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ANATOMY AND CRANIAL MORPHOMETRY OF PAROARIA DOMINICANA (LINNEAUS, 1758)

ANATOMIA E MORFOMETRIA CRANIANA DO PAROARIA DOMINICANA (LINNEAUS, 1758)

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Abstract. *Paroaria dominicana* (Linnaeus, 1758) is a species whose habitat predominates within national territory, occurring across the Northeast, Southeast, North, and part of the Central-West regions of Brazil. This species, commonly known as the "galo-de-campina" (red-cowled cardinal), belongs to the kingdom Animalia, class Aves, order *Passeriformes*, and family *Thraupidae*. The genus *Paroaria* is characterized as monophyletic, indicating that all species within the genus share a common ancestor. Understanding the osteological and anatomical particularities of this species may contribute to future studies involving its biological history, the morphological adaptations that supported its expansion, its ecological niche, as well as assist in veterinary medical procedures for the rescue and rehabilitation of its populations. Six anatomical specimens of adult individuals (three males and three females) of Paroaria dominicana (Linnaeus, 1758) were provided by the Wildlife Screening Center (CETAS), located in the Mata do Amém restinga forest in the city of Cabedelo, Paraíba, Brazil. The skulls were dissected to expose their bony structures, using a stereomicroscope for detailed observation. The bones corresponding to the neurocranium and viscerocranium of the species were described to contribute to its morphological and phylogenetic data. The skulls of Paroaria dominicana (Linnaeus, 1758) presented light and fragile bones, with anatomical particularities associated with their diet. The neurocranium is mainly composed of the frontal, parietal, and occipital bones, with notable features including the cerebellar prominence and multiple foramina at the cranial base. The splanchnocranium, in turn, exhibits large orbits, a well-developed quadrate bone that articulates the beak and mandible, a slender palatine region, and a robust beak with elliptical nostrils. In summary, this study provides a significant contribution to the understanding of the cranial morphology of *Paroaria dominicana* (Linnaeus, 1758), emphasizing its complex structure and anatomical adaptations.

Keywords: Morphology; Osteology; Passerines.

Resumo. O *Paroaria dominicana* (Linnaeus, 1758) é uma espécie cujo habitat predomina em território nacional, ocorrendo principalmente nas regiões Nordeste, Sudeste, Norte e em parte do Centro-Oeste. Popularmente conhecida como galo-de-campina, essa espécie pertence ao reino Animalia, à classe Aves, à ordem Passeriformes e à família Thraupidae. O gênero *Paroaria* é caracterizado como monofilético, o que demonstra que todas as espécies do gênero compartilham um ancestral comum. Compreender as particularidades anatômicas osteológicas dessa espécie pode contribuir para estudos futuros relacionados à sua história evolutiva, às adaptações morfológicas que possibilitaram sua expansão e ao seu nicho ecológico, além de auxiliar em procedimentos médico-veterinários no resgate e na reabilitação de populações dessa espécie. Foram cedidas pelo Centro de Triagem de Animais Silvestres (CETAS), localizado na floresta de restinga Mata do Amém, na cidade de Cabedelo – PB, seis peças anatômicas de exemplares adultos (três machos e três fêmeas) da espécie *Paroaria dominicana* (Linnaeus, 1758). Foi realizada a dissecação do crânio para exposição das estruturas ósseas componentes. Com o auxílio de uma lupa estereomicroscópica, foram descritos os ossos correspondentes ao neurocrânio e ao viscerocrânio da espécie, a fim de contribuir com dados morfológicos e filogenéticos. Os crânios de Paroaria dominicana (Linnaeus, 1758) apresentaram ossos leves e frágeis, com particularidades anatômicas associadas à sua dieta. O neurocrânio é formado principalmente pelos ossos frontal, parietal e occipital, destacando-se a presença da proeminência cerebelar e de múltiplos forames na base craniana. Já o esplancnocrânio apresenta órbitas amplas, um osso quadrado bem desenvolvido, que articula o bico e a mandíbula, além de uma região palatina delgada e um bico robusto com narinas elípticas.Em síntese, este estudo traz uma contribuição significativa para a compreensão da morfologia craniana de Paroaria dominicana (Linnaeus, 1758), destacando sua estrutura complexa e suas adaptações anatômicas.

