

## Identifying Characteristics of *Scapteriscus* spp. (Orthoptera: Gryllotalpidae) Apparent Predators of Marine Turtle Eggs

ALEXANDRA MAROS, ALAIN LOUVEAUX, ELODIE LIOT, JULIE MARMET,  
AND MARC GIRONDOT<sup>1</sup>

Laboratoire d'Ecologie, Systématique et Evolution (UMR 8079), Bât. 362, Université Paris Sud, Orsay 91405 Cedex, France

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**ABSTRACT** The leatherback turtle (*Dermochelys coriacea*) (Vandelli, 1761) is classified by the IUCN (The World Conservation Union) as a critically endangered species. Hatching success is as low as 35% in French Guiana, which hosts  $\approx 40\%$  of the worldwide nesting activity. It has recently been shown that mole crickets contribute to the destruction of the leatherbacks at the Amana Natural Reserve. The aim of this paper is to document our observations about these potential predators of marine turtles. Identification keys and sound recordings are provided for *Scapteriscus didactylus* (Latreille, 1804) and *Scapteriscus borellii* (Giglio-Tos, 1894), mole cricket species that live in French Guiana. An abundance index of the presence of juveniles and adults was developed to study mole cricket populations in turtle rookeries and promote new observations.

**KEY WORDS** *Dermochelys coriacea*, *Scapteriscus didactylus*, *Scapteriscus borellii*, sound recordings, rookeries

THE LEATHERBACK TURTLE, *Dermochelys coriacea* (Vandelli 1761), is classified as critically endangered on a worldwide scale by the IUCN (The World Conservation Union) (Hilton-Taylor 2000). Beaches in French Guiana and Suriname host  $\approx 40\%$  of the world nesting activity. However, their hatching success is low: only  $\approx 35\%$  of the eggs produced hatchlings in 2000 (Maros et al. 2003, Girondot et al. 2005). This result was confirmed by Boucharad and Bjørndal (2000), who observed 25% of hatchlings in a loggerhead turtle population. Dogs, black vultures, and humans are known to be the main causes of mortality (Viseux 2001). Our studies were conducted in the Amana Reserve (French Guiana) as a part of the annual survey of the rookery to evaluate the marine turtles conservation status. The study site was Yalimapo Beach, which is 3.6 km long, and  $4 \times 10^5$  eggs are laid in  $>5,000$  turtle nests every year (Girondot et al. 2002). Leatherback turtle nests are found at the ecotone of the beach at the boundary of vegetation bordering the beach. The eggs are laid at a depth of  $\approx 80$  cm in the sand. Green turtle nests are found further back in the vegetation. Yolkless leatherback eggs are unfertile and are deposited on top of the clutch after the yolked eggs have been laid. All green turtle eggs are fertile (Whitemore and Dutton 1985). Observations of mole crickets in turtle nests in French Guiana and Surinam were a first indication that they could be responsible for some egg mortality (Whitemore and Dutton 1985).

Mole crickets have enlarged and flattened fore-tibia with blade-like projections called dactyls for digging in soil. The genus *Scapteriscus* is characterized by two large toothed dactyls (Fig. 1). They spend most of their lives underground. The types of soils they occupy depend on the species in question (sandy, cultivated, or muddy soils). They make three kinds of cavities in the ground: deep mines or tunnels, horizontal mines or galleries just below the soil surface, causing the soil to bulge upward above the surface, and egg chambers made by females. The galleries are made mainly at night when the mole crickets forage in search of food (Fig. 2). Experimental evidence has shown that the mole cricket, *Scapteriscus didactylus* (Latreille 1804), damages the eggs of marine turtles (Maros et al. 2003). Mole crickets reared in 20-liter buckets filled with beach sand and one turtle egg placed at a depth of 25 cm pierced a hole in the egg within 3 d. Three replicates confirmed this observation, and preliminary observations in the field showed that cricket damage could be identified (Maros et al. 2003). A study in progress reveals that a variability of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  in the cuticle of *S. didactylus* is correlated to the temporal availability of food resources (Maros 2003, A.M., A.L., and M.G., unpublished data). Twelve percent of the adults had high isotopic values; a result interpreted as the consequence of a predatory diet on marine animals at the midpoint of the turtle nesting season. This predation relationship had not been previously described. However, *S. didactylus* from the north of South America was introduced on the coast of Puerto Rico, in Martinique, St. Lucia, St. Vincent, Granada, and

<sup>1</sup> Corresponding author, e-mail: marc.girondot@ese.u-psud.fr.

