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# Guidelines to identify individual giant armadillos, *Priodontes maximus* (Kerr, 1792), through camera traps

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**Abstract** Camera trapping is one of the main tools used to advance *Priodontes maximus* research as it can provide information on the species' presence, densities, relative abundance, home ranges, movement, activity patterns, habitat use, reproduction, and parental care. Photographic records obtained by camera traps allow the individual identification of *P. maximus* if properly examined. The aim of this work is to provide researchers with the tools to identify individuals of *P. maximus* in their regions and stimulate further research and conservation work on the species. We use nine years of camera trap work to present and illustrate the different individual identification patterns that can be used to distinguish individuals as well as reproductive status and age class. We describe six different morphological characteristics that can be used for individual identification: cephalic scale pattern, tail markings, light band width and shape above the base of tail, hind limbs, flank scale pattern, and natural marks. Furthermore, we identified two characteristics that can be used to determine sex and age class of individuals. Using these individual identification patterns, a total of 88 *P. maximus* were individually identified in three areas of Brazil.

***Keywords:*** Cerrado savanna, Cingulata, external morphology, individual identification, Pantanal, record

### Guia de identificação do tatu-canastra, *Priodontes maximus* (Kerr, 1792), através de armadilhas fotográficas

**Resumo** Armadilhas fotográficas são uma das principais ferramentas usadas para avançar nas pesquisas do *Priodontes maximus*, podendo fornecer informações sobre a presença da espécie, densidades, abundância relativa, áreas de vida, movimento, padrões de atividade, uso de habitat, reprodução e cuidados parentais. Registros fotográficos obtidos pelas armadilhas fotográficas, se forem devidamente examinados, podem permitir a identificação individual do *P. maximus*. O objetivo deste trabalho é fornecer aos pesquisadores as ferramentas para identificar indivíduos de *P. maximus* em suas regiões e estimular novos trabalhos de pesquisa e conservação da espécie. Utilizamos nove anos de trabalho com armadilhas fotográficas para apresentar e ilustrar os diferentes padrões de identificação individual que podem ser usados para distinguir indivíduos, assim como o estado reprodutivo e estimar a classe etária. Neste estudo são descritas seis características morfológicas diferentes que podem ser aplicadas para identificação individual (padrão de escamas cefálicas, marcas na cauda, largura e forma da faixa clara acima da base da cauda, membros posteriores, padrão de escamas no flanco e marcas naturais). Além disso, identificamos duas características que podem ser usadas para determinar o sexo e a idade dos indivíduos. Utilizando os padrões descritos por esse estudo, um total de 88 *P. maximus* foram identificados individualmente em três áreas no Brasil.

***Palavras-chave:*** Cerrado, Cingulata, identificação individual, morfologia externa, Pantanal, registro

## Introduction

Camera trapping, the use of remotely triggered cameras that automatically take images of animals passing in front of them, is a widely-used tool to survey and monitor wildlife. Camera traps have been used to assess wildlife distribution, abundance, behavior, and community structure (Rovero & Zimmermann, 2016). Furthermore, technological advances in infrared sensors and digital photography have led to cost-effective, non-invasive means of generating reliable information on elusive wildlife (Kucera & Barrett, 2011). Camera traps reduce disturbance, as units can be left unattended for weeks or months, and are therefore particularly well suited for monitoring and identifying elusive, cryptic species with low densities in remote areas (Long *et al.*, 2008).

The giant armadillo (*Priodontes maximus*) is the largest representative of the order Cingulata. It can reach 150 cm in body length and weigh up to 50 kg (Carter *et al.*, 2016; Desbiez *et al.*, 2019b). Despite a wide distribution throughout South America, *P. maximus* is always rare (Meritt, 2006). In addition to low densities, the species is solitary, nocturnal and has fossorial habits, making it particularly difficult to capture and study in the wild (Desbiez *et al.*, 2019c). For this reason, camera traps have always been a very important tool in *P. maximus* research (Leite-Pitman *et al.*, 2004; Noss *et al.*, 2004; Silveira *et al.*, 2009; Porfirio *et al.*, 2012; Desbiez & Kluyber, 2013; Aya-Cuero *et al.*, 2015, 2017; Massocato & Desbiez, 2017; Quiroga *et al.*, 2017; Esteves *et al.*, 2018; Desbiez *et al.*, 2019a, c).

Noss *et al.* (2004) were the first to use individual identification for camera trap records of *P. maximus*. The authors describe using "the dividing line between dark and light scales on the carapace and on the hind legs" as well as "the number of light scales per row from the lower edge of the carapace up to the dividing line" (Noss *et al.*, 2004:47) to identify individuals. All later researchers using individual identification of *P. maximus* cite this publication, sometimes adding another identifying characteristic such as scars (Aya-Cuero *et al.*, 2017) or the scales on the tail (Desbiez *et al.*, 2019c). The purpose of this study is to clearly present and illustrate the different individual identification patterns that can be used in camera trap research to distinguish individual *P. maximus* as well as to assess their reproductive status and age class.

## Materials and Methods

Our work is based on nine years of camera trapping in three different study areas in Mato Grosso do Sul state, Midwestern Brazil. All records are from Reconyx camera traps (HC–500, HC–550, HC–600, and PC–850; Reconyx, Holmen, USA) set to rapid fire mode, recording three to ten consecutive photos without any intervals.

**Site 1: Pantanal.** July 2010 to September 2019 in an area of 350 km$^2$ in the Brazilian Pantanal (Nhecolândia sub-region; 19°16'60"S, 55°42'60"W). We installed camera traps laterally to the entrance of burrows used by animals monitored with transmitters. Cameras were used to document the animals' health (weight loss, lesions or injuries), other species visiting the burrow, and potential transient animals (8,110 camera trap/nights). Furthermore, cameras were also set in a 100 km$^2$ grid within the study area where the monitored armadillos were known to be active (4,500 camera trap/nights).

**Site 2: Cisalpina.** September 2014 to February 2018 in an area of 30 km$^2$ in the Cerrado of Eastern Mato Grosso do Sul state, Brazil (21°16'03"S, 51°54'96"W). We installed camera traps laterally to the *P. maximus* burrow entrances to document visitors, in front of feeding excavations, and on trails (4,060 camera trap/nights).

**Site 3: MS–040.** April 2018 to October 2018 in an area of 360 km$^2$ in the Cerrado in the center of Mato Grosso do Sul state, Brazil (21°06'27"S, 53°52'00"W). We positioned camera traps primarily to detect giant anteaters (*Myrmecophaga tridactyla*) along fences, river banks, old roads, trails, as well as in open areas and occasionally in front of the entrance of burrows (5,132 camera trap/nights).