Palavras-chave: Morfologia; Osteologia; Passeriformes.

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INTRODUCTION

The genus Paroaria is classified within the order Passeriformes, suborder Oscines, family Fringillidae, subfamily Emberizinae[1]. However, phylogenetic analyses using mitochondrial DNA (mtDNA) gene sequences suggest that the genus Paroaria belongs to the genus Thraupini[2]. The family *Thraupidae* (Passeriformes, Passeri) comprises 408 species, distributed in 105 genera[3]. Among the genera, Paroaria stands out, divided into three subspecies: P. dominicana (field cardinal), P. coronata (southern cardinal), and P. gularis (Amazon cardinal). The latter has three subspecies, based on morphological and ecological characteristics[4].

Paroaria dominicana (Linnaeus, 1758) is predominant in Brazil, especially in the Northeast, Southeast, North, and part of the Midwest, and is also found in Argentina and Bolivia. Due to its significant presence in the Northeast region, especially in Paraíba, studies on the anatomy and morphometry of this species are essential. In addition, there is a growing interest in bird studies among food producers and as models for biological research.

Although classified by the Brazilian Biodiversity Information System (SiBBr) as a species of "least concern," *Paroaria dominicana* still requires attention due to research on wildlife trafficking and environmental impacts on its habitat.

This study aims to describe the cranial morphology of adult males and females of Paroaria dominicana, contributing morphological data that may assist in future anatomical research.

MATERIALS AND METHODS

Study characterization and sample collection

This study is characterized as a morphological study, analytical and exploratory in nature, of the anatomy and cranial morphometry of six cadavers of *Paroaria dominicana* (Linneaus, 1758). To conduct the study, six anatomical specimens of Paroaria dominicana (Linneaus, 1758) (3 males and 3 females) were donated by the Paraíba Wildlife Screening Center (CETAS-PB).

Dissection and preparation of samples

Several steps were involved in dissecting and preparing the samples. The first was the controlled maceration of the skulls, with the skin, fascia, and musculature being removed using dissection instruments. The skulls were then cleaned by insects in order to preserve the bone joints. After organic cleaning, the pieces underwent a bleaching process using 3% hydrogen peroxide, carried out according to the methodology previously described[5].

Sample description process

For the description of the samples, a stereomicroscope magnifying glass (Zeiss brand ©, Discovery. V8 model) was used, where the bones comprising the viscerocranium and neurocranium were identified, which could be delimited. Photographs were taken in accordance with anatomical planes and axes. The nomenclature of the bone structures of the samples and their distinctions was based on the International Committee for Avian Anatomical Nomenclature[6].

RESULTS

The skulls of *Paroaria dominicana* (Linneaus, 1758) that were dissected presented fragile structures with light bones. Some peculiarities were observed that differed from other species, particularly in aspects related to their diet.

Neurocranium

The brain was surrounded by the neurocranium, which was composed of the frontal (F), occipital (O), and parietal (P) bones, in addition to the sphenoid bone. The frontal bone is extremely important for the formation of the anterior portion of the cranial cavity (Figure 1). It is caudally connected to the craniofacial flexure. In the lateral region, there is a connection with the lacrimal bone (L), and in the ventral region, there is a fusion with

the interorbital septum (SI) (Figure 4). Identifying the exact points of contact between these bones is difficult, particularly in the transition between the frontal and parietal bones, due to the bone junction. The frontal bone is almost flat, with a slight suture in the median region (MS), near the orbits (O). The bones that form the dorsal portion of the orbits and the posterior region.