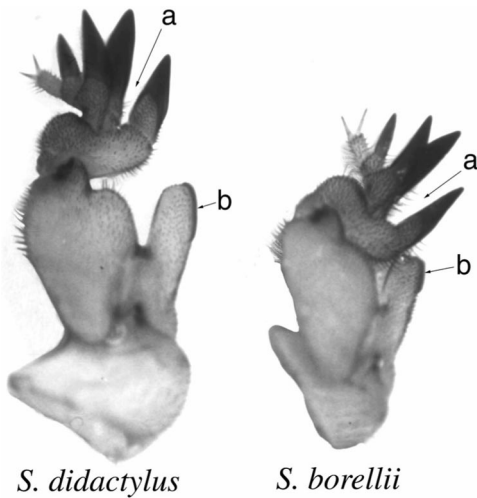


Fig. 1. Right forelegs of *S. didactylus* and *S. borellii* adults. *S. borellii* has a larger interdigit space than *S. didactylus* (a) and the length of the blade on the trochanter is smaller (b).

Trinidad (Nickle and Castner 1984, Frank et al. 1987, Fowler and Pinto 1989). Recently, *S. didactylus* established itself in Australia, where it damages turf (Rentz 1996, Cribb 1998). In the southeastern United States, *S. didactylus* is unknown, but *Scapteriscus borellii* (Giglio-Tos 1894), a carnivorous species, is a pest on the Florida coast (Matheny 1981, Fowler et al. 1985). All the above-mentioned countries have marine turtle rookeries. However, no report has yet been published on mole cricket damage to nests.

In this study, we present morphological traits of cricket juvenile development and singing characteristics to distinguish *S. didactylus* from *S. borellii* and further to quantify turtle nest damage attributable to mole crickets. Individual rearing of 40 *S. didactylus*

specimens showed that juvenile development passes through eight instars, although this number may vary (Maros 2003). The number of instars of *S. borellii* varies from 8 to 10 (Braman 1993).

Three mole cricket species are established in the Amaná Reserve (Maros et al. 2003). *Neocurtilla hexadactyla* (Perty 1832), which seems limited to irrigated crops in heavy clay soils (Fowler and De Vasconcelos 1989), is not discussed here. Two *Scapteriscus* species are reported on sand habitats: *S. borellii* (Giglio-Tos 1894) [syn.] = *S. acletus*, (Rehn and Hebard, 1916), and *S. didactylus* (Fowler and De Vasconcelos 1989, Maros et al. 2003). These last two species are carnivorous (Castner and Fowler 1984, Frank et al. 1987) and of interest as possible egg predators on marine turtle nests. The *Scapteriscus* genus is complicated by introduced species not always detected in new areas, by synonymies, and by sibling species (Nickle 1992, 2003). The structure of an insect signal and its emission frequency could help identification because it is classically used as a specific acoustic signature (Forrest 1983a, b). However, the *S. didactylus* songs have not yet been described.

## Materials and Methods

**Identification of Mole Crickets.** To locate and identify the two *Scapteriscus* species in the field, we recorded the song of 12 males of *S. didactylus* and 1 male of *S. borellii* indoors. *S. didactylus* adults were caught on the beach where the turtles nest. The male of *S. borellii* was caught near a traditional house. The adults were reared alone in containers (30 liters) filled with beach sand (Forrest 1983a). Male courtship and rivalry songs of a female or a male of both species were obtained by introducing the rival or the partner at the very moment of the recording. Containers were maintained indoors at room temperature (25–30°C).

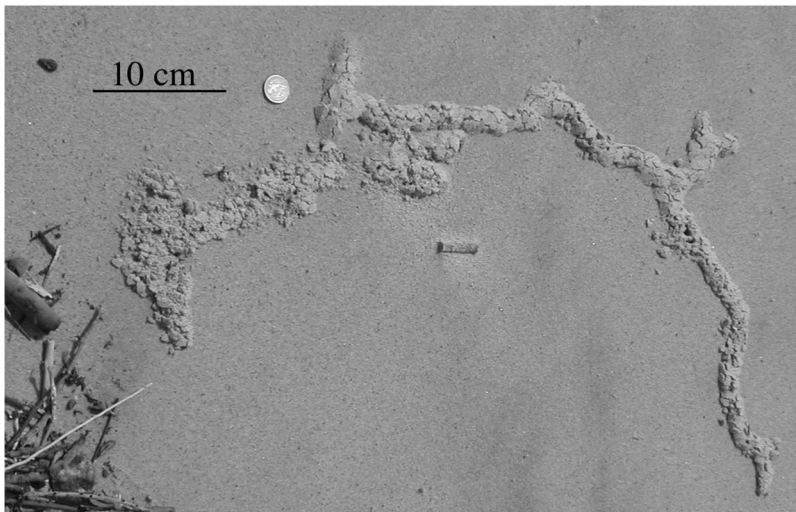


Fig. 2. Mole cricket galleries on Yalimapo Beach. Mole crickets construct a network of galleries beneath the surface and leave trails of pushed-up soil that look like miniature mole tunnels.

