

## ***Cicindis horni* Bruch (Coleoptera: Carabidae, Cicindini): The Fairy Shrimp Hunting Beetle, its way of life on the Salinas Grandes of Argentina**

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### **Abstract**

Discovery of a large population of the rare and poorly known carabid beetle *Cicindis horni* Bruch on the Salinas Grandes of Córdoba Province, Argentina provided an opportunity to record aspects of its behavior and life history, and to test several hypotheses previously made about its way of life. This highly unusual species was known in the literature from the description of only two museum specimens and its phylogenetic relationships ambiguous. Adults spend the night in search of food or mates swimming on the water surface of alkaline water bodies. Mid-tibial natatorial setae, tarsal setal fringes, ventral vestiture, and genal/pronotal planing surfaces plus decumbent and very sharply pointed mandibles are specific adaptations that permit adults of this species to behave as swimming superspecialist predators. Therefore, there have been four independent invasions of the aquatic habitat by aedeophagan Coleoptera. Populations of *C. horni* Bruch are probably limited by the extent of the great salt flats of Argentina (550,000 hectares) located in north-central Argentina and are further limited edaphically within the overall geographic range.

**Key words:** Cicindini, *Cicindis horni*, Argentina, Salinas Grandes, adult beetle behavior, semi-aquatic carabid beetle, anostracan fairy shrimp, *Thamnocephalus* sp., The Fairy Shrimp Hunting Beetle

### **Resumen**

El descubrimiento de una gran población del raro y poco conocido carábido *Cicindis horni* Bruch en las Salinas Grandes de la provincia de Córdoba, Argentina, permitió registrar aspectos de su comportamiento e historia natural y evaluar diferentes hipótesis anteriormente propuestas sobre sus hábitos de vida. Esta rara especie, de la cual hasta el presente solo se habían descrito únicamente dos especímenes en la bibliografía y sus relaciones filogenéticas se desconocen, presenta características marcadamente inusuales entre los carábidos. Los adultos transcurren la noche en busca de ali-

mento o cópula nadando sobre cuerpos de agua alcalinos. La presencia de sedas natatorias en la tibia, filas de sedas en el tarso, pubescencia ventral y una superficie de desplazamiento genal/pronotal sumada a sus mandíbulas decumbentes y aguzadas serían algunas adaptaciones que permiten a esta especie comportarse como un predador acuático “superespecialista.” Por lo tanto, han ocurrido cuatro invasiones independientes del hábitat acuático por los Coleópteros adefagos. La distribución de las poblaciones de *C. horni* Bruch estaría delimitada al ambiente de salinas (550.000 ha) que se extiende por el norte y centro de Argentina, y edáficamente restringida dentro de este rango geográfico.

**Palabras clave:** Cicindini, *Cicindis horni*, Argentina, Salinas Grandes, comportamiento de los adultos, carábido semiacuático, anostraco, *Thamnocephalus* sp., Cascarudo cazador de camaroncitos

## Introduction

R.G. Beutel (1995:178) wrote of adult Gyrinidae: “Riparian; surface dwelling. Surface dwelling habits are not found in any other group of Coleoptera.” On January 12, 2004, the very rare carabid beetle species *Cicindis horni* Bruch (Figure 1) was represented by two well-described museum specimens (Kavanaugh & Erwin 1991). However, neither specimen had associated data about habitat, nor precise collecting locality. Therefore, Kavanaugh & Erwin (1991) had set forth predictions based solely on morphological attributes of the two available adults as to where populations of this rare species might live and their way of life. We test these hypotheses herein. Later, Kavanaugh (1998) attempted to place the tribe within current carabid classification using a phylogenetic analysis. His placement of Cicindini amongst the basal clades of Carabidae is likely correct, but its alignment with an adelphotaxon needs further data to obtain resolution.

By midnight on January 13, 2004, we had already observed hundreds of individuals at a unique habitat, the Salinas Grandes of Córdoba Province, Argentina (Figures 2, 3) doing remarkable things for a carabid beetle, namely swimming, much like adults of Gyrinidae do only slower, on the surface of a salty vernal pool: a century-old carabid conundrum confronted and cracked. Here we report our studies of the species in its natural habitat in January through March 2004 and on several days of observations of live beetles in a makeshift laboratory in Tucumán, Argentina.

