Registration and Skeletal Preparation of a Specimen of the Black Shearwater (Procellaria aequinoctialis- Linnaeus, 1758), Found Dead at the Arpoador Center, Juréia-Itatins Mosaic, São Paulo, Brazil

Registro e preparação esquelética de um espécime da pardela-preta (Procellaria aequinoctialis – Linnaeus, 1758), encontrado morto no Centro do Arpoador, Mosaico Juréia-Itatins, São Paulo, Brasil

Registro y preparación esquelética de un ejemplar de pardela negra (Procellaria aequinoctialis - Linnaeus, 1758), hallado muerto en el Centro Arpoador, Mosaico de Juréia-Itatins, São Paulo, Brasil

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ABSTRACT
The preparation and mounting of skeletons are fundamental techniques for anatomical, taxonomic, and ecological studies, as well as for the preservation of biological material in scientific collections. They enable studies related to the anatomy, evolution, systematics, and conservation of seabird fauna. The procedures used in the preparation, cleaning, identification, and mounting of the skeleton highlight their importance in the conservation of anatomical specimens in biological and osteological collections, as well as in environmental education activities. The process involved the removal of soft tissues, bone cleaning, drying, cataloging, and articulation of the skeletal structures. The purpose of this article is to describe and discuss the skeletal anatomy of a specimen of *(Procellaria aequinoctialis)* black shearwater. The results demonstrated the effectiveness of the technique used in obtaining preserved osteological material suitable for display and study.

Keywords: Veterinary Anatomy, Skeletal Mounting, Seabirds, Comparative Anatomy, Osteological Collections.

RESUMO
A preparação e a montagem de esqueletos são técnicas fundamentais para estudos anatômicos, taxonômicos e ecológicos, bem como para a preservação de material biológico em coleções científicas. Elas possibilitam estudos relacionados à anatomia, evolução, sistemática e conservação da fauna de aves marinhas. Os procedimentos utilizados na preparação, limpeza, identificação e montagem do esqueleto destacam sua importância na conservação de espécimes anatômicos em coleções biológicas e osteológicas, bem como em atividades de educação ambiental. O processo envolveu a remoção de tecidos moles, limpeza óssea, secagem, catalogação e articulação das estruturas esqueléticas. O objetivo deste artigo é descrever e discutir a anatomia

esquelética de um espécime de pardela-preta (Procellaria aequinoctialis). Os resultados demonstraram a eficácia da técnica utilizada na obtenção de material osteológico preservado, adequado para exibição e estudo.

Palavras-chave: Anatomia Veterinária, Montagem Esquelética, Aves Marinhas, Anatomia Comparativa, Coleções Osteológicas.

RESUMEN

La preparación y el montaje de esqueletos son técnicas fundamentales para los estudios anatómicos, taxonómicos y ecológicos, así como para la conservación del material biológico en colecciones científicas. Permiten realizar estudios relacionados con la anatomía, la evolución, la sistemática y la conservación de la fauna de aves marinas. Los procedimientos utilizados en la preparación, limpieza, identificación y montaje del esqueleto ponen de relieve su importancia en la conservación de especímenes anatómicos en colecciones biológicas y osteológicas, así como en actividades de educación ambiental. El proceso consistió en la extirpación de los tejidos blandos, la limpieza de los huesos, el secado, la catalogación y la articulación de las estructuras esqueléticas. El objetivo de este artículo es describir y analizar la anatomía esquelética de un espécimen de pardela negra (Procellaria aequinoctialis). Los resultados demostraron la eficacia de la técnica utilizada para obtener material osteológico conservado apto para su exposición y estudio.

Palabras clave: Anatomía veterinaria, Montaje esquelético, Aves marinas, Anatomía comparada, Colecciones osteológicas.

1 INTRODUCTION

Osteological collections play a fundamental role in scientific research, enabling studies related to the anatomy, evolution, systematics, and conservation of fauna. The preservation of skeletons provides important information about the anatomy and osteology of wild and domestic animals. Assembling a skeleton using osteotechnical methods allows for detailed observation of the bone structures of the animal's entire skeletal system. Techniques for preparing and cleaning carcasses are essential for studies and for preparing animals for scientific and educational collections (Lopes, 2019).

In practical terms, this allows the black shearwater (*Procellaria aequinoctialis)* to be used as a teaching model in anatomy research centers, especially when there is a shortage of complete osteological collections. Studies conducted by IBIMM itself on wild animals Queiroz *et al*. (2024) and Lopes *et al*. (2019) suggest that osteology and osteotechnology play a central role in this process. The preparation of skeletons, when conducted with method, documentation, and descriptive standardization, enhances the

quality of teaching, benefits the conservation of anatomical specimens, and strengthens scientific collections. Studies applied to domestic and wild species have shown that the correct preparation of specimens allows for better anatomical interpretation, greater reproducibility, and more effective use in interspecies comparisons, university extension programs, and scientific outreach (Cavinatto *et al*., 2016; Rankrape, Baungratz, & Haas, 2020).