**Table 1. Distinctive characters of *Scapteriscus* species occurring in French Guiana**

Distinctive characters	<i>Scapteriscus borellii</i>	<i>Scapteriscus didactylus</i>
Space at the base of the tibia dactyls (Fig. 1) Trochanter blade (Fig. 1)	Dactyls widely separated >0.3 mm short	Dactyls narrowly separated <0.3 mm long
Distinctive colors on the dorsal side of the pronotum	Dark brown with four pale dots arranged in trapeze	Pale brown with a U-shaped drawing
Acoustic signature (Fig. 2); fundamental frequency (mean ± SE); number of teeth on the stridulatory rape (mean ± SE)	2,504 ± 7.2 Hz (n = 140); 47 ± 0.6 (n = 8)	Chirps: 3,756 ± 18.8 Hz (n = 119); sequences of groups of pulses: 3,422 ± 13.2 Hz (n = 30); 83 ± 1.6 (n = 16)
Feeding habits	Mainly carnivorous (Matheny 1981, Castner and Fowler 1984, Fowler et al. 1985)	Herbivorous and carnivorous feeding on growing parts of plants (Castner and Fowler 1984); feeding on arthropods (Frank et al. 1987)
Habitat	Muddy or sandy soils. Often in crops, pastures, river banks (Matheny 1981)	Sandy soils, supporting occasional floods. Often found in golf lawns, beaches and sometimes in forests (Castner and Fowler 1984, Frank et al. 1987, Fowler and De Vasconcelos 1989)

The songs were recorded at night between 2200 and 2400 hours. An Electret Condenser Stereo Microphone (Sony ECM-MS907) was placed ≈30 cm above the container. A portable minidisc recorder (Sharp MT200H, Sharp Corporation, Japan) was used.

In the field, the color pattern on the pronotum is the easiest way to distinguish *S. borellii*, which has four pale dots, from *S. didactylus*, which has a U-shaped color pattern. Distinctive traits are listed in Table 1. For more details, see Nickle and Castner (1984).

**Estimates of Egg Mortality.** After the emergence of leatherback and green turtles, the nests were inspected to identify the causes of mortality. Eggshells were classified according to the type of damage observed on dead eggs or as having been hatched if the remains of the shell were broken in two halves. Counting took place between June and September 2002, during the nesting season at Yalimapo Beach. Thirty-three leatherback turtle nests, *D. coriacea*, and 21 green turtle nests, *Chelonia mydas* L. (1758) were examined. Mole crickets are usually studied by means of light or sound traps during adult flying activity (Walker and Fritz 1983, Walker et al. 1983, Fowler and Pinto 1989). Unfortunately, these beaches are too windy to apply these methods. Extraction methods like pouring diluted liquid detergent onto the sand surface was found to be ineffective because of the low density of crickets and this was hazardous to the turtle nests. The only way to collect adults and juveniles was to catch them by hand in their subsurface galleries. They were inspected at night, using a finger, when crickets were foraging for food. We found the manual technique to be time-consuming. To follow the seasonal variation of the mole cricket population, we used the tunneling activity of *S. didactylus* as an index of presence. The cricket index of presence is based on our observation that only one individual occupies one gallery network at a time. In only 1 of >100 cases, a couple was found in a gallery. On the beach, unoccupied galleries do not remain for a long time. They are swept away by the wind and washed away by the sea. Mole cricket abundance was calculated by counting gallery networks every 2 or 3 d on a quadrant measuring 100 m long and 10 m wide. Galleries were

sampled on 42 occasions from April until 30 September 2002. The captured individuals were categorized into three age groups. A measurement of the width of the pronotum of a cricket and the width of its own gallery was used to link the size of the galleries to the age structure of the *S. didactylus* population.

Statistical analyses were performed using StatView 5 (Abacus Concept 1992) and Microsoft Excel 8. Student's *t*-test and regressions were performed at the 0.05 level.

**Results**

**Habitat Requirements.** In French Guiana, *S. didactylus* frequents wet sandy soils, irrigated crops, and the wettest parts of traditional houses. *S. borellii* was collected in the same inland communities, especially around the fishermen houses. *S. didactylus* was observed in some of the Amana Natural Reserve's beaches: Yalimapo, Farez, and Pointe Isère. These three beaches all have turtle rookeries. It is suspected that the low salinity of the water at Yalimapo Beach (<10 g/liter) is the reason why the mole crickets have established themselves there. However, this mole cricket is also present at Farez Beach, which faces the ocean. *S. borellii* was not observed on the beaches but behind the sand hill bar instead (Maros 2003).