Kavanaugh & Erwin (1991) reported all that was known at that time about the tribe’s two species, one of which lives in the Persian Gulf (known from Kuwait and Iran) and the other in Córdoba Province of Argentina. One specimen of *Archaeocindis johnbeckeri* (Bänninger) of the Persian Gulf was recorded from a “mud grab” on an open intertidal mud flat by an investigator of mud skippers; his evaluation of the catch was that the beetle was probably in a crab’s burrow (Stork, 1982). Not much was known about the Argentine species’ habitat, although specimens cited by Reichardt (1977:375), but not seen by Kavanaugh & Erwin (1991), came from “near large salt flats.” We have not been able to

locate these specimens collected by the Argentine collector, A. Martinez. One other specimen that was seen by the latter authors was labeled as being collected at UV light. Kavanaugh & Erwin (1991) noted that adults of *C. horni* have what appeared to be swimming hairs on their middle tibiae (Figure 6) and fringes of setae on their other tibiae and tarsi (Figure 5). In order to rediscover this species in the field, the present authors took these structural attributes and the known (restricted) type locality (Kavanaugh & Erwin 1991) as clues to where we might find additional specimens for the purpose of knowing something of their way of life and obtaining specimens in 95% ethanol for later DNA analysis. The tribe Cicindini has not been well classified within the Carabidae because of the lack of study specimens, lack of knowledge of their way of life (Kavanaugh & Erwin 1991), and the lack of access to DNA samples that might provide additional data for phylogenetic analyses.

Kavanaugh & Erwin (1991) after describing in detail structural attributes of adults of this species wrote the following: "Their swimming hairs, elevated eyes, and mouthparts lead us to suggest that they are superspecialist, amphibious predators at the edges of shallow alkaline pools, the carabid equivalent of a crocodile." This hypothesis was central to our study plans, as described herein. We needed to find living beetles so that we could observe them. Hence the present report focuses on a description of the species' habitat and that habitat's availability in northern Argentina, as well as behavior of adults. With these, we test predictions made by Kavanaugh & Erwin (1991) based solely on their observations of structural attributes of adult beetles, along with scant label data.

## Materials and Methods

### *Field sites*

Reichardt (1977:375) reported that beetles were collected near salt lakes by A. Martinez, an Argentine general collector (these specimens have not been located). Therefore, in October 2003, we traveled to the restricted type locality of *C. horni* at Guanaco Muerto, Córdoba Province, Argentina (30°29'S, 65°03'W). This restricted type locality (Kavanaugh & Erwin 1991) is not within 5 km of such a salt-lake habitat, rather it is in the Chaco plant community that is heavily grazed by cattle in the area around Guanaco Muerto. Likely, because this small cattle ranching area of Guanaco Muerto may have been the only one with a formal name in 1979, the collector used it as the nearest locality to where one adult was actually collected at UV light. So, we continued past Guanaco Muerto several kilometers on a dirt road north to Los Baños (merely a farm house at 30°16'S, 65°07'W) and found extensive salt beds, a small salty stream, and what might have been a salt lake, now trampled by cattle. The habitat was very dry, the rains usually not coming until December. The next day while traveling north to Tucumán on Route 60, we discovered an easy access onto the Salinas Grandes (Figure 2) at Km. 895.5 on Route 60 (30°00'S, 64°30'W).

We returned to Los Baños in January 2004 and found the habitat no different than in October 2003; the rains were late in coming. We established a UV light and observed that there was considerable insect activity, but no *Cicindis* beetles were found. That night, a large storm hit the area. Since the storm seemed to cover a large area, we went to the other very accessible site on Route 60 two evenings later to set up our UV light and examine the shore line (Figure 3) after dark with head-lamps. Once the beetles were discovered swimming, we spent hours making visual observations of their behavior. Later, in March 2004, with our Sony HandyCam, we made extensive videos of the beetles in action.

During the project, from early January through early March, a total of 78 beetles were collected and part of the series was kept alive for breeding, part was collected into 95% ethanol, and part was preserved in ethyl acetate soaked paper towel for later preparation as museum specimens. As specimens died in the laboratory, they were similarly preserved in ethyl acetate soaked paper towel, or put in 95% ethanol.

### *Laboratory*

We collected live specimens to carry out laboratory observations on their behavior and reproductive cycle. Beetles were kept in plastic cups with wet substrate and water collected from the pool where we made our field study. We separated the beetles by sex by observing their genitalia under a hand lens (the nearly transparent ventral abdominal segments permitted this) and finally we had seven couples of *C. horni* for reproductive experiments, plus three lonely males. We fed them with salty ham and periodically moistened the surface of the substrate with salty water collected from the pool. Other types of meat was offered, but ignored by the beetles. We made observations during day and night. Night observations were done under red light, in order not to disturb their behavior. An artificial pool was set in a plastic tray using water and substrate from the pool on Rte. 60 to observe combing, standing, swimming and diving behavior, all of which was captured on video.