The black shearwater is a procellariiform bird of the family Procellariidae. It is also known as the white-chinned shearwater, white-billed shearwater, and white-billed procellaria. The species is classified globally as Vulnerable (VU) by the IUCN/BirdLife and is listed in Appendix II of the Convention on Migratory Species (CMS) (Sick, 1997). The species measures approximately 50-58 cm in body length and weighs around 1.2-1.4 kg, with morphometric differences between the sexes and an approximate wingspan of 134–147 cm. The plumage is predominantly dark, with a variable white patch on the chin; the bill is robust and light-colored, and the legs and feet are dark. (Sick, 1997).

Osteology, combined with preparation and osteomounting techniques, is an important resource for anatomical study, as it allows for the identification and description of skeletal structures, in addition to producing specimens for teaching and research. In a study conducted on the domestic duck (*Tadorna tadorna*), Sarott, Lima, and Lopes (2024) demonstrated that the description of the skeleton and the application of laboratory techniques for handling the carcass and bones enable the assembly of educational materials, contributing significantly to veterinary medicine education.

The purpose of this article is to describe and discuss the skeletal anatomy of a black shearwater specimen found on Arpoador Beach in Peruíbe, with an emphasis on the main bone complexes observed after preparation of the material; to contextualize the figures in relation to the analysis; and to highlight the educational and scientific applicability of skeletal mounting as a solution for teaching veterinary anatomy and biology.

2 MATERIALS AND METHODS

2.1 ACQUISITION OF THE SPECIMEN

A specimen of the black shearwater (*Procellaria aequinoctialis*) was used, which was found dead during beach monitoring conducted by the SOS Sea Turtles Project at the Arpoador Center in the municipality of Peruíbe, São Paulo. The specimen was collected under authorization from ICMBio (SISBIO license No. 50132) and SEMIL/IPA-Institute of Environmental Research. After collection, photographic records were taken, a macroscopic evaluation of the carcass was performed, and biometric measurements were recorded on forms developed by IBIMM and added to the collection. The specimen was transported to the laboratory, kept frozen until processing, and subsequently added to the IBIMM biological collection at the Peruíbe Center, catalog number 453.

. The specimen was transported to the laboratory and kept frozen until the start of the research.

2.2 OSTEOLOGICAL PREPARATION

The specimen was thawed under controlled conditions and dissected using a scalpel, forceps, and scissors. The skin, musculature, and internal organs were removed manually and gradually, with special attention paid to the cranial region and the distal ends of the limbs in order to minimize the loss of small bone fragments.

2.3 CLEANING AND PRESERVATION

Preparation began with the manual removal of the skin, musculature, and internal organs. Soft tissues were removed gradually to preserve delicate structures and minimize loss, particularly in the cranial and distal limb regions, where small bone fragments may be more fragile during handling.

Following a methodology similar to that employed by Queiroz *et al*. (2024), after the initial dissection, the carcass was macerated in water heated to approximately 80 °C, with the addition of a neutral detergent, for about 1 hour per day, until the remaining soft tissues were gradually removed.

Next, the bones were separated by anatomical region and bleached in a solution containing water and 5% sodium hypochlorite; after 24 hours, the material was rinsed under running water and allowed to air dry. They were then subjected to a new bleaching process using 10% hydrogen peroxide in warm water, kept in the solution for approximately 30 minutes, under visual monitoring to prevent the specimens from becoming brittle and to avoid excessive bleaching.

After bleaching, the bone elements were rinsed under running water and dried in an oven equipped with a 100-watt halogen lamp for 36 hours, until residual moisture was completely eliminated a technique used in anatomical preparation due to its favorable balance of cost, efficiency, and process control.

Next, the anatomical separation and identification of each skeletal element were performed.

The practical processing of the material, from dissection to the final organization of the parts, took approximately seven days of work, with an average workday of five hours. The preparation resulted in a sufficiently intact set for regional analysis, which allowed for the identification of the main components of the axial and appendicular skeletons.

2.4 SKELETON ASSEMBLY

After the identification and organization of the bone elements, the skeleton was assembled using galvanized steel wire and contact adhesive. The components were positioned according to their anatomical relationships, based on the literature on avian anatomy and the photographic records taken prior to disassembly.

2.5 APPROVAL BY THE ETHICS COMMITTEE - BIOCEUA-IBIMM

The research project involving a specimen of the black shearwater (*Procellaria aequinoctialis)* was submitted on June 10, 2024, to the Ethics Committee of the Institute of Marine Biology and Environment (BIOCEUA-IBIMM) and approved at a meeting on July 11, 2024, under number 027.