**Acoustic Signature of *S. borellii* and *S. didactylus*.** *Scapteriscus borellii*'s calling song, emitted when the male is alone, was analyzed on a sample of 25 suprapulse elements. The signal lasted >10 s at the mean fundamental frequency of 2,642 ± 4.50 (SE) Hz and 55.2 ± 0.04 pulses/s. The structure of this continuous song was very similar to *S. borellii*'s song available on the Web (Walker 2004). The mean fundamental frequency was 100 Hz lower: 2,753 ± 2.38 Hz. The consistency of these results validated our recording method. Because no other recorded songs were available for *S. borellii*, we recorded the male singing in the presence of a female. This courtship song was a long repetition of the same suprapulse element but at a lower amplitude and mean frequency (2,504 ± 7.2 Hz) than the calling song (Table 1; Fig. 3a). No song was recorded when *S. didactylus* was alone. In the com-

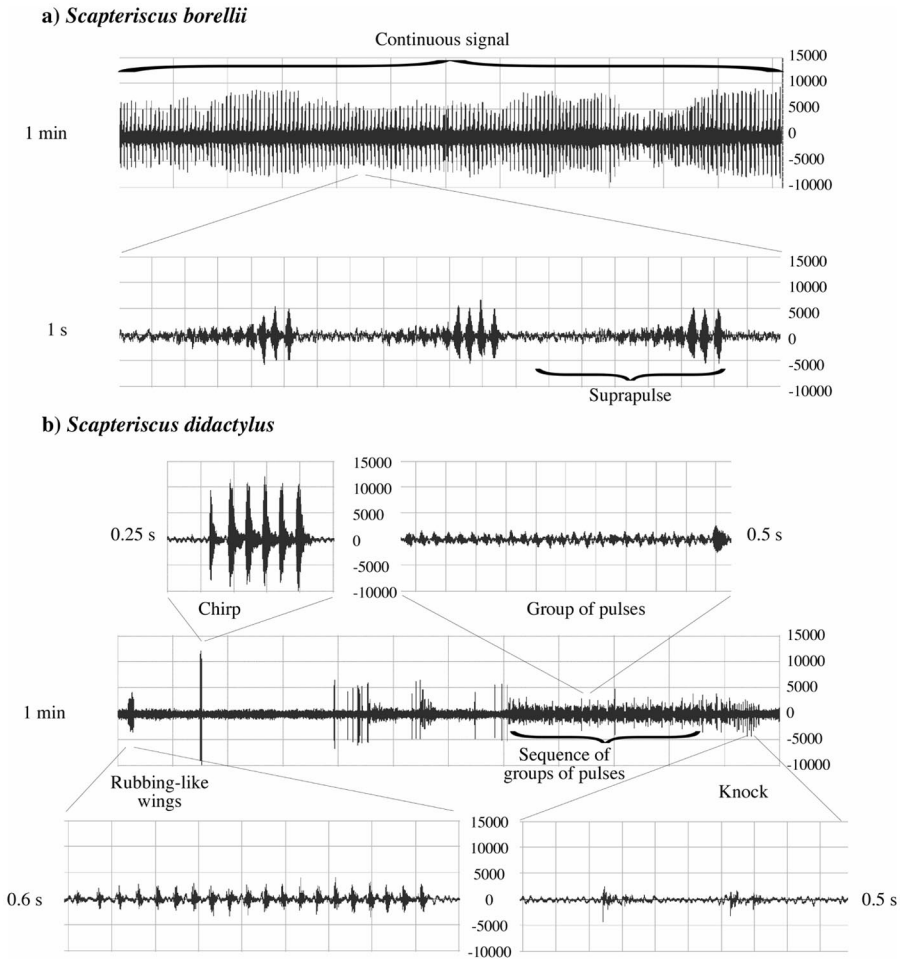


Fig. 3. Oscillogram of the courtship song of a male of (a) *S. borellii* and (b) *S. didactylus*. Recording conditions: temperature: 27°C. Male in the presence of a female. Length of song: 1 min. Analogic signal analyzed with PC software Cool Edit 2000.

pany of a female, *S. didactylus* emitted a complex song from a closed chamber in its gallery. This species does not sing from a horn-shaped outer chamber as most mole crickets do (Nickerson et al. 1979). The song was composed of brief chirps (high in amplitude, irregularly spaced), long sequences of groups of pulses (at lower amplitude), and knocking noises. Knocking was also recorded when the male faced a rival. A rubbing-like noise of wings was also recorded, but we could not ascertain if it was emitted by the male or by the female (Fig. 3b).