## **Morphology**

### *Unique attributes*

Kavanaugh and Erwin (1991) provided line drawings made from one or the other of the four specimens (Argentina and Persian Gulf) of cicindines available for that study. Now that fresh specimens became available, we took the opportunity to make SEM images to amplify previously drawn attributes (Figures 4–7), and add an image of one not previously illustrated (Figure 8), that is the ventral vestiture found on both sexes.

Figure 6 provides clear evidence of the swimming hairs and the extent to which they are developed in adults of this species. Figure 8 includes the femur with its hydrofuge setae providing evidence that only the tibia and tarsus submerge while surface swimming. Also, Figure 8 demonstrates the pervasive amount of ventral hydrofuge setae that keeps beetles afloat while hunting their fairy shrimp prey.

The asymmetric claws (Figure 4) are likely used for moving about the surface under water, a feature of many water beetles that have the same attribute and behavior (Kavanaugh & Erwin 1991). The antennal comb (Figure 7) is normal for several basal carabid beetle lineages (Kavanaugh & Erwin 1991; Kavanaugh 1998).

### Description of habitat

The Salinas Grandes (Figures 2, 3) area is part of a larger saline environment covering some 550,000 hectares in Argentina located across the north of Córdoba Province, the southeast of La Rioja Province, the west of Catamarca Province and the southwest of Santiago del Estero Province. Salinas Grandes is located in the Chaco Phytogeographical Region (Cabrera 1994). This region covers an extensive area and contains complex landscape units corresponding to terrain and soil properties. The predominate vegetation is that of dry forest, but there are also scrublands, grasslands, and salt desert areas. The salt desert areas correspond to internal drainage basins, where the flat land accumulates water during the rainy season and upon evaporation saline crystals are deposited on the soil surface (Figure 2).

The altitude of this basin ranges between 150 and 300 meters above sea level. The climate of this region has a monsoonal regime with an average annual precipitation of less than 500 mm. The average annual temperature is 19.9 °C (Cabido & Zak 1999).

Our study was carried out in the southern area of the Salinas Grandes (near 30°30'S, 64°50'W), where a large vernal pool was formed after the first rains in January 2004 (Figure 3). We estimated the size of the pool to be about 15,000 m<sup>2</sup>. The pool overall was shallow and reached no more than 20 cm in depth. The soils there are rich in sand, lime, and clay (45.2% sand, 22% lime, 32.8% clay. PH= 8.35, electric conductivity = 90 m/s) and they have a 2.3% proportion of sodium carbonate which indicates an incomplete percolation. They are moderately rich (CO=1.91%; MO 3.3%) in organic matter. As water evaporates and the substrate surface dries, tiled-soil polygons are formed (Figure 9).

We visited numerous other sites within the predicted range of *C. horni* and found several types of soil surfaces. Knowledge of the diurnal habits of the adults lead us to believe that only where the soil, when dry, can form tiled-soil polygons will populations of these beetles be supported because they dig burrows under the polygons in which they rest during the hot day-time temperatures, and perhaps even aestivate in the dry season.

At our study area, the vegetation is determined by the local edaphic characteristics and it can be classified as Low Halophytic Scrubland (Cabido & Zak 1999). The vegetative community in the area consists of xerophilic and halophilic species between 30 to 70 cm in height. The plants are widely spaced leaving considerable portions of soil uncovered (Figure 2). The nearest vegetation to this pool consists of shrubs of *Allenrolfea patagonica* (*Quenopodiaceae*), *Prosopis strombulifera* (Lam.) Benth (*Leguminosae*) and a member of *Poaceae*. *A. patagonica* was the predominate shrub in the area.

**Behavior of adults of *Cicindis horni* Bruch***Diurnal and crepuscular activities*

*Resting behavior:* During the day, adults rest in small burrows (Figure 10) which they excavate under cracked and tiled-soil polygons (Figure 9). We found these 5–6 cm deep burrows with adult *C. horni* in them up to 5 meters from the edge of the pool. Examination of the burrows did not reveal any pupal skins, thus we suspected that the adults made the burrows; later, in the laboratory we watched the beetles make such burrows using their mandibles and front tarsi leaving a granular clay wall for their burrow. Thus, we assume they do this as well on the pool margin late each night or in the morning after a night of feeding and/or mating. Possibly they reuse the tunnels themselves, or perhaps other individuals might encounter ready-made burrows and use them. We did not have the opportunity during our fieldwork due to time constraints to test for this possibility.