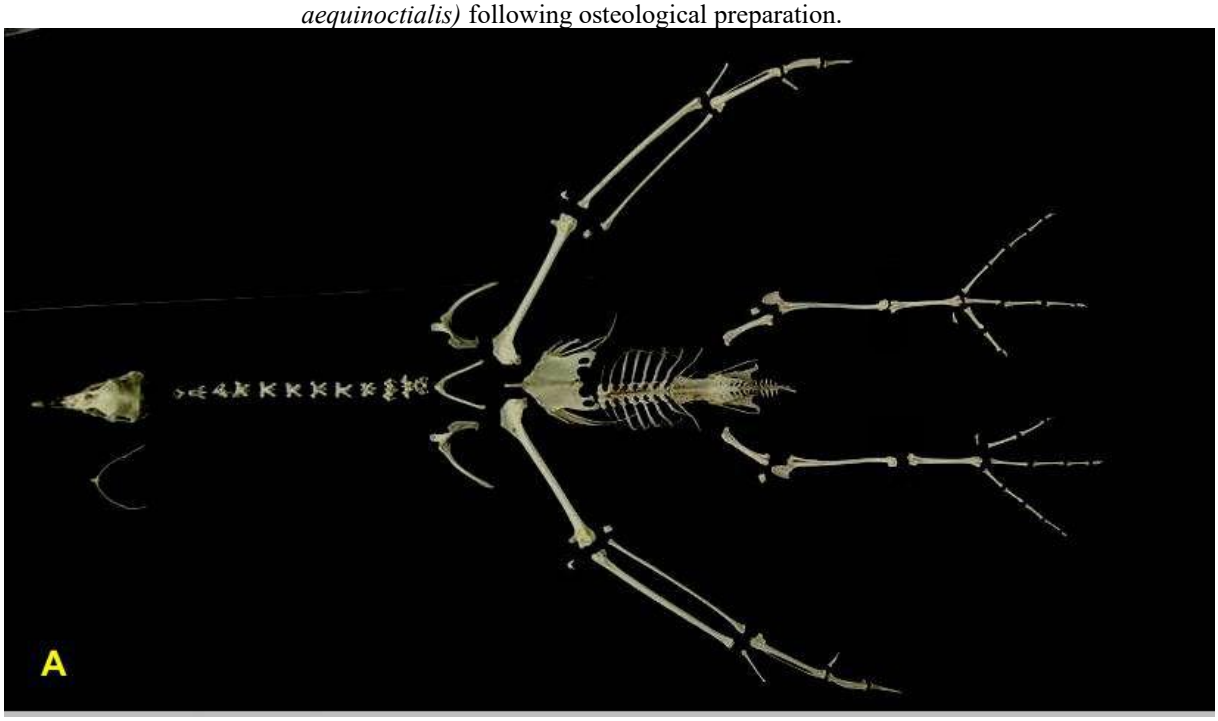
3 RESULTS

3.1 OVERVIEW OF THE PREPARATION OF THE OSTEOLOGICAL MATERIAL

The two-dimensional arrangement of the specimens prior to final assembly facilitated verification of the material's completeness and the preliminary identification of paired, fused, and reduced bones. From an educational standpoint, this step is particularly important because it allows the observer to understand the general organization of the skeleton before segmental analysis, thereby facilitating anatomical interpretation during practical classes and scientific exhibitions.

The image in Figure 1 illustrates the initial stage of checking the osteological material, in which the two-dimensional arrangement of the specimens facilitates the recognition of anatomical complexes and the verification of the integrity of the collected specimens. From an educational perspective, this procedure facilitates a comprehensive understanding of the skeleton and provides more reliable guidance for the subsequent stages of identification, comparison, and osteomontage.

Figure 1. General arrangement of the bone specimens from the black shearwater (*Procellaria aequinoctialis)* following osteological preparation.



Source: Prepared by the authors (2026).