The mean fundamental frequency of *S. didactylus*' courtship song was  $3,756 \pm 18.8$  Hz for chirps and  $3,422 \pm 13.2$  Hz for sequences of groups of pulses. This was higher than that of *S. borellii* ( $2,504 \pm 7.2$  Hz; Table 1).

Analysis of the stridulatory files on the tegmen showed that there are, on average, more teeth on the file of *S. didactylus* ( $83 \pm 1.6$  teeth) than on the file of *S. borellii* ( $47 \pm 0.6$  teeth; Table 1). Moreover, the

length of a tooth and the distance between two teeth are greater for *S. borellii* than for *S. didactylus*.

**Distinctive Characteristics of Juvenile Instars.** The reversal of the pterotheca divides the juveniles into two distinct groups. Before the reversal occurs, instars are grouped as  $I_L$  juveniles, with the pterotheca in a lateral position (Fig. 4a). At this stage of development, the wing rudiments are too small to be measured, and individuals could not be differentiated, except by counting molts in rearings. At two molts before the imaginal molt, pterotheca turn on their axes and reverse themselves. These instars of *S. didactylus* are referred to as  $II_R$  and  $III_R$  juveniles (Fig. 4b and c). The ratio of pterotheca length over femur length (Pt/Fe) doubles between the last two instars. At the  $II_R$  instar,  $Pt/Fe = 0.35$  ( $r = 0.60$ ,  $n = 38$ ); at the final instar ( $III_R$ ), this ratio increases up to 0.70 ( $r = 0.61$ ,  $n = 31$ ). At the  $II_R$  and  $III_R$  instars, the male's stridulatory files are conspicuous on the reversed pterotheca, and the subgenital plate of the male is short but

