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Apparent Extinction of the Tiger Beetle, *Cicindela hirticollis abrupta* (Coleoptera: Carabidae: Cicindelinae)

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Abstract

The results of this study indicate the historic range of *Cicindela hirticollis abrupta* Casey was limited to only five sites within the Sacramento Valley of California. Extensive searches within and beyond its historic range along the Feather and Sacramento Rivers in 2001–2004 failed to find any individuals of this tiger beetle and very little suitable habitat. Another tiger beetle, *C. o. oregona* Dejean, which occurs in a much greater array of water edge habitats, was common at some sites. The cumulative effects from the Oroville and Shasta Dams, including loss and deterioration of sandy edge river habitats and prolonged high water levels, probably caused the extirpation of *C. h. abrupta* in the late 1980's to early 1990's.

Cicindela hirticollis Say, 1817 is a polytypic species with eleven recognized subspecies (Graves *et al*. 1988) and is one of the most widely distributed tiger beetles in North America. It is a littoral-riparian species of sandy soils, occurring in water edge habitats including on both the Atlantic and Pacific coasts, major estuaries, the Great Lakes and many other large lakes and major rivers of the United States and Canada (Knisley and Schultz 1997; Acorn 2001). *Cicindela hirticollis* may be abundant on wet beach sand, sandbars or moist pans within dune fields, but always where underground moisture is near the surface (Shelford 1908; Wilson 1967). This species has a spring-fall activity period but is distinctive in that some adults are typically active in the summer also (Shelford 1908; Knisley and Schultz 1997). The length of the life cycle ranges from two years in the northern parts of its range to one year in the south (and probably in California also). Although widespread and often abundant, many populations of *C. hirticollis* have declined because of habitat loss and disturbance due to human activities. For example, Nagano (1982) reported that a great increase in human construction and habitat alteration of the shoreline caused a significant decline in southern California populations. In New England, populations disappeared from many sites in the past 30–40 years because of increased beach usage and other human disturbances along the coast (Leonard and Bell 1999). The species also declined in distribution and abundance along the Rio Grande River in New Mexico, apparently because altered water flows have eliminated or modified the terraced floodplain (Knisley *et al*. 2001).

Cicindela hirticollis abrupta was described by Casey (1913) from Sacramento, California. Graves *et al*. (1988) confirmed the validity of this subspecies in their taxonomic review of the species, and distinguished it from other subspecies (including *C. h. gravida* from the southern California coast) by the combination of dark black-brown dorsal coloration and a pronounced recurved humeral lunule. Collection records in Graves (1988) indicated its range was limited to a few sites along the Sacramento and Feather Rivers, most commonly along the Feather River near Nicolaus, Sutter County. The potential rarity of this tiger beetle was indicated by its listing as a category 2 species by the U. S. Fish and Wildlife Service (USFWS 1989). The category 2 designation (no

longer used) was for species that were believed rare but information was insufficient for formal listing as threatened or endangered. The objective of this study was to determine the current distribution and abundance of *C. h. abrupta* and its conservation status.

Methods

This study involved a review of both the historic and current distribution of *C. h. abrupta*. To determine the historic and recent distribution of *C. hirticollis*, we searched the literature, examined specimens from the relevant university, museum and private collections, and consulted with knowledgeable colleagues and collectors. The collections we examined or obtained records from were: California Academy of Sciences (San Francisco), California Department of Food and Agriculture (Sacramento), University of California–Davis, University of California–Berkeley, Carnegie Museum of Natural History (which had recent acquisitions of several major collectors), American Museum of Natural History (New York), U. S. National Museum (Washington), Arizona State University (Tempe), Los Angeles County Museum (provided by Chris Nagano) and private collections of David Brzoska, Walter Johnson, Ron Huber, and Tom Schultz. We also contacted several other private collectors who recently searched for this insect.

Field surveys for *C. h. abrupta* were conducted during the adult activity period (April to early October) in 2001, 2002, 2003, and 2004. We surveyed all potential sites within its known historic range and many additional sites from over 150 km north to 300 km south of this area (Fig. 1). Potential sites (sandy water edges habitats) were identified from an examination of topographic maps and aerial photographs, and from field reconnaissance. The most intensive searches occurred along the Feather River from just south of Nicolaus north to Yuba City and along the Sacramento River from Colusa north to Butte City. These were the river sections that had the most recent collection records (Colusa in 1951 and Nicolaus on numerous dates from the 1950's to 1985) and were believed to have the best potential remaining habitat. These river sections were accessed by boat. All edge and interior sand or gravel bars along the entire length of each of these river sections were completely surveyed 4–6 times from 2001 to 2004. Additional river sections that were surveyed by boat 1–2 times were the Feather River from Nicolaus to Verona and the Sacramento River from Colusa south to the City of Sacramento. Other survey areas that were accessed by land and spot checked included the Sacramento River north of Butte City and from Colusa south to the delta area, and sections of the Yuba, American, San Joaquin, Mokulumne, and Kings Rivers.