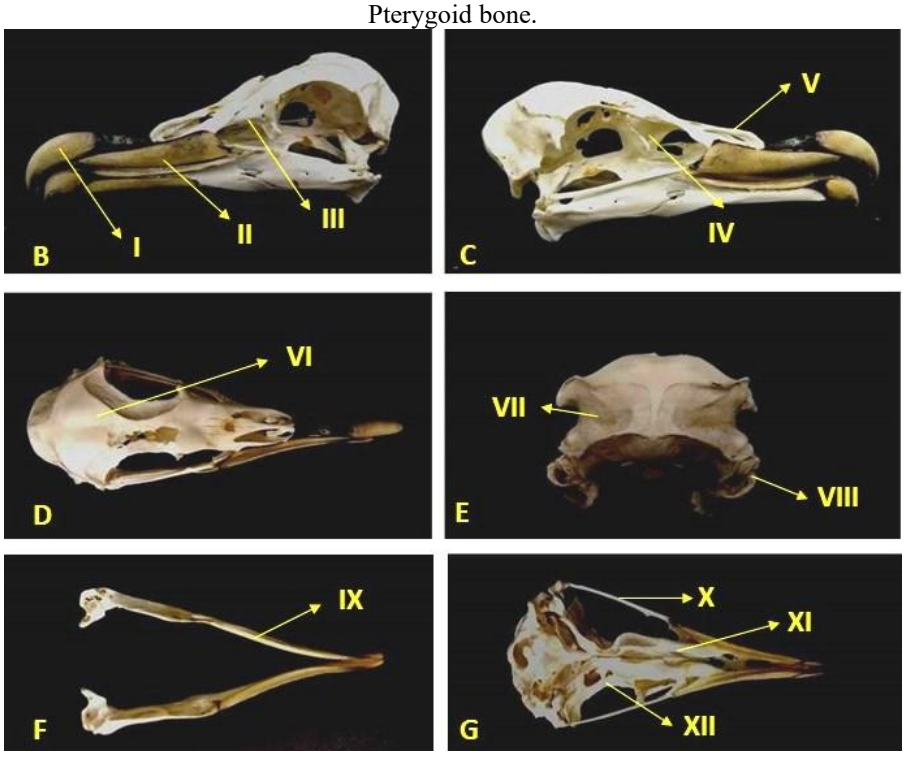
3.2 SKULL

Supplementary documentation of the skull in different anatomical planes enhances the descriptive reliability of the study, as it reduces identification ambiguities and allows the same element to be viewed from different perspectives. This strategy is recommended for studies with an educational purpose, as it facilitates subsequent verification of the structures by faculty, students, and external readers interested in replicating the identification of the specimens.

In the specific case of the black shearwater, the detailed photographic documentation of the cranial region also facilitates future comparisons with other Procellariiformes and with seabirds of similar size. This comparative perspective is valuable for studies in anatomy, practical taxonomy, osteotechnology, and the development of institutional collections.

The set of views presented in Figure 2 enhances the descriptive reliability of the study, as it reduces identification ambiguities and allows for the observation of the same cranial region in different anatomical planes.

Figure 2. Black *Shearwater (Procellaria aequinoctialis)* – In (B): I – Premaxilla; II – Maxilla; III – Lacrimal bone; (C): IV – Ethmoid bone; V – Nasal bone; (D): VI – Frontal bone; (E): VII – Parietal bone; VIII – Quadrate bone; (F): IX – Complete mandible; (G): X – Jugal bone; XI – Palatine bone; XII – Pterygoid bone.



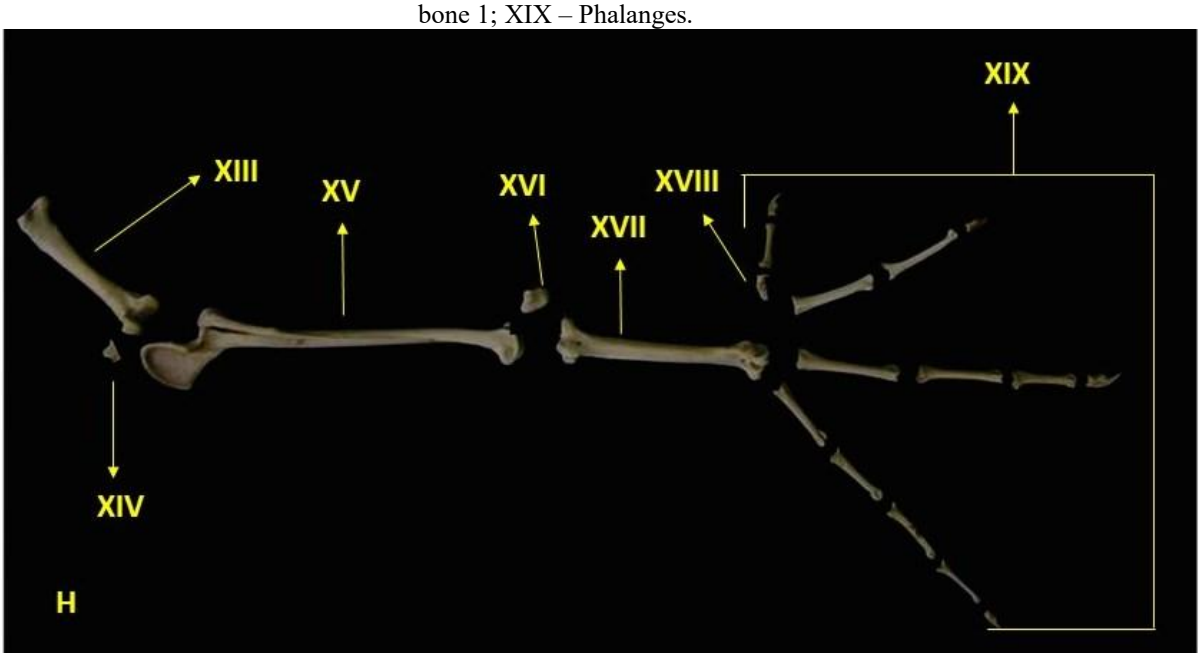
Source: Prepared by the authors (2026).