*Crepuscular emerging behavior:* The earliest we observed beetle activity was at 1930 hrs while it was still light; a few individuals were swimming on the pool surface in the manner of adult Gyrinidae, but much more slowly and often making short hopping flights with rapid take-off behavior. Crepuscular activity (1930 to 2100 hrs) consisted of beetles leaving their burrows on the shore, flying low or running to the water and then swimming short distances alternating with a “hopping” flight, that is, repeatedly rising to about 0.5 meters and landing again on the water surface within a meter or two.

We did not witness the beetles using the shore line for moving around except to move from burrows to water and back, and for the most part we saw this as a flight movement, not running. Therefore, they are not like the coexisting tiger beetles (*Cicindela* (*Sumlinia*) *hirsutifrons* Sumlin, *C. (Sumlinia) halophila* Sumlin, *C. (Plectographa) siccalacicola* Sumlin, and *Megacephala* sp., the last of which is apparently new). Their *Cicindis* elytral pattern markedly resembles that of *C. hirsutifrons* Sumlin (Figure 11). In flight, the *Cicindis* adults were from a few centimeters to a meter above the soil on their way to the pool and back.

During the day, the shoreline is used by adults of the three *Cicindela* species, however, we did not see the tiger beetles and cicindine beetles together at the same time; adults of *Cicindela* spp. retired before adults of *Cicindis horni* emerged from their burrows. The incredibly similar elytral pattern with that of *C. hirsutifrons* adults (Figure 11) probably indicates that some sort of pattern mimicry exists or perhaps convergence toward a useful cryptic pattern; this will be a subject for future studies. A tiger beetle species of the Red Sea shoreline also has this elytral pattern. Is there a counterpart species of cicindine living there?



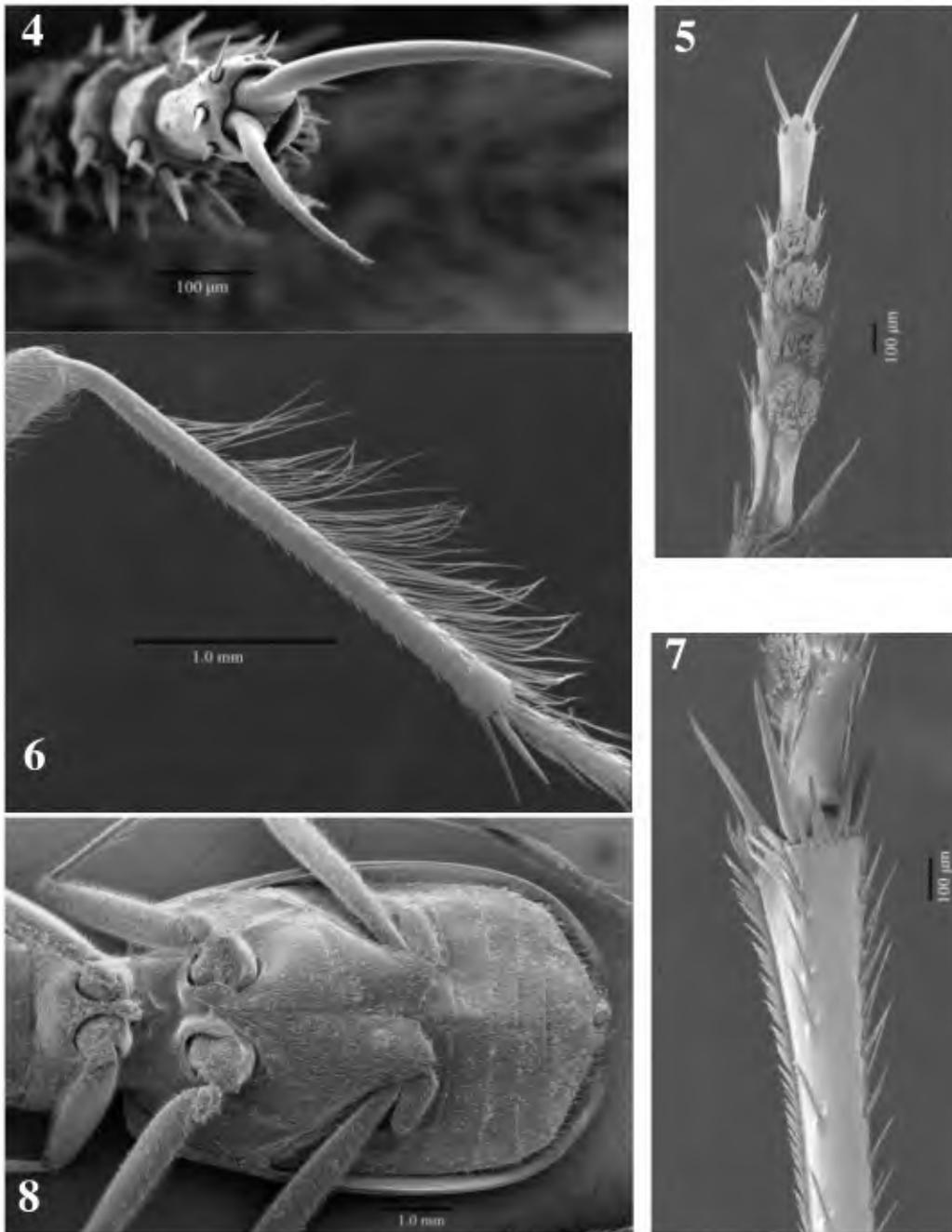
**FIGURE 1.** Adult *Cicindis horni* Bruch feeding on fairy shrimp.