We used a visual search index method (Knisley and Schultz 1997) to determine the presence and numbers of *C. h. abrupta* and any other tiger beetles. This method is appropriate for determining presence or absence and also may provide a relative index of abundance. The method involves a visual examination of the ground surface 5–10 m ahead while walking slowly along the water edge of the site. The back beach areas, where present, were also checked, but since nearly all surveys were done on warm, sunny days, tiger beetles would typically be active on the cooler and wetter sand near the water edge. Spot searches were also made for larvae at sites where there were adult tiger beetles or potential habitat. When we found larvae they were dug out and identified in the field. Larvae of *C. hirticollis* are easily distinguished from other tiger beetle larvae by the presence of short thick pronotal setae that are visible with the naked eye (Knisley, unpubl. notes). Potentially important habitat features, such as size of the site, substrate type (sand, gravel, pebbles), vegetation cover and human disturbances were also recorded. These factors contributed to an evaluation of the site's apparent suitability or unsuitability as habitat for *C. h. abrupta*. Coordinates of all survey sites were recorded using a Garmin Legend GPS unit.

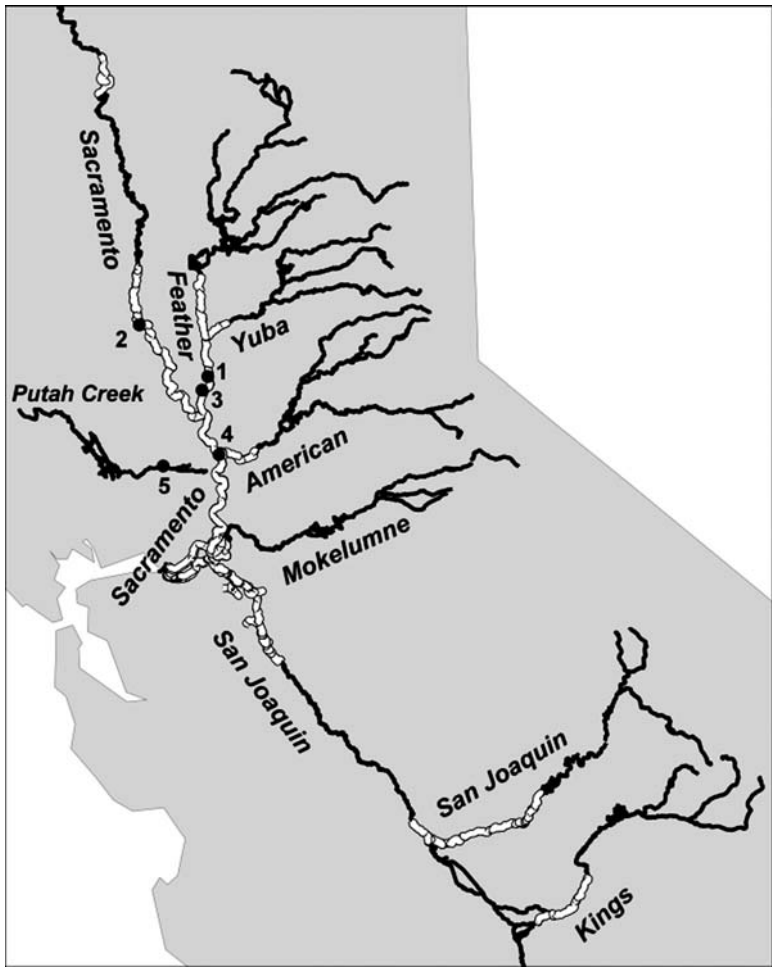

Fig. 1. Map showing the surveys areas for *C. h. abrupta*. Specific river sections surveyed are indicated as double lines. Single bolder lines were unsurveyed sections.