3.3 PELVIC LIMB

The pelvic limb proved to be particularly robust, a feature consistent with locomotion when at rest. The femur, patella, tibiotarsus (reduced fibula), and tarsometatarsus, first metatarsal, and phalanges were present. These elements were sufficiently intact to recognize the continuity between the thigh, leg, and autopod. Figure 3.

The lateral view of the pelvic limb allows one to recognize the robustness of the bony structure and the functional continuity between the thigh, lower leg, and foot. The sequence of the femur, tibiotarsus, tarsometatarsus, and toes demonstrates how the posterior segment is organized to bear weight, maintain stability, and facilitate terrestrial locomotion. The photographic record also aids in the identification of smaller structures, such as the patella and the reduced fibula, enhancing the anatomical interpretation and educational use of the prepared specimen.

Figure 3. Pelvic limb of the black shearwater *Procellaria aequinoctialis* in (H): XIII – Femur; XIV – Patella; XV – Tibiotarsus; XVI – Hypotarsal sesamoid bone; XVII – Tarsometatarsus; XVIII – Metatarsal bone 1; XIX – Phalanges.



Source: Prepared by the authors (2026).

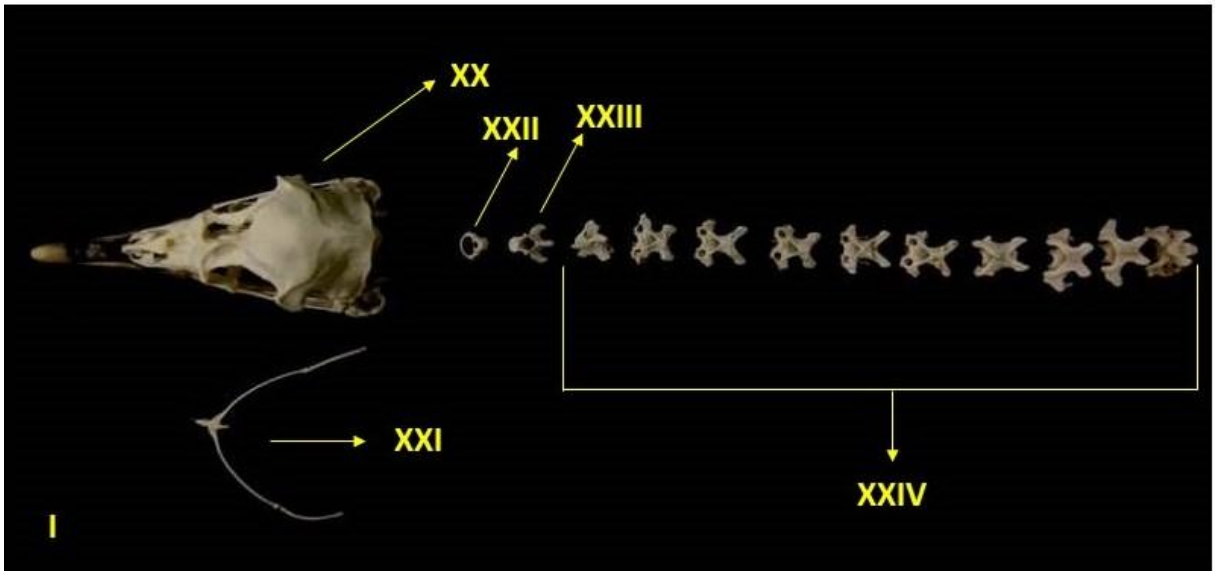
3.4 CRANIAL STRUCTURES

The cranial views obtained in this study allow for the identification of components important for feeding, mandibular articulation, and head mobility. The mandible,

premaxilla, quadrate, orbit, occipital region, and hyoid apparatus form an integrated complex that supports grasping, food manipulation, and head movement.

In the black shearwater, the robustness of certain cranial regions must be interpreted in relation to feeding patterns and cervical movement. The articulation with the atlas and axis, for example, is essential for the range of head movement, while the hyoid apparatus aids in the intraoral manipulation of food. This integrated analysis goes beyond the simple identification of bones and promotes a functional understanding of the system as a whole, Figure 4.

Figure 4. Skull and cervical series of the black shearwater *Procellaria aequinoctialis* in (I): XX – Skull; XXI – Hyoid; XXII – Atlas; XXIII – Axis; XXIV – Cervical vertebrae.



Source: Prepared by the authors (2026).