**FIGURE 2.** Margin of the Salinas Grandes, Córdoba Province, Argentina, at Km 895.5, National Highway 60 in October, 2003.



**FIGURE 3.** Vernal pool at margin of Salinas Grandes, Córdoba Province, Argentina at Km 895.5, National Highway 60 after the first of seasonal rains in January, 2004.



**FIGURES 4–8.** *C. horni* Bruch, male. **4.** front tarsal claws, apical aspect. **5.** front tarsus, ventral aspect. **6.** middle tibia, dorsal aspect. **7.** antennal comb, dorsal aspect. **8.** ventral vestiture, ventral aspect.

#### *Nocturnal activities*

*Flying behavior:* By 2130 hrs, flight activity was extensive with tens to hundreds of adults hunting for their prey in our limited study area of no more than 500 square meters of

pool surface of the total available of 15,000 square meters. Given the total size of the vernal pool, there were likely thousands of active individuals. At about this time, they also began flying to the UV light set up about 20 meters from the water's edge. The seven individuals we found at UV light were either on the sheet moving slowly or running erratically on the ground in front of the sheet. These beetles are slow fliers, although their take off from the water surface is rapid. We observed two types of flight patterns (see crepuscular activity above for one of these). When it was dark, after 2115 hrs, activity of the adults was mostly swimming, although many beetles that we tried to capture rose and flew well away above the water surface on which our net swept.



**FIGURE 9.** Tiled-soil polygon typical of some stretches of the shoreline surrounding Salinas Grandes.



**FIGURE 10.** *Cicindis* adult burrow after removing a tiled-soil polygon.



**FIGURE 11.** Adult *Cicindis horni* Bruch and *Cicindela hirsutifrons* Sumlin.



**FIGURE 12.** Adult *Cicindis horni* Bruch swarming, one individual swimming, two perching, two eating fairy shrimp, another standing.



**FIGURE 13.** Adult *Cicindis horni* Bruch perching with slightly bioluminescent fairy shrimp nearby in water (lower left of image).

*Swimming behavior:* Adults swim (Figure 12) on the surface of the water as predicted by Kavanaugh & Erwin (1991). Their ventral vestiture (Figure 8), hydrofuge in nature, keeps them afloat while all 6 legs (tibiae and tarsi) are used as propelling or guiding organs below the surface of the water. We suspected from field observations that the posterior tibiae and tarsi are used as rudders in addition to propelling and the mid and fore-legs are mainly the propelling organs. Adults move their legs alternately, as do Amphizoidae and Hygrobiidae adults. A forward planing surface composed of a genal flange and the forward extension of the thin, fin-like plane established by the anteriorly extended apical angle of the pronotum under the eye allows these beetles to swim in a very directed fashion by using the hind legs as rudders, floating on the hydrofuge vestiture and being propelled with the fore and mid tibiae/tarsi. Although we could not observe it, we believe that by angling down their planing surfaces, the beetles can quickly dive under the water surface, which we observed as we approached them with our collecting nets.

In the artificial pool established in the laboratory, we observed in detail the locomotion of legs during swimming and walking on emergent substrate. When beetles are swimming on the water surface they do so by alternative movement of mid-legs (tibiae with natatorial setae) used as propellers. The propelling function is carried mainly by fast movement of the mid-legs, but we observed some propelling movements also with the fore-legs (tarsi with setal fringes) and the posterior legs. The tarsi and tibia of the mid, fore-legs, and posterior legs are submerged below the surface of the water. The posterior legs are kept almost still and extended posteriorly on the water surface supporting our hypothesis that these legs are used as “rudders.” When walking on emergent substrate the beetle’s locomotion is also the common terrestrial march (Beutel 1995), that is the legs are moved alternately. Thus, the movement of legs is the same no matter the medium on which adults are moving.