Results

A search of collection records and the literature confirmed that the historic distribution of *C. h. abrupta* was within a relatively small area of the Sacramento Valley, from west of Davis (and possibly as far as Oakland), east to West Sacramento and north to Colusa (Fig. 1). Confirmed collection records and specimens are known from only five locations, as follows: the Feather River near Nicolaus, six miles south of Nicolaus, Sacramento (probably West Sacramento), Davis, and Colusa (Table 1). An additional eight older records from San Francisco (7) and Oakland (1) are not included because the specimens are of uncertain taxonomic status (but probably *C. h. gravida* LeConte). Most records (20 of 30) are from the Feather River near Nicolaus. This does not include additional Nicolaus specimens in some collections that had the same dates.

Table 1. Known collection records for the Sacramento Valley Tiger Beetle, *Cicindela hirticollis abrupta*. Source abbreviations: AMNH, American Museum of Natural History; CALAC, California Academy of Sciences; CDFA, California Department of Food and Agriculture; CSU–LB, California State University, Long Beach; LACM, Los Angeles County Museum; RRMC, Robert Murray collection. See Figure 1 for site locations.

Site no.	County	Locality	Date	Numbers	Source	Collector
1	Sutter	Feather R., S of Nicolaus	20-VI-42	25	CALAC	N.L. Rumpp
1	Sutter	Nicolaus	23-V-44	1	LACM	A.T. McClay
1	Sutter	Nicolaus	23-V-44	29	U.C. Davis	A.T. McClay
1	Sutter	Feather R., S of Nicolaus	6-VII-51	3	CALAC	N.L. Rumpp
1	Sutter	Feather R., 1 mi NNE Nicolaus	2-VII-70	1	CSU–LB	J.M. Sheppard
1	Sutter	Nicolaus, Feather R	4-VII-70	9	CDFA	F. Andrews
1	Sutter	Nicolaus, Feather R	5-VII-70	3	Carnegie	F. Andrews
1	Sutter	Nicolaus, Feather R	21-VII-70	7	CDFA	F. Andrews
1	Sutter	Nicolaus, Feather R	21-VIII-70	2	CDFA	F. Andrews
1	Sutter	Nicolaus, Feather R	21-VIII-72	3	Carnegie	F. Andrews
1	Sutter	Nicolaus	VII-74	4	CDFA	F. Andrews
1	Sutter	Nicolaus	VII-74	1	Carnegie	F. Andrews
1	Sutter	Nicolaus	30-V-74	2	CDFA	F. Andrews
1	Sutter	Nicolaus	13-IX-74	2	CDFA	F. Andrews
1	Sutter	Nicolaus	13-IV-74	12	CDFA	F. Andrews
1	Sutter	Nicolaus, Feather R	30-V-75	1	Carnegie	F. Andrews
1	Sutter	Hwy 99 Feather R, .2 mi N bridge	13-VI-83	25–50 seen	D. Brzoska	D. Brzoska
1	Sutter	Nicolaus, Feather R	14-IV-84	18	Carnegie	H.P. Boyd
1	Sutter	Hwy 99 Feather R, .2 mi N bridge	14-IV-84	>250 seen	D. Brzoska	D. Brzoska
1	Sutter	Hwy 99 Feather R, .2 mi N bridge	11-V-85	10	J. Shetterley	J. Shetterley
2	Colusa	Colusa	15-VIII-55	1	U.C. Berkeley	D. Burdick
2	Colusa	Colusa	1-VIII-57	2	U.C. Berkeley	D. Burdick
3	Sutter	6 mi SW Nicolaus	7-IV-59	13	CALAC	N.L. Rumpp
4	Sacramento		July	4	CALAC	F.E. Blaisdel
4	Sacramento	Sacramento	27-V-18	3	CALAC	E.P. vanDuzee
4	Sacramento	Sacramento West	5-VII-1944	3	U.C. Davis	A.T. McClay
4	Sacramento	Sacramento	1950	?	RRMC	J.H. Robinson
4	Sacramento	Sacramento	1-VIII-55	1	U.C. Davis	E.A. Kurtz
5	Yolo	Davis (possibly Putah Creek)	1934	?	AMNH	?
5	Yolo	Davis (possibly Putah Creek)	Aug. 1935	14	U.C. Davis	J.J. duBois

The Nicolaus site may not have supported the largest population, but was probably the most accessible to collectors. Concentration of collection records at one site is common with many tiger beetle species as a result of an earlier worker (probably Norman Rumpp in this case) finding a convenient site for collecting a rare or localized form and subsequent collectors going to that site to obtain specimens. This situation often results in the true range of a species being underestimated.