3.5 VERTEBRAL COLUMN, PELVIS, AND STERNUM

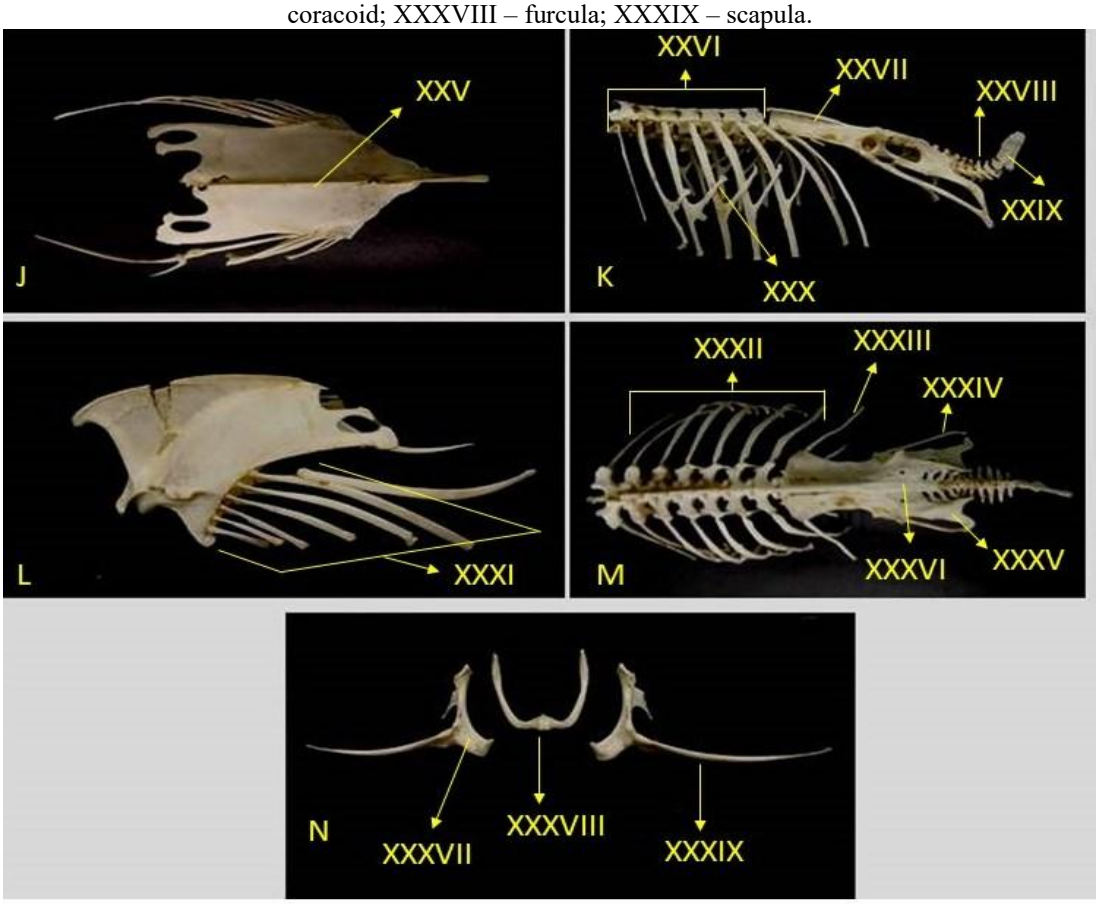
The cervical and thoracic series, together with the pelvis and sternum, reveal some of the most characteristic features of avian anatomy. The elongated cervical spine increases neck mobility, an essential condition for feeding, surveillance, and food manipulation, while the thoracic region exhibits greater structural rigidity. This contrast between mobility and stability is central to understanding the functionality of the avian skeleton (Baumel, 1993).

The black shearwater is a pelagic bird with a high capacity for long-distance flight; the term “bird of limited flight” is inappropriate. Suggestion: “In a pelagic bird adapted to oceanic travel, the keeled sternum, the coracoids, the furcula, and the ribs with hooked

processes form part of the thoracic apparatus associated with flight musculature, visceral protection, and ventilation.

The pelvis, in turn, showed a close association with the synsacrum, forming a stable base for the hind limbs. This integration reduces mobility between certain segments but enhances the capacity for force transmission during standing and walking. The relationship between the spine, pelvis, and sternum can be observed in Figure 5, which highlights the functional organization of the body axis. As can be seen, the body axis of the black guillemot combines cervical mobility, greater thoracic rigidity, and strong integration between the pelvis and synsacrum. This arrangement is significant because it supports posture, protects the viscera, and distributes mechanical forces between the trunk and hind limbs. The combined visualization of the cervical vertebrae, sternum, ribs, and pelvic elements enhances understanding of the bird's axial organization and reinforces the value of the material for studies of functional anatomy and avian morphology, Figure 5.

Figure 5. Sternum, thoracic series, caudal series, and pelvis of the black shearwater *Procellaria aequinoctialis* in (J): XXV – Keel; (K): XXVI – Notary; XXVII – Ilium; XXVIII – free caudal vertebrae; XXIX – Pygosty; XXX – uncinate process; (L): XXXI – ventral segments of the ribs; (M): XXXII – ribs; XXXIII – floating rib; XXXIV – pubis; XXXV – ischium; XXXVI – synsacrum; (N): XXXVII – coracoid; XXXVIII – furcula; XXXIX – scapula.



Source: Prepared by the authors (2026).