Images of individual patterns used to identify *P. maximus* were selected and classified to create guidelines to help other researchers to distinguish between individual *P. maximus* as well as to assess their reproductive status and age class.

## Results

A total of 50 *P. maximus* were identified at Site 1 using both data sets from the study area: 28 females, 21 males, and one individual we were unable to individually identify. At Site 2, a total of four *P. maximus* were identified: three adult females and one juvenile male. At Site 3, a total of 15 *P. maximus* were identified including seven adult females, seven adult males, and one juvenile female. We also recorded 19 adults that we were unable to individually identify.

Six morphological characteristics that can be used for individual identification were identified and used to distinguish *P. maximus* from each other. The use of each of these patterns depends on the position of the animal and the angle of the camera. Not all patterns are visible on a single picture, but usually several characteristics can be recorded and later used to confirm if the same animal is photographed again.

## Individual identification patterns

**Cephalic scale pattern.** The pattern of scales displayed on the animal's head is unique. These scales are large and easily distinguished; they also vary in shape, number, and arrangement. However, this requires a frontal image, which is unlikely if the animal is walking on a trail perpendicular to the camera. This image is easier to obtain when the camera is placed near a burrow or feeding excavation (**Fig. 1**).

**Tail markings.** *Priodontes maximus* individuals may have dark scales along the tail interspersed among the lighter scales. When present, these dark scales may vary in number and arrangement along the tail. Some individuals have multiple dark scales that are easy to distinguish and facilitate identification. In general, these dark scales originate at the base of the tail and are present on its dorsal portion (**Fig. 2**).

**Light band width and shape above the base of tail.** The width and shape of the light band between the base of the tail and the darker scales at the upper part of the carapace can be a useful pattern for identifying individuals. Some animals have a thin or thick light band, depending on how close the dark scales from the top of the carapace are to the base of the tail. The intersection between the dark and light scales can be formed by round to pointed scales, which are also unique and a good characteristic to examine when identifying individuals. This pattern is commonly visible in photos of animals entering their burrows (**Fig. 3**).

**Hind limbs.** Some individuals have a dark ankle brace on the upper hind limb that may be of varying shape or size on each side or even absent in some individuals. This is usually easy to distinguish but one must be cautious of soil masking the markings (**Fig. 4**). The shape, size or absence of the ankle brace is different on each hind limb.

**Flank scale pattern.** Only one of the flanks of *P. maximus* is recorded in a single photograph and the patterns can be different for each side of an individual. It is therefore important to note the side for which a pattern is being identified. For the flanks, identification patterns are comprised of the number of light scales between the edge of the carapace and the dark scales, as well as indentations and shapes formed by the light and dark scales (**Figs. 5, 6, 7**). For identification purposes, the flanks of the animal are divided in three areas: anterior, medial, and posterior. The anterior area comprises the scale pattern on the laterals of the scapular portion of the carapace (above the front foot, ending before the first flexible band; **Fig. 5**). The medial area is comprised of flexible bands in the middle of the animal's body (**Fig. 6**). The posterior area covers the area of the pelvic portion of the carapace (after the last flexible band; **Fig. 7**).

**Natural marks.** Some animals may have striking morphological features, such as scars on the armor or scale color variation (*i.e.*, a dark scale in the light band or a patch of light scales on the dark armor). However, this characteristic may be difficult to assess, especially when evaluating black and white camera images, as scars or dark patches sometimes result from soil stuck on the armor (**Fig. 8**).

## Identification of sex, age class, and reproductive status

Desbiez *et al.* (2019b) report that morphometric differentiation between sexes is possible through the association of three morphological parameters (carapace length, thorax circumference, and hind limb length) and that adult males are larger and heavier than females. Silveira *et al.* (2012) also found significant sex differences in mean body measurements in seven out of the 14 parameters recorded. In camera traps, at first glance it seems impossible to distinguish between male and female *P. maximus*. However, upon careful examination and depending on the angle, sex, reproductive status, and age class can be identified and/or estimated.

**Females.** Adult female *P. maximus* present a visible elongated vulva that measures about 7 cm, while the vulva of younger females will be smaller and harder to detect (Desbiez *et al.*, 2019b). Visible teats, located high up in the thoracic region almost under the armpits, were measured during anesthesia procedures in Site 1. They can be more than 2.5 cm long when a female has been through at least one lactation period. A nulliparous female will have teats that are about 1 cm long (**Fig. 9**). Finally, if a female is nursing, the area around the teat will be lighter in color, since the dirt is constantly removed from this area when the young is suckling (**Fig. 10**).

**Males.** The size of the reproductive organ of male *P. maximus* can allow the observer to evaluate its reproductive stage. As illustrated in **Fig. 11**, there is a visible difference between reproductive adult males and younger sub-adult males (Desbiez *et al.*, 2019b).

Based on these eight characteristics, a total of 88 *P. maximus* were individually identified in all of our study areas.

## Discussion

Camera trapping has been one of the key tools used to advance *P. maximus* research. This technique has provided information on species presence (Porfirio *et al.*, 2012; Massocato & Desbiez, 2017; Quiroga *et al.*, 2017; Esteves *et al.*, 2018), density (Noss *et al.*, 2004; Silveira *et al.*, 2009; Aya-Cuero *et al.*, 2017), relative abundance (Quiroga *et al.*, 2017), home range and movement (Noss *et al.*, 2004), activity patterns (Silveira *et al.*, 2009; Aya-Cuero *et al.*, 2017), habitat use (Aya-Cuero *et al.*, 2017), reproduction, and parental care (Aya-Cuero *et al.*, 2015; Desbiez *et al.*, 2019a).

Individual identification of *P. maximus* can be challenging, especially when analyzing camera trap data from a rapid survey or from studies designed for other species (*e.g.*, large felids, such as jaguars). For example, camera traps set in Site 3 were placed to capture images of *M. tridactyla* rather than *P. maximus*, and cameras were only maintained in the same area for, on average, 30 days. Despite the experience of the authors, less than half of *P. maximus* recorded could be individually identified. Nevertheless, the proportion of positive identifications can be increased by taking into account some recommendations, which we will list below.

In the Pantanal, 50 *P. maximus* have been individually identified. This was a species-specific long-term study, which means that cameras were placed purposely in locations where *P. maximus* would stop, such as excavations or termite mounds. Cameras were also maintained in the same area for long periods of time (at least over a year). In addition, 30 of the animals have been captured and were registered and photographed at different angles while under anesthesia. For this reason, even pictures showing few details or low quality images could render a positive individual identification.