All records for the localities other than Nicolaus are from much earlier years with the most recent being from 1955 and 1957 (at Colusa). Other specimens were taken at

Table 2. River sections, numbers of sites surveyed and general habitat characteristics.

River	Location of river section	No. of sites	Sites with *C. oregona*	Characteristics of section
Feather	Jct. with Sac. River to Yuba City	28	13	Many bars with coarse sand, many vegetated; little habitat
Feather	North of Yuba City	6	4	Most bars with coarse sand substrates
Sacramento	Colusa to Butte City	16	11	Most bars with coarse sand to gravel; little potential habitat
Sacramento	Butte City to Redding	10	0	Most bars with gravel to cobble substrates
Sacramento	Colusa to Sacramento	18	0	Few bars with fine sand but high; most channelized
Sacramento	Sacramento to Delta	8	7	Little or no sand edge; vegetated banks
Yuba	Yuba City to 15 km east	5	0	Most bars with gravel to cobble substrates
American	Folsom Dam to West Sacramento	6	0	Most bars with gravel to cobble substrates
Mokolumne	Near junction with Sacramento R.	3	0	Little or no sand edge; vegetated banks
San Joaquin	Delta to east of Fresno	33	0	Little or no sand edge; vegetated banks
Kings	River west of Kingsville	9	0	Little or no undisturbed sandy edge; vegetated banks

localities labeled as "Sacramento" (1918, 1950, 1955) and "Sacramento West" (1944). Exact locations of these sites are uncertain but they may have been near the confluence of the Sacramento and American Rivers. There is, at present, a sandy floodplain habitat in this area (Discovery Park) where we found some *C. oregona*, but heavy disturbance from human activity has impacted this site historically and at present. No major river or habitat occurs at Davis, but this site might be west of Davis at Putah Creek, which according to some earlier workers had extensive sandy habitat before construction of a dam there (C. Rogers, pers. comm.). The collection records do not provide any useful information on numbers of individuals present at the site since usually only small numbers were present in collections. The only indication of population size was estimates of 25–50 adults in 1983 and over 250 in 1984 at the Nicolaus (D. Brzoska, pers. comm.). These records were among the most recent ones we found for *C. h. abrupta*.

The most significant result of this study was our inability to find any individuals of *C. hirticollis abrupta* at any of the more than 140 sites surveyed between 2001–2004 (Table 2). Except for a few sites along the Feather and Sacramento Rivers, most sites surveyed lacked appropriate habitat for *C. hirticollis*. This species requires fine sand and terraced floodplain habitat with low sandy water edge bars. Twenty of the Feather and Sacramento River sites surveyed did have adults and sometimes larvae of *C. o. oregona*. The presence of this species is not unusual because it is probably the most common and widespread west coast tiger beetle (especially in California), occurring in a great variety of water edge and other habitats. We found it at sites where there was considerable disturbance from human activity or cattle trampling and on river bars where substrates consisted of coarse sand, gravel or pebbles. Its presence at many of these sites may also be related to its dispersal and colonizing characteristics. For

example, we sometimes found it on wet sand bars that had been exposed only 1–2 weeks earlier by lowering water levels.

Our examination of sites during the field surveys indicated there is now very little suitable sandy floodplain habitat for *C. hirticollis abrupta* within its historic range. Many river bars were present along the Sacramento River north of Colusa and on the Feather River north of Nicolaus, but most were unsuitable as habitat because of coarse-grained substrates that ranged from coarse sand to cobble. Other bars were unsuitable because of heavy vegetation along the water edge, especially where there were silt deposits over the sand or gravel substrates (Table 2). The Sacramento River south of Colusa had very few bars because this area was extensively channelized and had rip-rap (boulders used to fortify the river banks) in most sections. Surveyed sites well south of the historic range along the San Joaquin and Kings Rivers most often had little or no low sandy edge because of dense water edge vegetation or steep banks. The only remaining possible habitat was a few sand bars north of Nicolaus on the Feather River and just north of Colusa on the Sacramento. Some of these were large (100+ m long and 20+ m wide), low enough to provide larval habitat and had substrates composed of medium grain sand.

Discussion

The results of this study strongly support the extinction of *C. h. abrupta*. Because the river edge sites where *C. hirticollis* would have occurred were easily identified and thoroughly searched, and because the adults would have been active in open areas during the survey periods, there seems little likelihood we would have not found individuals if they had been present. Also, the repeat surveys of all of the historic and other sites at least once per year for four years would have accounted for the year-to-year variations in abundance seen for many tiger beetles. Further evidence is the failure of several other tiger beetle workers to find this beetle along the Feather River during the 1990's.