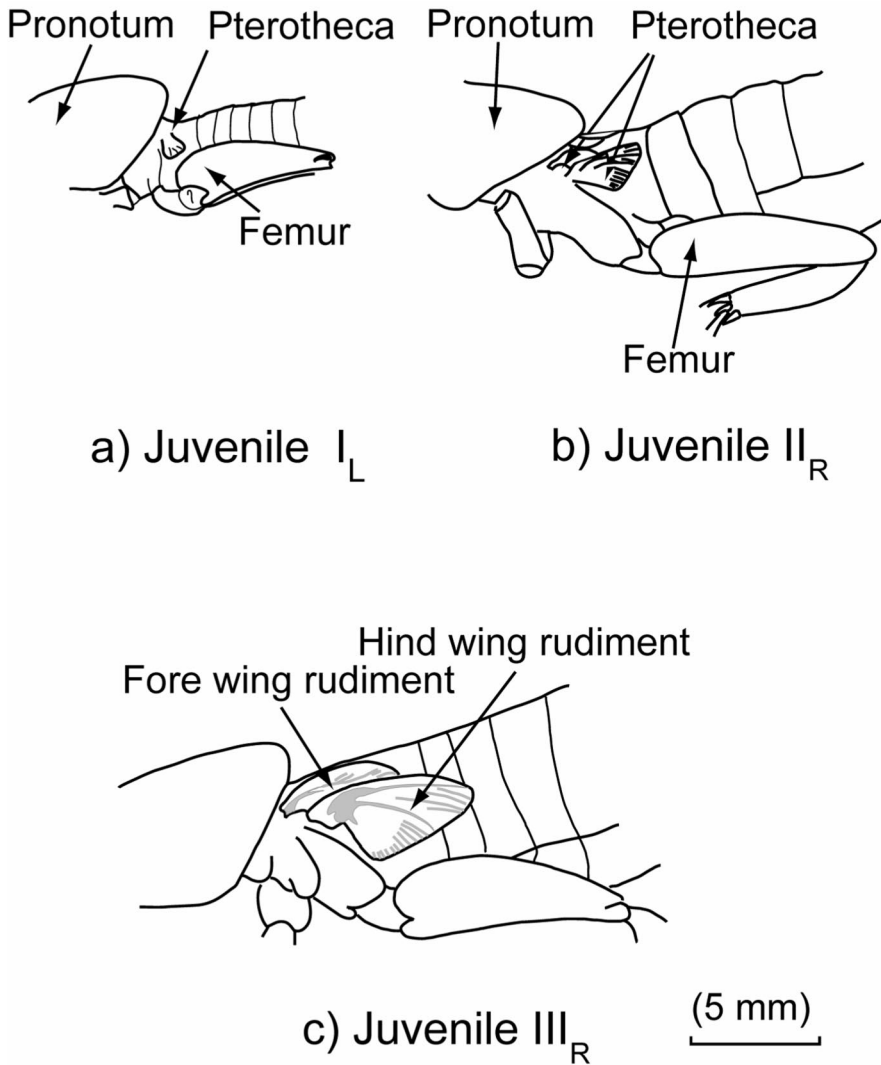


Fig. 4. Stages of development of the juveniles were identified on the basis of the position and size of the pterotheca. (a) Juveniles before reversal of the pterotheca (I<sub>L</sub> juveniles). (b) Reversal of the pterotheca at the penultimate stage of development (II<sub>R</sub> juveniles). (c) Last instar before the imaginal molt (III<sub>R</sub> juveniles).

apparent. The same morphological criteria are valid for differentiating *S. borellii* instars.

**Egg Mortality in Turtle Nests.** Cricket damage to turtle eggshells appears as round holes ≈5 mm in diameter with sharp edges (Fig. 5a). Ghost crabs (*Ocyropa* spp.) cut a large slit in the egg (Fig. 5b) (Viseux 2001), and ants pierce one or many tiny holes (1–2 mm diameter; Fig. 5c). (Viseux 2001, Maros et al. 2003). In nests, eggs damaged by predators are rotten and different from hatched eggs broken in two halves.

All of the turtle nests inspected after hatching at the boundary of the vegetation bordering the beach were attacked by mole crickets (Table 2). In one leatherback turtle nest, we found up to 27 eggs pierced by mole crickets in a clutch of 91 fertile eggs. The overall mortality of leatherback eggs was an average of 57.4% of the fertile eggs laid, and mortality caused by pre-

datation by mole crickets was an average of 15.3% (range, 2.5–40%) of the fertile eggs. During the same 2002 season, green turtles, *Chelonia mydas*, which lay nests higher up on the beach, suffered less predation. From 21 green turtle nests inspected in May 2002, the overall egg mortality did not exceed 21% in any nest. On average, the crickets ate only 7% (range, 0–21.4%) of green turtles eggs. This is about one-half the damage suffered by the leatherbacks (Table 2).

The length of the galleries ranged from 0.5 to 4 m. In addition to these galleries, a few tunnels descend into the sand to a depth of 80 cm to the turtle nest level. The number of mole cricket galleries was at its maximum in June and July ( $n = 25$ , mean =  $201.9 \pm 25.3/1,000 \text{ m}^2$ ), when the maximum density of turtle nests was reached at Yalimapo Beach. Before and after the periods of April–May and August–September, the

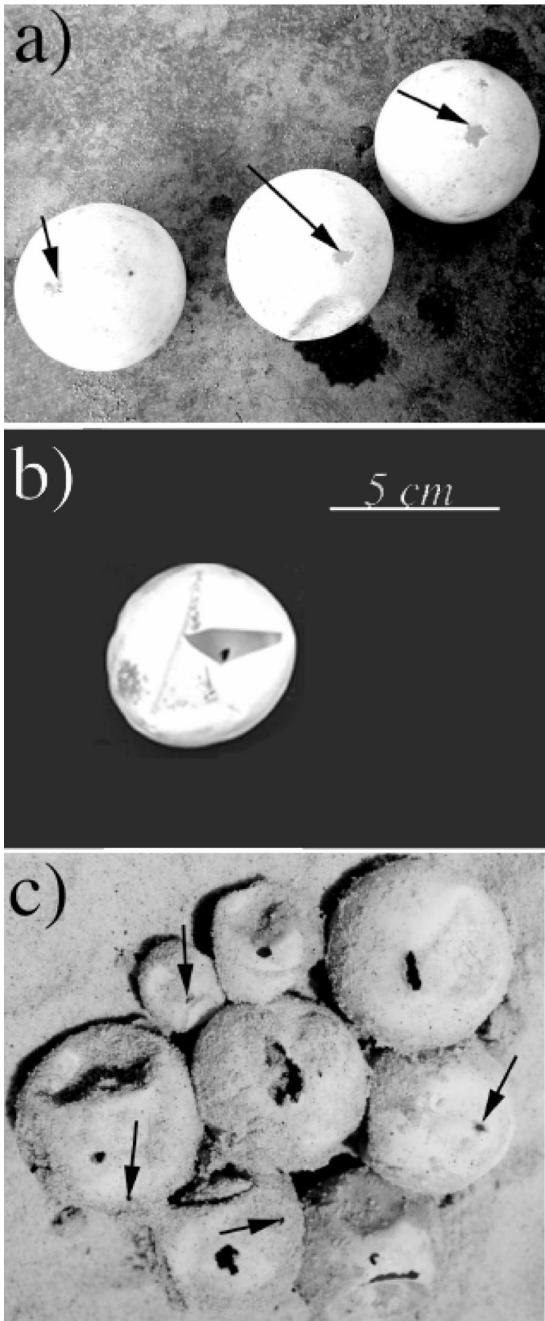


Fig. 5. Damage to leatherback turtle eggs: (a) hole pierced by mole crickets; (b) slit made by a ghost crab; (c) tiny holes made by ants.