To increase the chances of identifying individual *P. maximus*, cameras with high resolution must be used (Newey *et al.*, 2015) and strategically placed. The best photographs can be obtained by placing the camera near evidences of *P. maximus*, such as sleeping burrows, feeding excavations or even a termite mound with recent signs of predation. At these locations, the animals pause to seek olfactory clues, which increases the chances that photographs will capture details of scale patterns. Very often images captured on trails are blurry because the animals are moving.

It is often helpful to use a combination of morphological clues to ascertain an individual's identity. Maintaining cameras in the same area for a prolonged amount of time (more than six months) allows to take several images of an animal, ensuring various angles of the same individual are captured, which facilitates its identification. When camera traps are placed near excavations, it is best to do so on the side, rather than in front, as it prevents the camera from being covered with soil in case the animal excavates the burrow again. Additionally, it is best to always place the cameras on one specific side of the excavation so that the same flank will be captured, thus facilitating the identification of the animals.

The purpose of this article was not to discuss study designs or analysis methods, but rather to provide the tools so that researchers have a better chance to distinguish individual *P. maximus* recorded by their camera traps. Furthermore, the identification illustrations and suggestions proposed here may be extended and adapted to other armadillo species. We hope the figures will help researchers to identify individuals in their study regions and stimulate further research and conservation work on *P. maximus*.

## Acknowledgements

We thank the owners of the 43 ranches in the Nhecolândia region of the Pantanal and near the MS‒040 in the Cerrado as well as RPPN Cisalpina for their hospitality, and for permission to work on their lands. We are grateful to Vinícius Alberici, Danilo Kluyber, and the numerous project volunteers for their help in the field. We also thank Andrew Noss, Nina Attias, Mariella Superina, and an anonymous reviewer for their helpful comments. This study is part of the Giant Armadillo Conservation Program that receives funding from many different partners, mostly from zoos in North America and Europe listed at *www.giantarmadillo.org*.

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## Figures

**Cephalic scale pattern.** The pattern of scales displayed on the animal's head is unique. These scales are large and easily distinguished; they also vary in shape, number, and arrangement. However, this requires a frontal image, which is unlikely if the animal is walking on a trail perpendicular to the camera. This image is easier to obtain when the camera is placed near a burrow or feeding excavation.

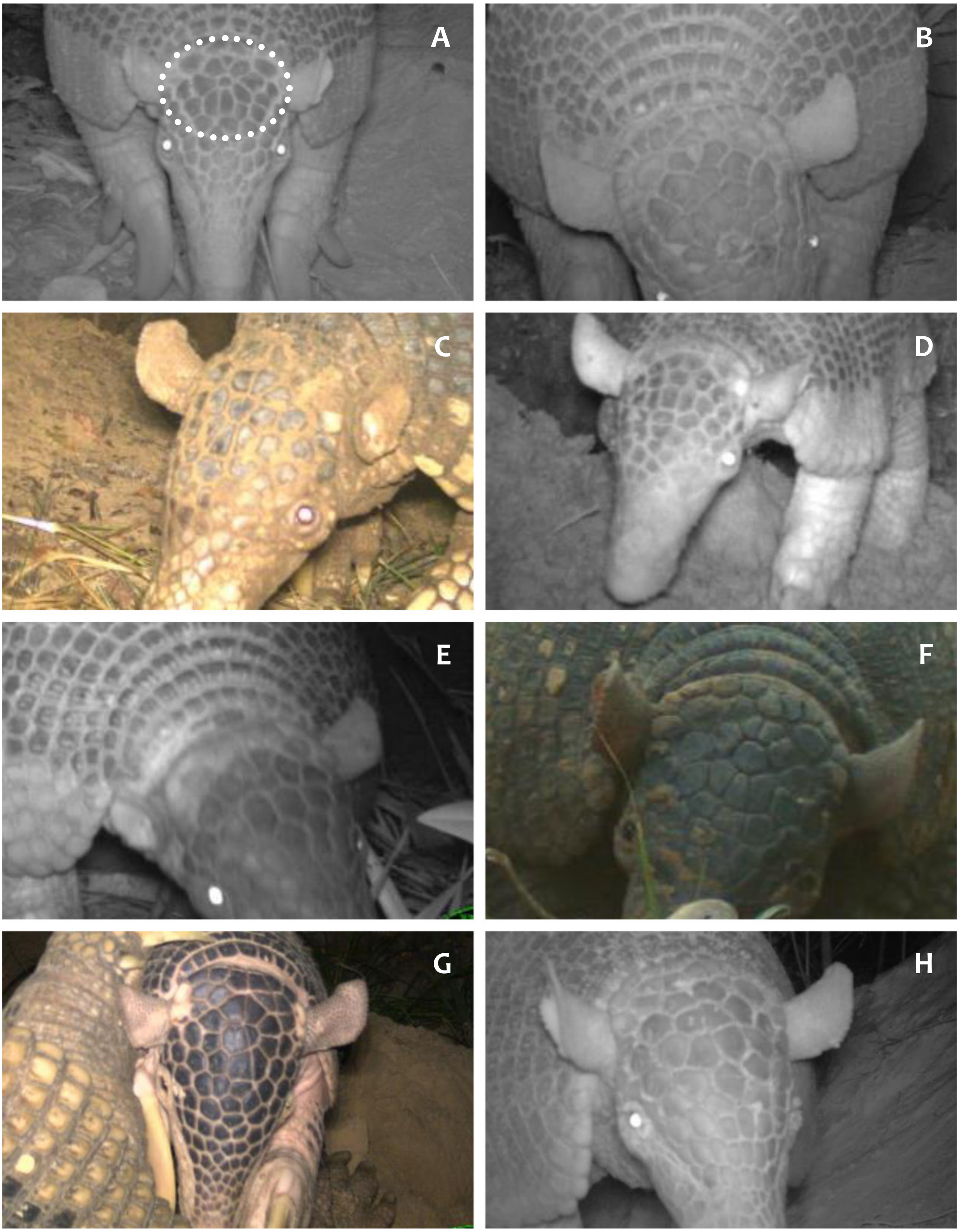


**Figure 1.** Individual scale pattern on the cephalic shield of giant armadillos (*Priodontes maximus*). (**A**) Region of the head to be evaluated for individual identification patterns. (**B–H**) Examples of variation in cephalic shield scale pattern.

**Tail markings.** *Priodontes maximus* individuals may have dark scales along the tail interspersed among the lighter scales. When present, these dark scales may vary in number and arrangement along the tail. Some individuals have multiple dark scales that are easy to distinguish and facilitate identification. In general, these dark scales originate at the base of the tail and are present on its dorsal portion.


**FIGURE 2.** Individual scale pattern on the tail of giant armadillos (*P. maximus*). (**A**) Region of the tail to be evaluated for individual identification patterns. (**B–F**) Examples of variation in tail scale pattern. (**H**) Example of absence of dark scales along the tail.