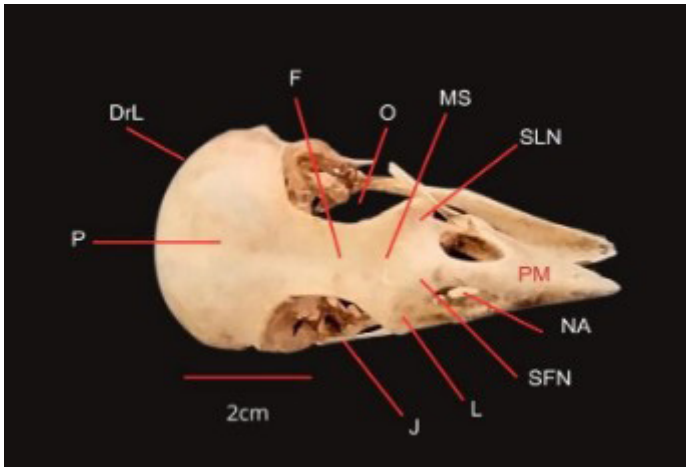

FIGURE 1: Rostral view of the skull. F = frontal; L = lacrimal; J = jugal bar; NA = nostril; PM = premaxillary; DrL = lateral depression; MS = medial suture of the frontal; O = orbit; P = parietal; SLN = lacrimal-nasal suture; SFN = frontonasal suture.

The cranial box is composed of the parietal and occipital spaces, which form the dorsocaudal region. These areas are located in the rear and upper regions of the skull. The transverse crystallization is a bony structure that delimits the caudal portion, i.e., the posterior portion of the cranial cavity. It may be brief and somewhat unexpressive. The parietal and occipital bone region shows contact between the parietal and occipital regions (Figure 4). The squamosal bone is subtle, which makes identification more challenging.
In addition, there is a relief structure known as the cerebellar prominence (CP). The structure is situated in the center of the oceanic region and is depicted in Figure 2. The cerebellar prominence establishes a connection with the parietal region at the top, while the foramen magnum is just below. The oceanic region has subtle features, such as small depressions or slight depressions, which make it relatively uniform. There is no supraorbital bone in this region.

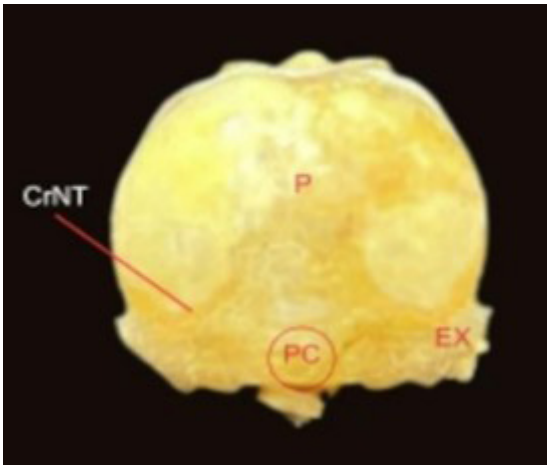

FIGURE 2: Caudal view of the skull. CrNT = transverse nuchal crest; P = parietal; EX = exoccipital; PC = cerebellar prominence.

The exoccipital (EX) is located on the side of the cerebellar prominence and has a slight depression. The foramen magnum, which is approximately circular, is located in the ventral region of the skull (Figure 3). The occipital condyle is in the rostral region of the foramen. The subcondylar fossa (SCF) can be seen laterally along the occipital condyle. Several foramina were observed in the basilar bone, such as the vagus nerve (FoV), the carotid canal (OCC), the ocular canal (OCO), and the hypoglossal nerve canal (CH). After the basilar bone, it is possible to visualize the parasphenoidal lamina (LPa), which has a semitriangular shape and is responsible for a large part of the base of the cranial cavity.