galleries were less numerous ( $n = 17$ , mean =  $134.5 \pm 16.2/1,000 \text{ m}^2$ ). This index of presence of the mole cricket varies significantly between the nesting and nonnesting period ( $t = 2.36$ ,  $df = 40$ ,  $P = 0.02$ ).

We observed two successive generations of mole crickets. This was documented by variations in the size of the galleries correlated to the age of the mole

Table 2. Predation by mole crickets in 33 nests of *D. coriacea* and in 21 nests of *C. mydas* during the 2002 nesting season

Mortality of eggs in nests	<i>Dermochelys coriacea</i>		<i>Chelonia mydas</i>	
	Mean	SE	Mean	SE
Total clutch size ( $n$ )	113.7	4.1	116.6	5.5
Yolkless eggs ( $n$ )	29.6	1.9	116.6	5.5
Yolked eggs ( $n$ )	84.1	3.8	0	
Number of hatched eggs ( $n$ )	35.8	2.6	99.2	5.3
Hatching success (%)	42.6	3.6	85.1	2
Total mortality (%)	57.4		14.9	
Predation by mole crickets				
On yolked eggs ( $n$ )	12.9	1.2	8.1	1.7
Percent of predation	15.3	1.6	6.9	1.4
Other causes of mortality (%)	42.1	2.6	8.0	1.4

Nests were exhumed after hatching on Yalimapo beach.

crickets. The linear positive relationship between the width of a gallery and the width of the cricket pronotum inhabiting the gallery is significant ( $r^2 = 0.83$ ; Fig. 6). On the basis of the gallery width, an age interval was ascribed to the inhabitant with a 70% chance of success (Fig. 6).

To establish the age structure of the population, three distinct age intervals were defined:  $<1.3 \text{ cm}$ , galleries of newborn individuals;  $1.4\text{--}2.4 \text{ cm}$ , galleries of  $I_R$  juveniles;  $>2.6 \text{ cm}$ , galleries of  $II_R$  and  $III_R$  juveniles and adults.

A new generation established itself in August, when small galleries of newborn individuals replaced the large galleries mainly present in June (Fig. 7).

## Discussion

Mole crickets at the Amana Reserve are as important a pest to turtle rookeries as any other vertebrate predators [dog, *Canis familiaris* L.; black vulture, *Coragyps atratus* (Bechstein, 1793); or humans] (Viseux 2001). One-quarter of the overall nest egg mortality was caused by crickets. An abundance of one or two gallery networks per  $10 \text{ m}^2$  does not seem very high compared with the severe damage to turf, as shown by Brandenburg (2002). However, the crickets were sufficiently numerous to damage every leatherback nest found on the beach.

Major efforts to identify *S. didactylus* on coastal beaches and in estuaries would help to determine to what extent the "cricket/marine turtle" relationship observed at Yalimapo is unique or has been underestimated elsewhere. It could not be shown that the other species (*S. borellii*) was a predator of marine turtle eggs. However, it would be interesting to know if this North American mole cricket is often encountered near marine turtle rookeries.

The reasons why *S. didactylus* settled on the beach might be related to the large number of eggs laid. Leatherback eggs represent an important potential food source for predators. Approximately 5,000 turtle nests are built each year within the first 80 cm of the beach (Girondot et al. 2002). French Guiana hosts  $\approx 40\%$  of the worldwide nesting activity, and Yalimapo Beach is the biggest leatherback rookery in the world