**Light band width and shape above the base of tail.** The width and shape of the light band between the base of the tail and the darker scales at the upper part of the carapace can be a useful pattern for identifying individuals. Some animals have a thin or thick light band, depending on how close the dark scales from the top of the carapace are to the base of the tail. The intersection between the dark and light scales can be formed by round to pointed scales, which are also unique and a good characteristic to examine when identifying individuals. This pattern is commonly visible in photos of animals entering their burrows.

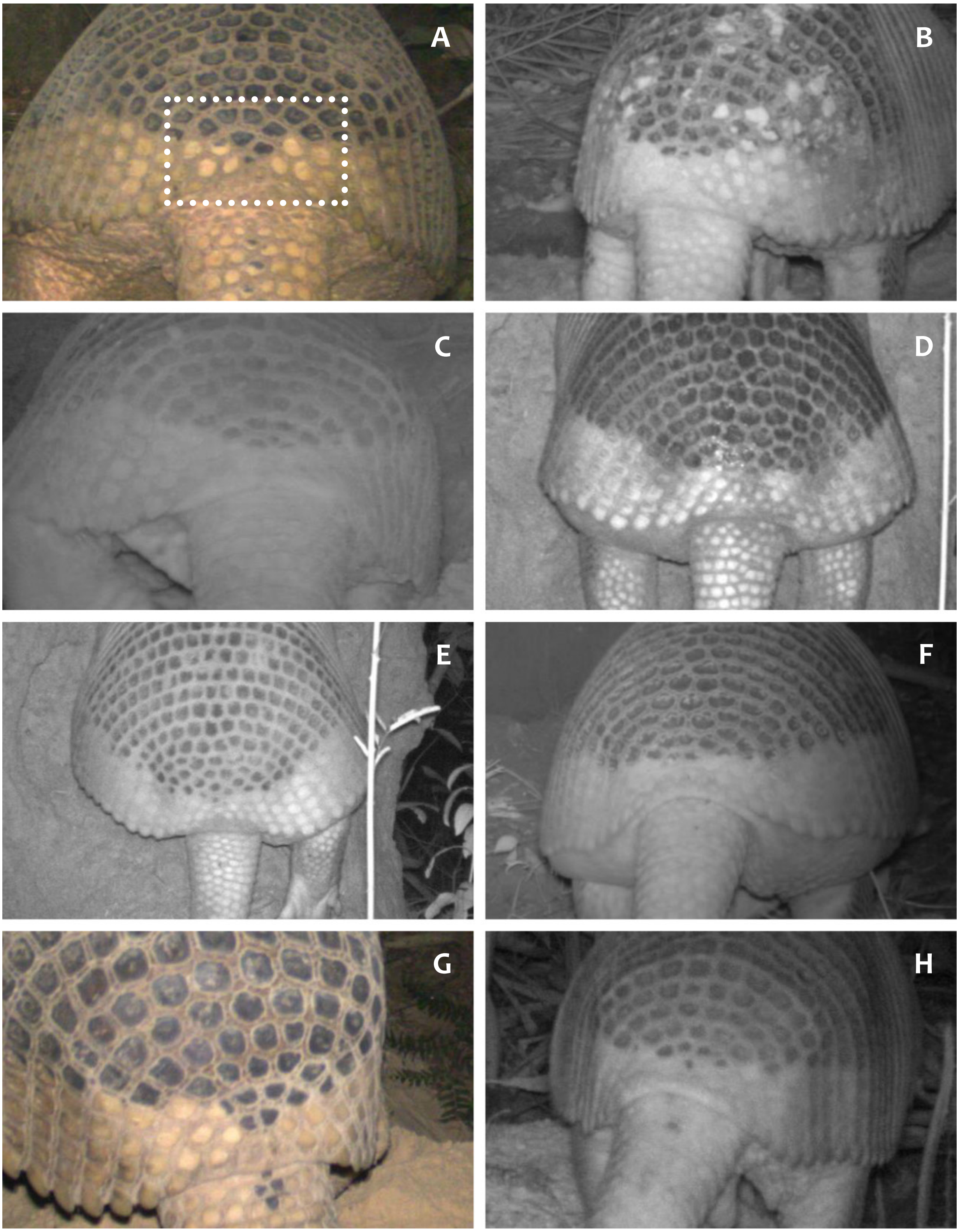


**Figure 3.** Individual scale pattern of light band width and shape above the base of the tail of giant armadillos (*P. maximus*). (**A**) Region of the base of the tail to be evaluated for individual identification patterns. (**B–H**) Examples of pattern variation on the light band width and shape above the base of the tail.

**Hind limbs.** Some individuals have a dark ankle brace on the upper hind limb that may be of varying shape or size on each side or even absent in some individuals. This is usually easy to distinguish but one must be cautious of soil masking the markings. The shape, size or absence of the ankle brace is different on each hind limb.