*Feeding behavior:* Fairy shrimp, likely *Thamnocephalus* sp. (Cohen, et. al 1999; Cohen, 2000, Cohen 2002), were plentiful in the salty water of the pool and apparently are the specific food items of adult *C. horni*. We observed beetles catching fairy shrimp from the surface while swimming and also saw them searching while walking beneath the surface exploring submerged cracks and crevices for them; beetles engaged in this activity were captured on video. After catching their prey, adults return to the surface, find emergent substrate (soil islets or dead plants stems, see Figure 3), and eat by masticating the prey and imbibing the fluids therein (Figures 1, 12). We also observed adults diving when swimming on the surface and we suspect they had encountered prey beneath them. When not swimming, perching (Figure 12, 13) behavior with head down preceded an excursion beneath the surface and it appeared to be that they were waiting to see the faintly bioluminescent fairy shrimp (Figure 13, lower left of frame). Stance of an adult beetle in the field was often at a kilter, either to the right or left. We suspect this was another form of “perching,” that is, adjusting their lower-level eye (when standing askew) to see beneath the surface of the water. Throughout our study window in the field, we did not observe these beetles eating anything except fairy shrimp (Figures 1, 12), although in the laboratory they

did masticate salty ham meat for a couple days, but after that all our live beetles desisted from eating anything offered.

*Swarming behavior:* Swarming occurred at about 2200 hrs when we were using 3 flash light beams to obtain focus for our digital camera. Fairy shrimp were attracted to the light where it fell upon the water surface (see Figure 13, lower left). Beetles then began swarming and eating the fairy shrimp which they caught from the surface, or while diving, as described above.

*Grooming behavior:* The adult legs are groomed in the same fashion as in other carabids, that is, moving the soil particles from the hind legs to the middle, then to the front where they are removed by the mandibles. The antennae of *C. horni* adults are relatively short and are held erect at about a 45 degree angle and directed anteriorly and separated slightly distally. Both are normally cleaned by the sulcate antennal combs (Figure 7) at the same time, the front legs working to force the antennae down in parallel at about a 20 degree angle. We only observed single antennal cleaning occasionally.

*Mating behavior:* On one occasion at the field site, we observed a mating pair (the only time we saw mating in the field) floating on the salty water on their right side *in copula*. This lasted a few minutes until we disturbed them trying to photograph the event. We did not observe any mating in the laboratory over many days of observation. This may have been due to lack of appropriate food, hence energy, or the artificial water-soil interface we built was not conducive to mating behavior.

### Tests of earlier hypotheses

Predictions made by Kavanaugh & Erwin (1991) based on characteristics of the external structural attributes of adult *C. horni* Bruch are presented in Table 1. The fact that these beetles do swim and dive in alkaline pools supports many of these predictions. However, a few of their predictions are not supported.

One prediction was centered on the concept that, like crocodiles, these beetles lay in wait for prey at the edge of lakes. In fact, they use the entire vernal pool surface in their search for aquatic prey, the fairy shrimp.

We tested beetles in water to see if a bubble of air was trapped in the dense ventral vestiture, or in the deep cavity of the first visible (second) abdominal sternum, but we could not observe that phenomenon even though we entered them from a perching position, their normal way of submerging. However, bubbles of air were carried under the elytra and these may serve for the short length of time they stay under water (longest observed was a little over one minute). Thus, we do not believe the vestiture serves an air-trapping function.

In addition, the beetles are in burrows in the day, or on the surface of the water at night, thus the suggestion that the vestiture serves a thermo-regulating function on hot substrate is not supported.

**TABLE 1.** Predictions made by Kavanaugh & Erwin (1991) based on characteristics of the external attributes of adults of *Cicindis horni* Bruch compared to our observations of living adults in the field and laboratory.

PREDICTION	YES	NO
Live on hot, open, saline habitat	X	
Run on loose, particulate substrate		X
Day active		X
Amphibious	X	
Withstand emersion in water	X	
Surface swimmers	X	
Vestiture hydrofuge	X	
Planing capability	X	
Quick flight take off	X	
Thermal-regulating vestiture		X
Elytral pattern cryptic		?
Superspecialist predator	X	

Note: The question mark indicates our suggested prediction that needs further observations.

The beetles are active in the evening and at night; hence the suggestion that they are day-active like *Cicindela* tiger beetles and other carabid tribes with large eyes is not supported.