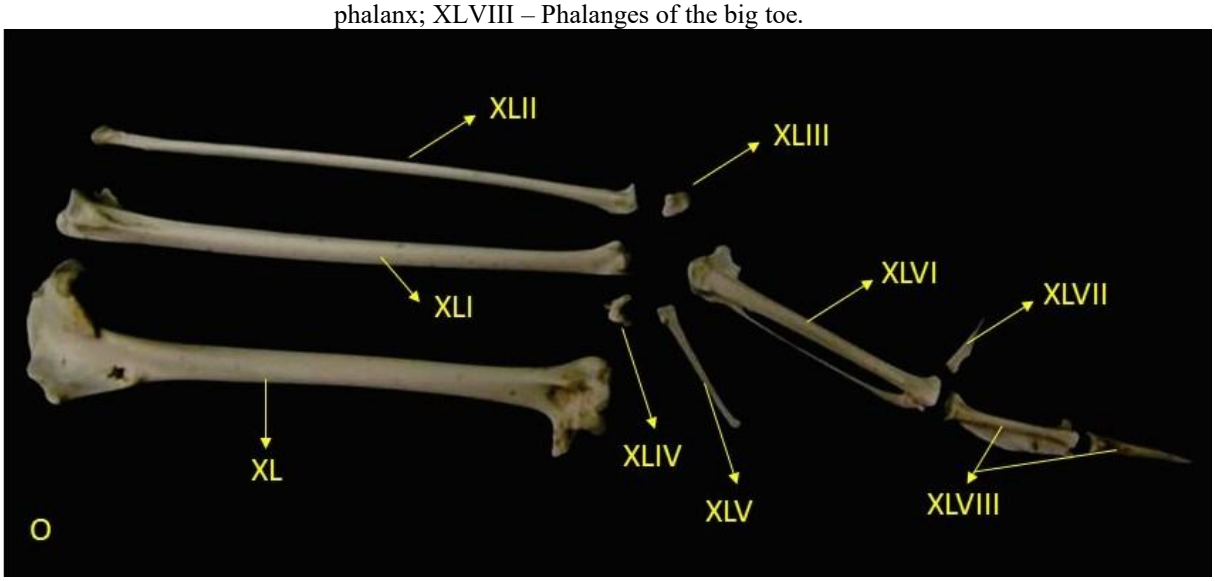
3.6 WING AND THORACIC LIMB

The elements of the wing maintained an organization consistent with the avian pattern, including the humerus, radius, ulna, carpal bones, carpometacarpus, and digital phalanges. The more developed ulna and the fused carpometacarpus are noteworthy because they are related to the support of flight feathers and the transmission of forces along the thoracic limb.

In addition to its biological value, the detailed documentation of the wing has direct utility in teaching practices. The macroscopic identification of each segment facilitates the association between nomenclature, anatomical position, and function, allowing students to understand how the avian skeleton combines relative lightness, selective rigidity, and mechanical efficiency across different scales of movement. The organization shown in Figure 6 highlights the proximal-distal sequence of the forelimb,

allowing for the precise distinction of the humerus, radius, ulna, carpometacarpus, and digital phalanges.

Figure 6. Major bony elements of the wing and forelimb of the black shearwater *Procellaria aequinoctialis*, where (O): XL – Humerus; XLI – Ulna; XLII – Radius; XLIII – Ulnar carpal bone; XLIV – Radial carpal bone; XLV – Phalanx of the little toe; XLVI – Carpometacarpus; XLVII – Single phalanx; XLVIII – Phalanges of the big toe.



Source: Prepared by the authors (2026).

3.7 ASSEMBLY AND FINAL RESULT OF THE BLACK GUILMOT SKELETON

The final assembly of the black guillemot skeleton allowed for the integration of the previously prepared, identified, and organized bone segments, resulting in a three-dimensional anatomical model suitable for educational, demonstrative, and scientific purposes. The final arrangement of the skeleton facilitates an understanding of the relationships between the axial axis, the pectoral girdle, the thoracic limb, the pelvis, and the pelvic limb, allowing for an integrated observation of the morphological adaptations associated with body support, terrestrial locomotion, and the general organization of the avian body plan.

The osteomount also enhances the educational potential of the material, as it enables the observer to understand not only the bones in isolation but also their relative position within the skeletal assembly. Thus, the final specimen contributes to the teaching of comparative anatomy, the development of osteological collections, and scientific outreach activities, as shown in Figure 7.

Figure 7. Final assembly of the skeleton of the black shearwater (*Procellaria aequinoctialis*).

Source: Prepared by the authors (2026).

4 DISCUSSION

The osteological preparation made it possible to preserve and organize the main components of the axial and appendicular skeletons of the *Procellaria aequinoctialis* specimen. The resulting integrity allowed for the identification of the skull, vertebral column, ribs, sternum, pectoral girdle, pelvis, and limb elements, in addition to producing a three-dimensional mount for the institutional collection. The result demonstrates the potential of carcasses found dead for the formation of scientific collections, provided that their provenance, processing, and cataloging are adequately documented.