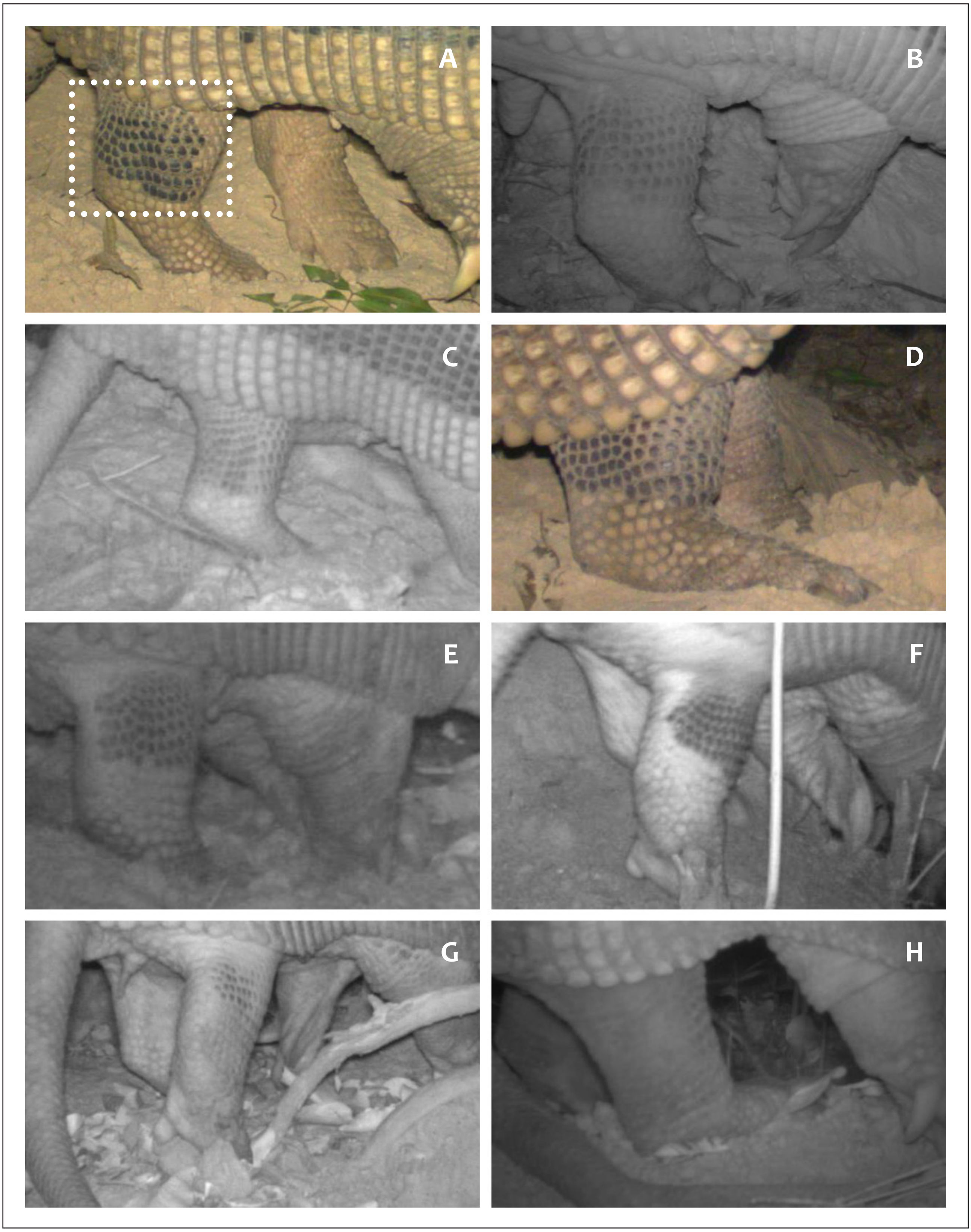


**FIGURE 4.** Individual scale pattern on the hind limb of giant armadillos (*P. maximus*). (**A**) Region of the hind limb to be evaluated for individual identification patterns. (**B–F**) Examples of variation in hind limb scale pattern. (**H**) Example of absence of dark scales along the hind limb.

**Flank scale pattern.** Only one of the flanks of *P. maximus* is recorded in a single photograph and the patterns can be different for each side of an individual. It is therefore important to note the side for which a pattern is being identified. For the flanks, identification patterns are comprised of the number of light scales between the edge of the carapace and the dark scales, as well as indentations and shapes formed by the light and dark scales (**Figs. 5, 6, 7**). For identification purposes, the flanks of the animal are divided in three areas: anterior, medial, and posterior. The anterior area comprises the scale pattern on the laterals of the scapular portion of the carapace (above the front foot, ending before the first flexible band).

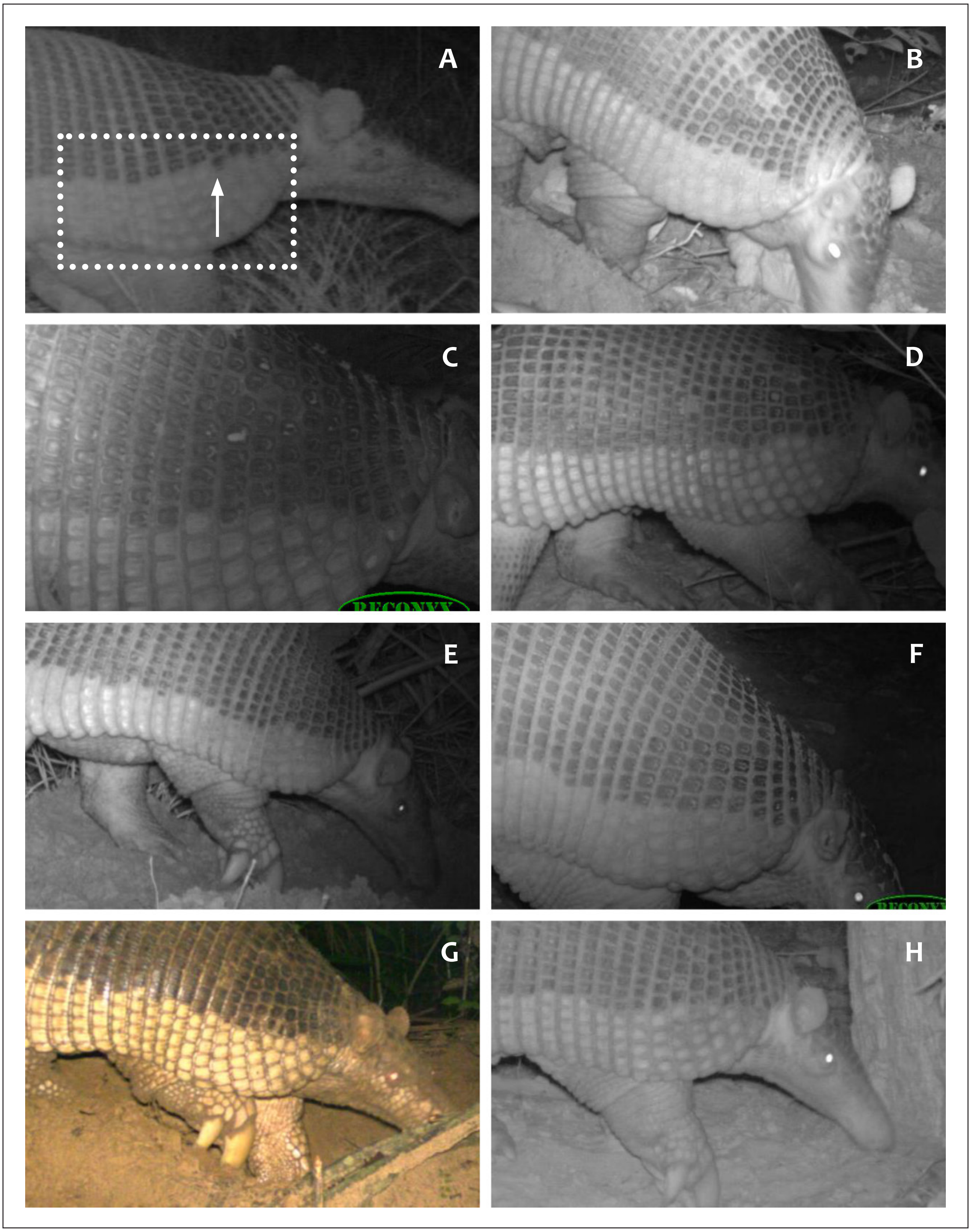


**Figure 5.** The prominent dark scale pattern between the light band and dark scales from the section of the armor of giant armadillos (*P. maximus*) above the front leg to the area where the flexible bands start. (**A**) Region of the anterior section to be evaluated for individual identification patterns. (**B–H**) Examples.