These beetles hardly ever use the substrate for running, although they do sometimes go back and forth from a burrow running on top of a rather smooth clay surface, so the suggestion that they, or their sister species in the Persian Gulf run on loose particulate substrate is not supported.

Adults of *C. horni* and adults of the three tiger beetle species with which they share the area do not overlap in the diel cycle. Adults of one of these tiger beetle species has the same elytral pattern as *C. horni* adults. We cannot think of a discerning nocturnal predator that would serve as a selecting agent for the *Cicindis* elytral pattern, however, we must leave this suggestion open to further study, since the similarity between the cicindine elytral pattern and that of one of the coexisting tiger beetle species is striking (Figure 11). We suggest that it may be a primitive attribute dating back to an early Gondwanian time when both lineages were competing for the shore line and perhaps cicindines were diurnal at that time (Ball, pers comm.). The fact that both cicindine species have maintained the pattern after at least 60 millions years of separation suggests that this is an ancient pattern.

Unexpected findings in our studies, that were not predicted by Kavanaugh & Erwin (1991) are: 1) A heretofore “rare” beetle occurs in high density populations and was never adequately collected; 2) These beetles are monophagous on anostracan fairy shrimp; 3) Adults dig burrows; 4) Adults are relatively weak flyers; 5) Adults swim like adult Gyrinidae, but much more slowly; 6) Adults use their hind legs as rudders and propellers, their front and middle legs as propellers; 7) Adults dive for prey and may stay submerged for

longer than a minute (apparently without an abdominal air bubble); 8) Swarming activity occurs when a high density of fairy shrimp are present; 10) Adults comb their antennae with both front tibiae at the same time in a coordinated manner (although they will occasionally do one at a time, as well). To our knowledge, no one has reported the symmetric combing behavior of both antennae at the same time; 11) Mating occurs on the water surface, adults floating on their sides (one observation only); 12) Ventral vestiture serves as a floating function, thus vestiture is hydrofuge in nature; 13) Adults use primarily the entire pool surface for their activities, not the soil at the edge of the pool.

Additional predictions and possible future studies: Kavanaugh & Erwin (1991) pointed out that only cicindine carabids possess asymmetry in claw length. Other beetles with this attribute are various water beetle species in some 2–3 families. We predict that their claws are used for walking and/or anchoring underwater on the clay substrate.

Decumbent mandibles occur in both species of the tribe Cicindini, more markedly so in adults of *C. horni*. Although adults of *A. jolmbeckeri* do not possess natatorial setae on their tibiae, we believe because of their mandibles, they do prey upon fairy shrimp. How this might occur on mudflats of an intertidal estuary is open to future studies.

Much like the explosive emergences of some Ephemeroptera species, we witnessed a similar phenomenon for adults of *Cicindis horni* on the night of January 13, 2004. This may be a characteristic of other vernal pool species of carabid beetles, too.

### Conservation aspects for the future of *C. horni* Bruch

For purposes of disseminating information regarding conservation involving this beetle species, we designate its common name as “The Fairy Shrimp Hunting Beetle,” (Cascarudo cazador de camaroncitos). The habitat of these beetles is well circumscribed, thus we predict their range will be about the same as that of the 550,000 hectares of salt flats in central Argentina, although we believe, importantly, that an edaphic soil type will determine the actual occurrence of populations within that range and that soil type occurrence must be investigated. These salt flats are not used for anything that will destroy the habitat thus far, and much of the Salinas Grandes in Córdoba Province is already under a protected status; hence the species *C. horni* is not immediately prone to extinction unless global warming has unforeseen effects on salt flats, such as even less rainfall for this already desertic environment. These extensive salt flats are now known to maintain three endemic species: the tyrannid bird, *Neoxolmis salinarum*, the octodontid rat, *Salinoctomys loschalchale-rosorum*, and the carabid beetle, *Cicindis horni*. How many more species have yet to be discovered, maybe even other species of *Cicindis* in this very old and unique habitat? We strongly believe that a well planned and concerted inventory effort will be scientifically rewarding and fully supportive of the important conservation efforts in the region.

## Conclusions

Our discovery of a second group of surface swimming beetles brings many questions to the debate about the evolution of early Adephaga. Unfortunately, because we do not yet know where cicindines belong exactly in carabid classification, we cannot yet know the significance of this find in the debate, as it may pertain to convergent adephagan evolution since the Triassic. Morphological studies have been intense with analyses detailing much structural evidence, but they are still inconclusive (Kavanaugh 1998). Aschero et al. (in prep) are exploring this subject with molecular studies at present. Beutel (1988) studied the swimming musculature of Amphizoid beetles and that will be necessary for *Cicindis horni* adults, as well. Because the adults swim like those of Amphizoidae and Hygrobiidae, i.e. alternating leg movements, we expect there to be no specially developed swimming muscles, as in the Noteridae and Dytiscidae where leg movement is synchronized. We have not found the immature stages of *Cicindis horni*, yet these may tell us much about the species, its relationships, and its early evolution. What can be stated presently is that there have been four independent invasions of the aquatic habitat by adephagans, not just three as envisioned by Beutel (1995).