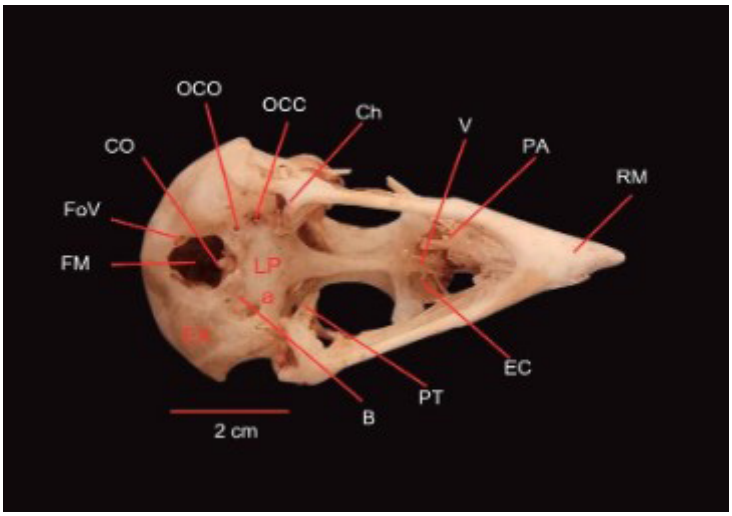

FIGURE 3. Ventral view of the skull. B = basioccipital; LPa = parasphenoidal lamina; PT = pterygoid; FM = foramen magnum; FvO = foramen magnum; CO = occipital condyle; EX = exoccipital; RM = maxillary rostrum; PA = palatine; Ch = hypoglossal nerve canal; OCC = carotid canal ostium; OCO = ostium of the ophthalmic canal; EC = ectemoid; V = vomer.

Splanchnocranium

The orbital region (O) (Figure 1) has a circular shape, with similar height and width. This region occupies a significant area of the skull and is located on the sides of the skull. In the interorbital septum, two caudal foramina are observed. One of them is the optic foramen (FO), which is wide and through which the optic nerve passes. Additionally, in this region, there is a very pronounced opening that connects the interorbital septum to the brain region, known as the orbitocranial foramen (OCF). The second foramen is the interorbital fronticus (IF), which is more developed in the interorbital septum compared to the optic foramen.

On the more caudal side of the orbits, it is possible to observe the postorbital process (PrPO) fused with the parietal bone. The interorbital septum is located near this process, but it is not very evident in the dorsal view. The postorbital process tapers toward its ventral end toward the jugal bar, where it is straight, connecting with the ventral portion of the premaxilla (PM) and, in the caudal portion, to the quadrate bone. It plays an essential role in the movement of the beak. The lacrimal bone is located in the rostrolateral portion of the skull, near the orbit. It is articulated to the nasal bone (N) by means of the lacrimal nasal suture (SLN), which is clearly evident in Figure 2. There is contact with the craniofacial flexory fissure, which is not very apparent.

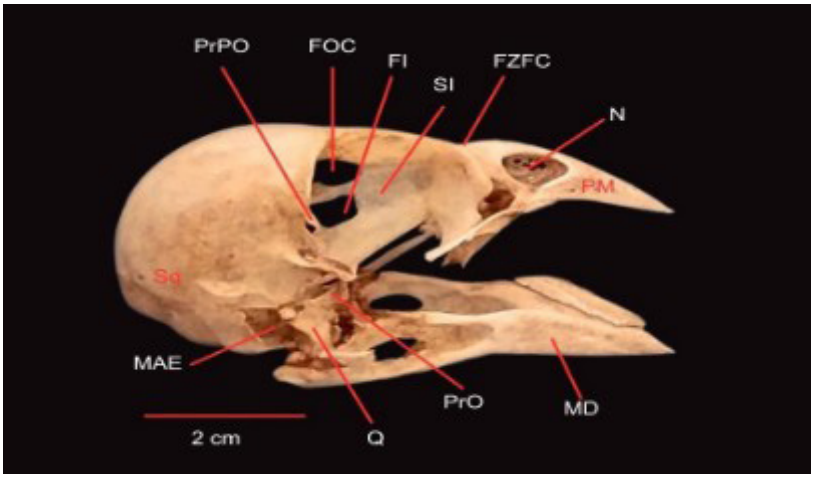

FIGURE 4. Lateral view of the skull. Captions: Sq = squamosal; FI = interorbital fronticle; FOC = orbitocranial foramen; PrPO = postorbital process; SI = interorbital septum; FZFC = craniofacial flexion zone fissure; N = nasal; PM = premaxilla; EAM = external auditory meatus; MD = mandible; Q = quadrate bone; PrO = postorbital process.