**Flank scale pattern.** The medial area is comprised of flexible bands in the middle of the animal's body.

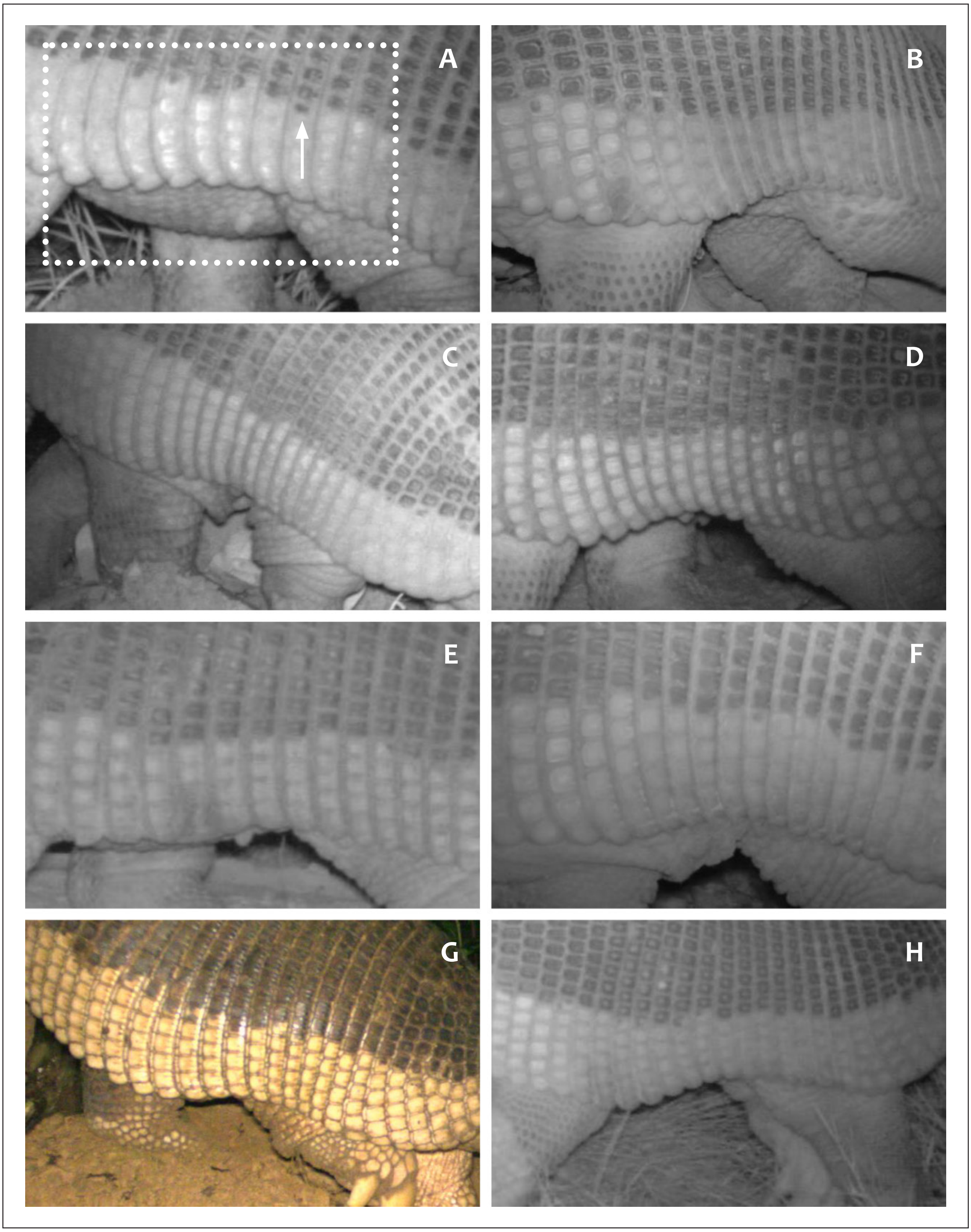


**FIGURE 6.** Medial individual scale pattern on the carapace of giant armadillos (*P. maximus*). (**A**) Region of the medial section to be evaluated for individual identification patterns. (**B–H**) The prominent dark scale pattern comprises the flexible bands in the central part of the animal's carapace.

**Flank scale pattern.** The posterior area covers the area of the pelvic portion of the carapace (after the last flexible band).