The general organization observed corresponds to the avian body plan described in the literature, characterized by fusions and specializations that provide stability to certain segments. The association between the notary, synsacrum, sternum, furcula, and coracoids, as well as the presence of the carpometacarpus and tarsometatarsus, should be interpreted in the context of avian anatomy (Baumel, 1993).

However, the present study analyzed only a single specimen and did not perform osteometry, interspecific comparisons, or biomechanical evaluations; therefore, inferences regarding robustness, locomotor performance, and feeding habits should be

considered hypotheses supported by the literature, rather than directly demonstrated results.

From a methodological standpoint, gradual dissection and regional organization contributed to the recovery of smaller elements. On the other hand, the use of oxidizing agents and drying at high temperatures requires caution, as they may affect the integrity of bone tissue. The lack of comparison between protocols does not allow for a determination of the superiority or efficiency of the technique used.

Future studies should record concentrations, proportions, exposure time, temperature, loss of elements, and macroscopic changes, thereby enabling an assessment of reproducibility and long-term conservation. The mounted specimen serves an educational purpose by allowing for a three-dimensional visualization of the relationships between the elements.

Maintaining properly cataloged osteological collections strengthens zoological research and aids in the conservation of biological heritage.

The preparation and assembly of the black shearwater skeleton involve procedures of great scientific and educational significance. The material obtained allows for detailed anatomical studies and contributes to the dissemination of knowledge about seabirds of the Southern Hemisphere.

In the case of the black shearwater, the preservation of the skeleton aids in understanding the evolutionary adaptations related to oceanic flight and the species' feeding habits.

The relevance of this study lies in the practical demonstration that obtaining relatively complete bird skeletons depends directly on both the initial condition of the carcass and the rigor applied during the maceration, cleaning, bleaching, and drying stages. The final quality of the specimens highlights the importance of methodological control throughout the osteotechnical process, since failures at any stage can result in structural losses, deformations, or compromise the anatomical integrity of the material.

The use of real skeletons in practical activities enhances three-dimensional learning of anatomy, facilitates the identification of bone structures, and improves understanding of the spatial relationships among the different elements of the skeleton. Furthermore, permanent osteological collections constitute important resources for teaching, research, and outreach, allowing the material to be used continuously by different classes and in environmental education activities, thereby bridging the gap

between the university and society. Recent studies demonstrate that real anatomical specimens remain among the most effective teaching resources for veterinary anatomy, even in the face of the growth of digital technologies and three-dimensional models.

In addition to their use in formal educational settings, the materials produced can be incorporated into permanent anatomical collections, educational collections, and outreach exhibitions. Organizing the specimens by anatomical regions facilitates the development of workshops, educational activities aimed at K-12 education, and science outreach initiatives for the general public. These initiatives foster closer ties between the community and scientific knowledge, promoting an appreciation for comparative anatomy and the biological diversity of domestic and wild species.

From a scientific perspective, the preparation and documentation of the skeleton are also significant as a morphological record. Although this study was based on a single specimen, the detailed description of the observed structures combined with the use of standardized anatomical nomenclature and a specialized bibliographic foundation contributes to the consolidation of anatomical knowledge regarding the studied species. Furthermore, the data generated can serve as a reference for future comparative investigations involving different individuals, lineages, or species, expanding the possibilities for studies in anatomy, functional morphology, and systematics.

5 CONCLUSION

The osteological preparation of the black shearwater specimen made it possible to preserve, identify, and assemble the main components of the axial and appendicular skeletons, resulting in a specimen suitable for inclusion in the institutional collection and for educational and scientific outreach activities. This study documents the utilization of a carcass found dead and reinforces the importance of recording provenance, cataloging, and providing a detailed description of the processing. However, because it is based on a single individual and does not include osteometry, comparisons between specimens, or an experimental evaluation of the protocol, the results do not allow for morphofunctional generalizations or the assertion of the superiority of the technique employed. Future studies with a larger number of specimens, standardized measurements, and comparisons between methods may expand our osteological knowledge of **Procellaria aequinoctialis** and assess the long-term preservation of the specimens.

The application of osteology proved effective in obtaining preserved anatomical material suitable for teaching, research, and outreach activities. The prepared skeleton has the potential to be integrated into educational and scientific collections, providing resources for the academic training of students in the fields of Veterinary Medicine, Biological Sciences, and related disciplines, while also supporting scientific outreach and education in comparative anatomy.

Thus, this study transcends its merely descriptive and illustrative nature, serving as a support tool both for educational activities and for the construction of anatomical databases that can inform future research and strengthen the preservation of the institution's scientific heritage.

Finally, it is concluded that the osteotechnical preparation and complete final osteomounting, combined with the anatomical description of *Procellaria aequinoctialis*, constitute an effective strategy for producing high-quality scientific and educational material, thereby reinforcing the importance of osteological collections as tools for teaching and preserving anatomical knowledge.

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