100 adults) of a number of species have persisted for many years with significantly fluctuating numbers (Knisley, 2012a; Knisley and Hill, 2013). These observations suggest that tiger beetles may be much less impacted by low population size than has been widely documented for vertebrates.

Overcollecting is very frequently mentioned having an important negative impact on tiger populations as it has for other popular groups that are widely collected. There is no doubt that adult tiger beetles, especially the rare ones are widely sought after and collected by tiger beetle workers, collectors and amateur naturalists. There also appears to be a marked increase in the sale of specimens on the internet in recent years. In general, however, we believe this factor has little impact for most forms and we have no evidence of collecting a negative impact. In general, tiger beetles are sufficiently elusive, ephemeral, or distributed throughout their habitat such that collection of a high proportion of adults at a site is unlikely and thus would not lead to a decline, if the habitat is suitable. Also important is the presence of one or more cohorts of larvae that will be available to produce new adults in the subsequent year or years. However, it is reasonable to assume that at some sites where adults are highly concentrated in a localized and limited area where they are easily found, collecting a high percent of the population over could cause declines, especially if it occurs before oviposition.

The future of tiger beetle conservation

Additional listing of tiger beetles and other insects by the USFWS is not likely to progress significantly in the coming years and overall prospects for conserving more tiger beetles are not encouraging. Among other issues, USFWS workers are presently spending much of their time responding to a law suit requiring them to deal with the long list of candidate species. Thus, undertaking new listings is being hampered. The budget and work force for the Endangered Species Program has always been much too limited for dealing with the existing and increasing numbers of declining forms. With so many rare species to deal with, including many high profile vertebrates, insects are often a lower priority. Some USFWS regions and state offices have no personnel with expertise or interest in insects and other invertebrates, so by default insects are less likely to be considered. We have found the listing of tiger beetles is most likely to occur when there is an individual at the USFWS who has a special interest and willingness to push along the process of listing and recovery. There is also a scarcity of professional and amateur tiger beetle workers with the time and interest in providing the necessary information needed by the USFWS to consider taxa for listing. Our experience with listed tiger beetles indicate the efforts to list was primarily a result of individuals contacting or petitioning the USFWS and/or providing results of their research with evidence of rarity. For example, petitions by individuals were the impetus for listing considerations of *C. ohlone* and *C. albissima* while the first author informed regional workers at the USFWS about presumed rarity of *C. puritana, C. d. dorsalis*, and *C. highlandensis* which resulted in funding provided to conduct status surveys of these species. Interest and study by researchers at the University of Nebraska led to the listing of *C. nevadica lincolniana*.

Other broader issues will also hamper progress in conservation in general and especially endangered species. Nationwide there seems to be a growing distrust, ignorance and even disdain for science and conservation issues. One example of this is continuing efforts by some political factions to weaken the Endangered Species Act and other conservation efforts. These efforts are finding more support in recent years because of the current economic and political climate. Relevant examples with tiger beetles are the recent withdraw of a proposal to list *Cicindela albissima* as a threatened species by the USFWS, probably in in part because of the public/political opposition in Utah, a state that overall is unfriendly to endangered species. Efforts to establish a recommended amount of critical habitat for the Salt Creek Tiger Beetle were also thwarted by public opposition to insect conservation. So, in summary, the future for listing and conserving more species, especially insects, will involve considerable resolve by amateurs and professionals alike.

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