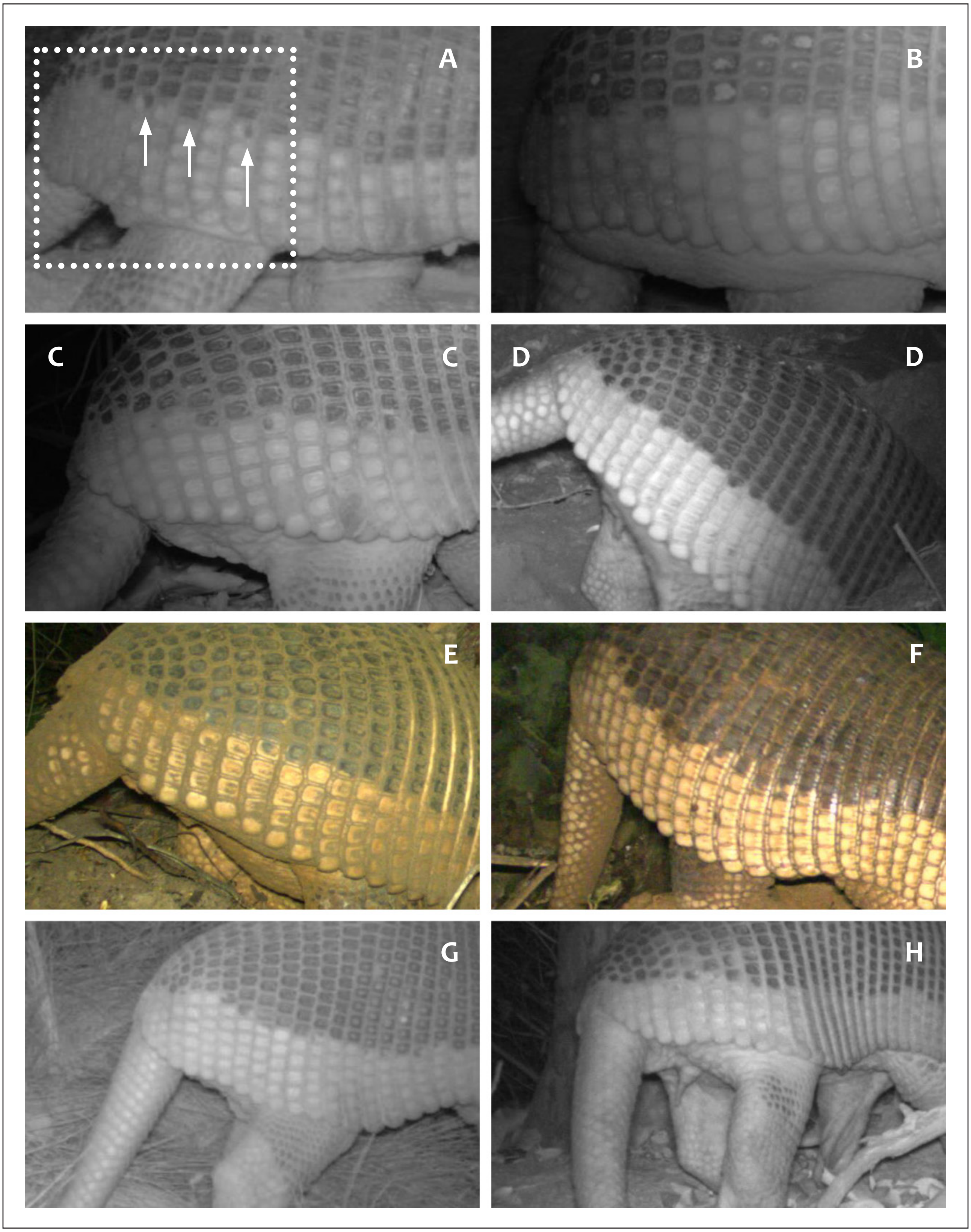


**FIGURE 7.** Individual scale pattern of the giant armadillo (*P. maximus*), after the last flexible band to the base of the tail. (**A**) Region of the posterior section to be evaluated for individual identification patterns. (**B–H**) Examples of the prominent dark scales after the last flexible band.

**Natural marks.** Some animals may have striking morphological features, such as scars on the armor or scale color variation (*i.e.*, a dark scale in the light band or a patch of light scales on the dark armor). However, this characteristic may be difficult to assess, especially when evaluating black and white camera images, as scars or dark patches sometimes result from soil stuck on the armor.


**FIGURE 8.** Natural marks on the scale pattern of giant armadillos (*P. maximus*). (**A–B**) Region of the scars to be evaluated for individual identification patterns. (**C–D**) Region of the scales of the opposite color range. (**E–F**) Example of wet soil stuck on the armor, covering the scars or light patches.

**Females.** Adult female *P. maximus* present a visible elongated vulva that measures about 7 cm, while the vulva of younger females will be smaller and harder to detect (Desbiez *et al.*, 2019b). Visible teats, located high up in the thoracic region almost under the armpits, were measured during anesthesia procedures in Site 1. They can be more than 2.5 cm long when a female has been through at least one lactation period. A nulliparous female will have teats that are about 1 cm long.

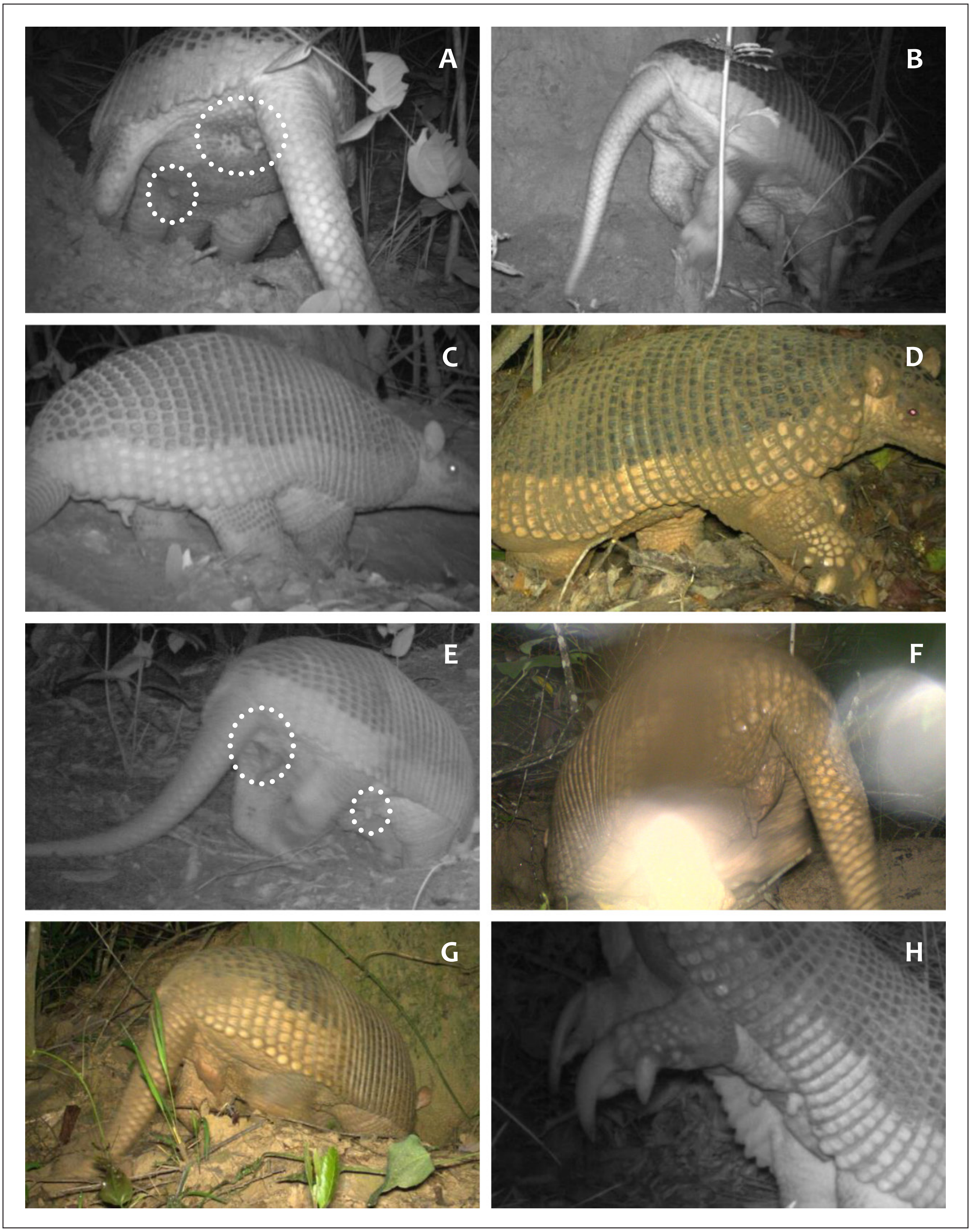


**Figure 9.** Sex and age class identification in female giant armadillos (*P. maximus*) (**A**) Region to be evaluated for identification patterns. (**B–D**) The smaller and harder to detect vulva and teats in young females. (**E**) Region to be evaluated for identification patterns. (**F–H**) Visible elongated vulva and developed teats of adult and reproductive female.