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During review of this paper, it came to our attention that Dr. Sergio Roig Juñent (Laboratorio de Entomología, IADIZA (CRICYT), Mendoza, Argentina) and Sr. Federico Ocampo (graduate student at University of Nebraska in TEAM SCARAB) had found three

specimens of *Cicindis horni* Bruch about 10 km north of our site on the Salinas Grandes in December, 2003. We had told Ocampo about our quest to find this beetle at the annual meeting of ESA in October, 2003. Subsequently, Dr. Sergio Roig Juñent and the present authors, along with Dr. David H. Kavanaugh of the California Academy of Sciences who co-authored the monograph on the tribe, agreed to join forces to work on DNA aspects at the Maddison Lab (University of Arizona, Tucson), and during the next rainy season, 2005, we will search for immature stages of this incredibly interesting carabid beetle.

### Literature cited

- Beutel, R.G. (1988) Studies of the trout-stream beetle, *Amphizoa lecontei* Matthews (Coleoptera: Amphizoidae): contributions towards clarification of the systematic position of Amphizoidae. *International Journal of Insect Morphology and Embryology*, 17(1), 63–81.
- Beutel, R.G. (1995) The Adephaga (Coleoptera): phylogeny and evolutionary history. In: Pakaluk, J. & Îlipi-ski, S.A. (eds.) *Biology, Phylogeny, and Classification of Coleoptera: Papers Celebrating the 80th Birthday of Roy A. Crowson, Volume 1*. Muzeum I Instytut Zoologii PAN, Warszawa, pp. 173–217.
- Cabido, M.R. & Zak, M.R. (1999) *Vegetación del Norte de Córdoba*. Imprenta Nico, 52 pp.
- Cabrera, A.L. (1994) Regiones fitogeográficas Argentinas. *Enciclopedia Argentina de Agricultura y Ganadería*. Tomo II. Primera reimpression. Editorial ACME. 85 p.
- Cohen, R.G., Vernet, S., Corbella, C. & Michelutti, Y.P. (1999) Sobre la presencia de anostracos halófilos del género *Thamnocephalus* (Crustacea, Anostraca) en Salinas Grandes de Córdoba (Argentina). *Physis*, Secc B, 57(132–133), 5–7.
- Cohen, R.G. (2000) About the presence of halophilic anostracans of the *Thamnocephalus* genus from Salinas Grandes at NW of Córdoba (Argentina). *Physis*, (Buenos Aires) 57, 132–133.
- Cohen, R.G. (2002) Description of a new subgenus and a new species of *Thamnocephalus* (Crustacea: Branchiopoda, Anostraca) from the Salinas Grandes Basin, Córdoba Province, Argentina. *Hydrobiologia*, 486, 91–100.
- Kavanaugh, D.H., 1998. Investigations of phylogenetic relationships among some basal grade Carabidae (Coleoptera): a report on work in progress. In, Ball, G.E., A. Casale, & A.V. Tagianti (eds.). *Phylogeny and classification of Caraboidea (Coleoptera: Adephaga)*. Museo Regionale di Scienze Naturali, Torino, pp 329–341.
- Kavanaugh, D.H. & Erwin, T.L. (1991) The tribe Cicindini Bänninger (Coleoptera: Carabidae): Comparative morphology, natural history, and reclassification. *Proceeding of the Entomological Society of Washington*, 93(2), 356–389.
- Reichardt, H. (1977) A synopsis of the genera of Neotropical Carabidae (Insecta: Coleoptera). *Quaestiones Entomologicae*, 13, 346–493.
- Reichardt, H. (1979) The South American carabid fauna: Endemic tribes and tribes with Afriacan realationships. In: Erwin, T.L., Ball, G.E., Whitehead, D.R. & Halpern, A.L. (eds.) *Carabid Beetles: Their Evolution, Natural History, and Classification*. Proceedings of the First International Symposium of *Carabidology*. Dr. W. Junk b.v. Publishers, The Hague, pp 319–325.
- Stork, N.E. (1981) Discovery of *Cicindis*, a remarkable carabid beetle, in Kuwait. *Journal of Natural History (London)*, 16, 883–885.