The quadrangular bone is located between the mandible and the skull, characterized by a quadrangular body that constitutes the central portion, housing the orbital processes (PrO) on the medial facet and the optic processes (PrOQ) on the dorsal slope. The orbital process of the quadrate bone is distinguished by its projection toward the orbital cavity, evidenced by its marked development and more internal positioning. In contrast, the optic process of the quadrate bone exhibits less prominent development compared to the orbital process, distributed in two distinct sites, namely the squamosal and optic chapters.

A single condyle identifies the mandibular process. The area interfacing with the jugal bar is called the quadrate-jugal cotyle. Additionally, there is an area of articulation with the pterygoid bone, called the quadrate process (PrQPT). This articulation is located approximately in the middle of the parasphenoid rostrum, culminating in a notably marked space between the pterygoid and the palatine bone (PA) in its most caudal extension.

The palatine region is composed of the palatine, vomer (V), and pterygoid bones. However, these structures are not particularly prominent due to the large spaces in the ventral region of the skull. Additionally, both structures maintain contact with the parasphenoid rostrum. The vomer bone is a thin blade, positioned immediately after the ventral fossa, located between the palatine bones. The upper portion of the maxilla consists of the nasal, maxillary, and premaxillary bones, delineating a triangular configuration with sharp lateral edges. The beak, which is robust in nature, exhibits a slight curvature at its tip. The nostrils, which are elliptical in shape, extend in an oval manner.

In the mandible, there is a suture between the suprangular and dental bones, indicative of the separation of these bones in the mandibular region. The suprangular, located superior to the dental bone, plays a crucial role in the mandibular architecture of the species. The coronoid process 1 (PrC1) is observed on the lateral facet. The lateral condyle (CL) is prominent, as is the articular process of the mandible, which is more developed than the medial mandibular process. The height of the mandible is reduced in relation to the total height of the skull, and the intermediate region of the mandible exhibits a laterally flattened conformation, which denotes reduced density or less evidence compared to other areas of the skull.

DISCUSSION

The morphological and morphometric analysis of the skulls of Paroaria dominicana revealed notable characteristics that may be related to their diet and feeding behavior. The structural delicacy and lightness of the cranial bones are indicative of specific adaptations in this species, which deserve further investigation[3].

Regarding the neurocranium, the complexity of the sutures between the bones was observed, notably in the transition between the frontal and parietal bones. The presence of the transverse nuchal crest and cerebellar prominence in the occipital region are unique characteristics that may play an important role in neuromotor processes or in protecting the brain[7].

In the context of the esplancnocranium, the orbits were identified as circular structures occupying a significant area of the skull. The presence of foramina such as the optic and orbitocranial foramina indicates the importance of vision in this species. The fusion of the postorbital process with the parietal bone may be related to the strength required for handling food or other activities related to their diet[8].

The quadrate bone, together with its intrinsic relationship with the jugal bar and mandibular process, exhibits specific anatomical modifications that are possibly related to the characteristic feeding pattern of Paroaria dominicana. The robustness of the beak, its distinct curvature at the tip, and the triangular configuration of the maxilla suggest dietary requirements that demand vigor and dexterity in food handling, thus denoting a rigorous diet in which strength and precision play a paramount role[5].

Analysis of the palate revealed structures that were not very prominent, possibly due to large spaces in the ventral region of the skull. This may be related to a need for space to accommodate food or an adaptation to facilitate food manipulation[9].

The suture between the suprangular and dental bones in the mandible suggests a functional division of these structures, which may be related to a specific chewing process or food manipulation[9].

In summary, the results of the cranial analysis of Paroaria dominicana point to morphological adaptations that may be related to its diet and feeding behavior. These adaptations are indicative of a highly specialized species adapted to its environment and may serve as a basis for future studies on its ecology and biology[10].

CONCLUSION

The morphological adaptations identified, such as the robustness of the beak, the shape of the orbits, and the complex sutures between the bones, suggest that this species has developed specific cranial characteristics to meet the demands of its diet and feeding behavior. In summary, this study offers a substantial contribution to the knowledge of the cranial anatomy of Paroaria dominicana (Linnaeus, 1758), emphasizing its complexity and morphological adaptations. It is hoped that this information will serve as a basis for future research on this species, aiding in the understanding of its biology, behavior, and health, as well as supporting clinical decisions related to surgical and management procedures.

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