**Females.** Finally, if a female is nursing, the area around the teat will be lighter in color, since the dirt is constantly removed from this area when the young is suckling.

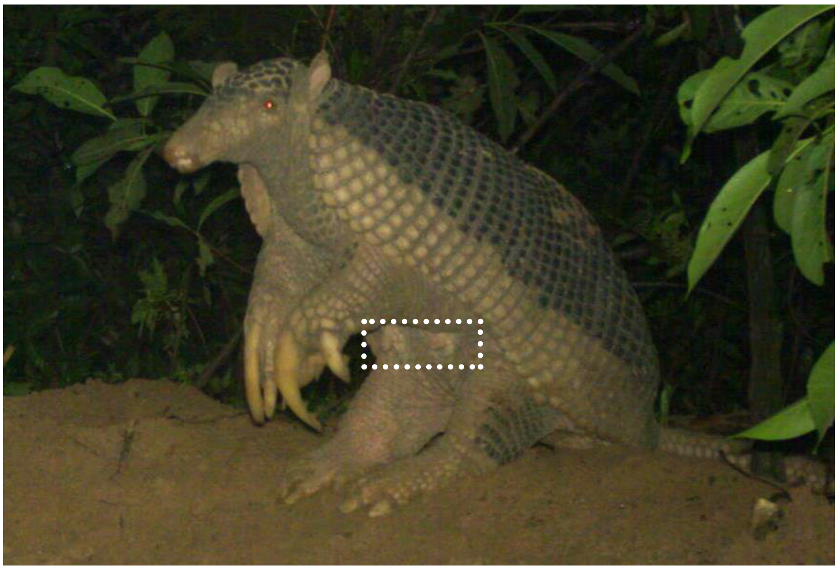

**FIGURE 10.** The area around the teats is lighter in color, evidencing that the female giant armadillo (*P. maximus*) is nursing.

**Males.** The size of the reproductive organ of male *P. maximus* can allow the observer to evaluate its reproductive stage. As illustrated in this figure, there is a visible difference between reproductive adult males and younger sub-adult males (Desbiez *et al.*, 2019b).

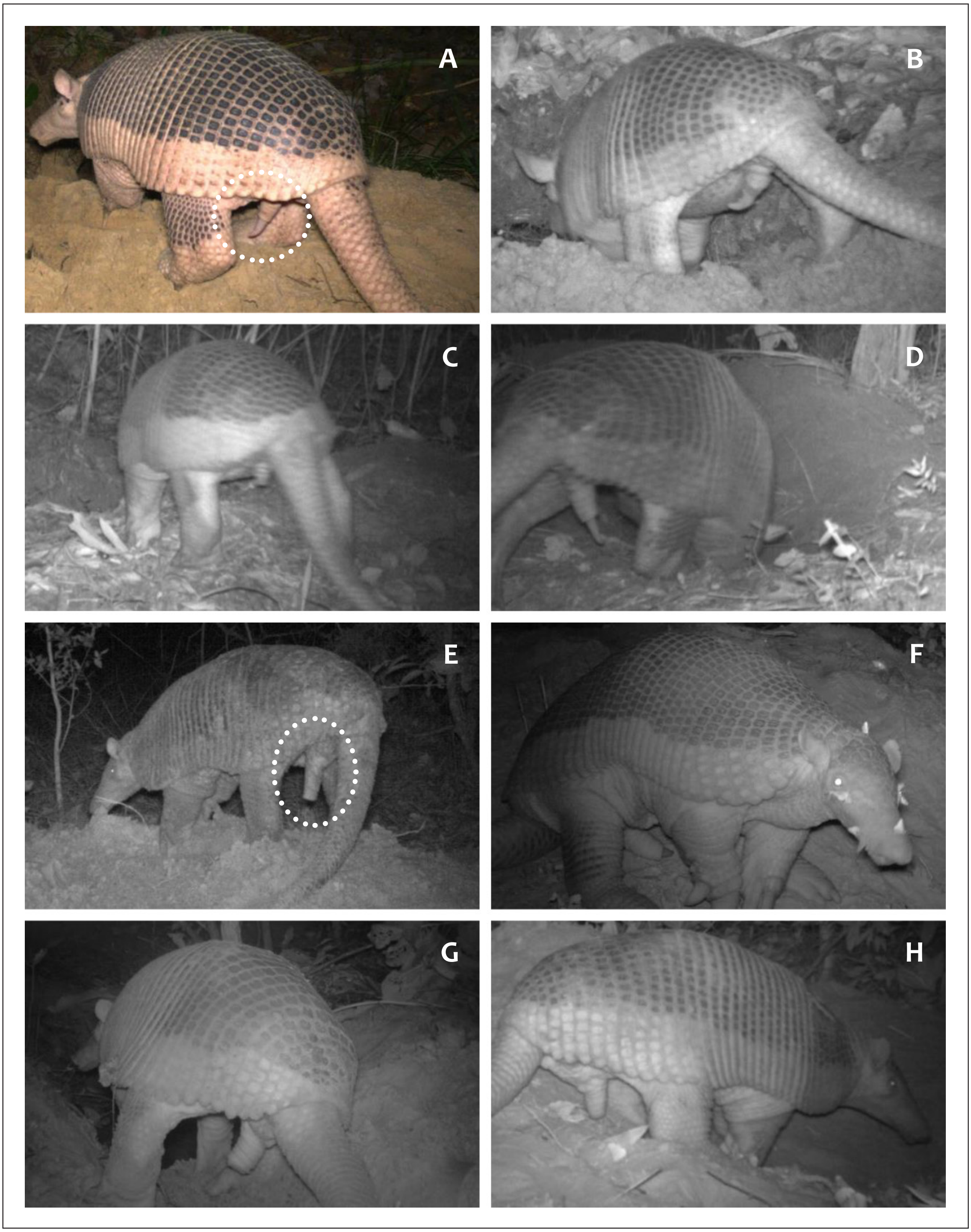


**Figure 11.** Sex identification and age class in male giant armadillos (*P. maximus*) (**A**) Region to be evaluated for identification patterns. (**B–D**) The male reproductive organ in a young animal. (**E**) Region to be evaluated for identification patterns. (**F–H**) The size of adult reproductive male organ. Age class and reproductive status can be inferred.