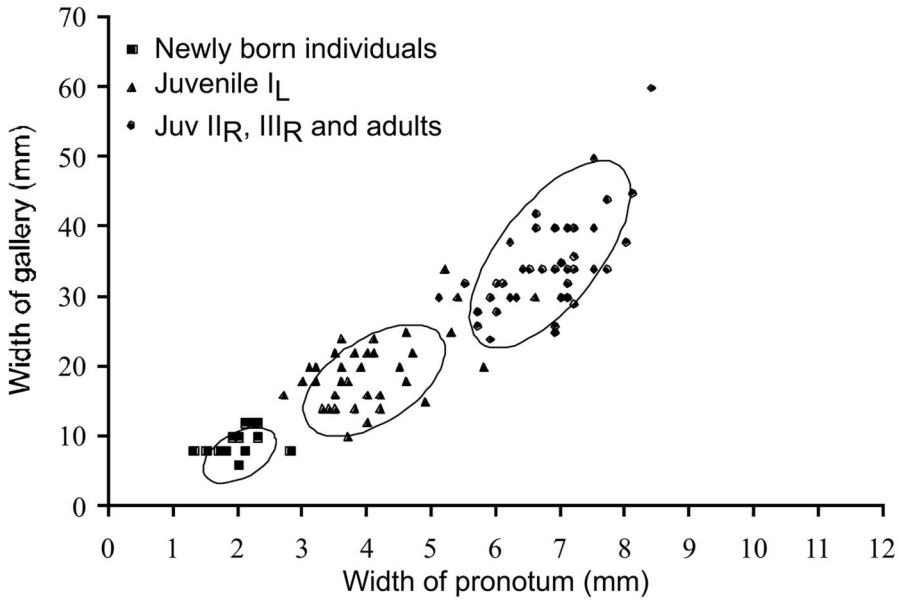


Fig. 6. Relationship between the width of a gallery and the width of the pronotum of an individual captured in the same gallery ( $n = 86$ ). Ellipses at the 70% CI delimit groups of individuals of a known age. This correlation was used to deduce the estimated age of the inhabitant from the size of its gallery.

(Hilton-Taylor 2000). Predation of the nests seems to be related to the spatial distribution of mole crickets that are generally found on the sand beach and not in the vegetation up-gradient (Maros et al. 2003). Green turtle nests in the herbaceous vegetation are less subject to predation than the leatherback nests on the vegetation-free sand beach. The diet of *S. didactylus* seems variable. It has been described as a herbivorous

cricket eating mainly turf grasses (Castner and Fowler 1984) or as a carnivorous species (Frank et al. 1987). *S. didactylus* could be an opportunistic species, which profits from turtle eggs encountered during its tunneling activities. Another hypothesis is that the cricket became specialized and developed a new predatory relationship to turtle eggs. The song recordings could help us to corroborate the status of *S. didactylus* at the

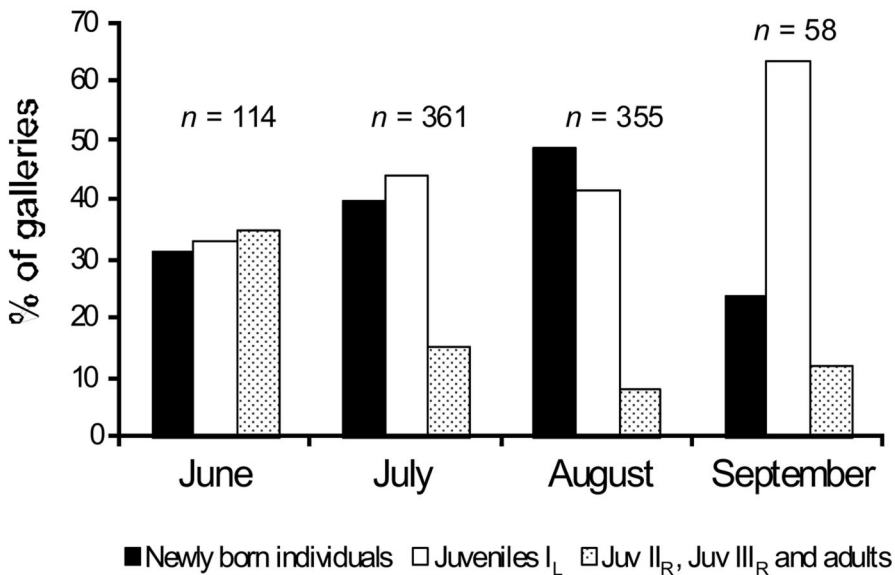


Fig. 7. Seasonal changes in the age structure of *S. didactylus*. The age of individuals was deduced from the size of their galleries (see Fig. 6). Sampling was repeated 42 times from June to September. The percentage of each age category was calculated from the total gallery count ( $n$ ) over 1 mo.

beach compared with inland populations. Are eggs eaten or only pierced? The guts of adults and juveniles ( $n > 20$ ) were found to be empty or with not enough remains to tell us to what extent they ate turtle eggs. In regard to the *S. didactylus*/turtle relationship, this is just one of the many questions that remains unanswered.

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