Cicindela h. abrupta was probably once more widespread within the historic range, specifically within the long section of the Sacramento River between Sacramento and Colusa and at many of the bars along the lower Feather River from its confluence with the Sacramento River at Verona to north of Yuba City. The lack of collection records in these sections is probably due to their being less accessible or because suitable habitat in these areas was lost much earlier. For example, much of the lower Sacramento River was heavily impacted by channelization, rip-rapping and construction of the Shasta Dam (built in the 1940's) well before the impacts on the Feather River (Scott *et al.* 1984). A few vestiges of potential habitat are still present here along the meandering channels in the form of fine to medium sand deposits on small elevated sand bars.

The apparent requirement of *C. hirticollis* for sandy river edge floodplain habitats where extensive low bars or edges provide near-surface moisture has made it susceptible to the effects of dam construction and resulting river changes. Our studies of *C. hirticollis abrupta* and its habitat in the Sacramento Valley suggest that construction of the Oroville and Shasta Dams was probably the most important cause of its decline and apparent extirpation. The habitat changes were probably gradual and cumulative over the past several decades, starting after the construction of the dams. Specific changes that we found were the loss of sandy point bar habitat, decline in habitat suitability from increased particle size, silt deposition, increased vegetation, and prolonged periods of high water levels which could cause beetle mortality and disrupt its life cycle (Fenster and Knisley, in prep.). By trapping sediments, the bars downstream from these dams continued to be eroded but not replenished by the periodic flush of sediments from upstream, except from tributaries below the dam. Thus, sand bars and sandy floodplains become changed, reduced or completely removed. Along the Colorado River,

Dolan *et al.* (1974) found that most of the sandy deposits were produced by summer floods and peak flow periods and fluvial river terraces were produced by the alternating cycle of erosion and deposition from natural variations in water levels. This type of loss or severe disruption of habitats could have eliminated populations of *C. hirticollis abrupta* and/or isolated them by distances from other populations that would be too great for successful recolonization. Several workers who collected this species in the past (Don Burdick, Fred Andrews, Dave Brzoska) all told us that the sand bars areas where they collected specimens were much larger then than what we found during our surveys.

The periods of reduced and stabilized flow associated with dams has also apparently lead to the increased vegetation growth we found on many bars. This reduces the open areas that *C. hirticollis* adults need for thermoregulation, foraging and other normal activities and which larvae need for foraging and development. In most natural, undammed rivers the seasonal pattern of episodic floods scour the sandy bars and create open, unvegetated substrates (Dolan *et al.* 1974).

The prolonged high water levels on the Feather River since the construction of the Oroville Dam, and especially in recent years, could have caused direct mortality to adults and larvae by drowning or indirectly through inundation of their habitat during critical periods of adult oviposition, larval development and overwintering. On the Feather River at Nicolaus, for example, the river gauge was at 6.4 m or higher for periods of several weeks to several months in 1986, 1993, 1995, and 1997–2000 (http://cdec.water.ca.gov). Our field observations at river edge sites in the area indicated that these levels would have inundated most or all of the bars where beetle populations might have occurred. Recent laboratory studies have demonstrated that adults and larvae can survive only several days of immersion in water and may respond to flooding by leaving their burrows and floating to the surface (Brust *et al.* in manuscript). These high water periods may have been the final extirpation event for any remaining populations, since there would be no refuge for adult beetles, and larvae in burrows would have been killed or emerged to be carried downriver where little available habitat would have resulted in larval mortality.

If *C. h. abrupta* is extinct, as believed, this would be the first tiger beetle known to have suffered such a fate. Several other species are Federally listed as endangered or threatened (*C. d. dorsalis* Say, *C. puritana* G. H. Horn, *C. ohlone* Kavanaugh) or are candidates for listing (*C. highlandensis* Choate, *C. albissima* Rumpp, *C. nevadica lincolniana* Casey). Two other tiger beetles (*C. chlorocephala* Chevrolat, *C. latesignata obliviosa* Casey) have apparently been extirpated from the United States but may still occur in Mexico. Many other species are rare or at risk of extinction, primarily because of habitat loss (Knisley and Schultz 1997). A much greater interest and more research in insect conservation are needed to protect these rare tiger beetles and many other insects from the increasing threats of extinction.

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