



Osteomorphological Features of the Carcass of *Inia geoffrensis* (Cetacea: Iniidae)

P. F. Santos^{1*}, Y. K. Soeiro-Avelar², A. S. Araújo³ and C. E. Costa-campos⁴

¹Mestranda da Universidade Federal do Pará, Brazil.

²Mestrando da Universidade Federal da Integração Latino-Americana, Brazil.

³Coordenadora do Laboratório de Zoologia, Prof.^a Dra. da Universidade Federal do Amapá, Brazil.

⁴Coordenador do Laboratório de Herpetologia, Prof. Dr. da Universidade Federal do Amapá, Brazil.

Authors' contributions

This work was carried out in collaboration among all authors. Authors PFS, YKSA, ASA and CECC designed the study, carried out the laboratory analyses for the study. Authors PFS, YKSA performed the write and proof-read the manuscript. Authors PFS, YKSA, ASA and CECC managed the literature searches. All authors thoroughly proof read and approved the final manuscript.

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ABSTRACT

Osteological studies can have implications that allow direct biological inferences to be made, such as locomotion, as well as indirect ones, such as species distribution, evolution and ecology. This study was aimed at describing some osteological traits of *Inia geoffrensis* (Blainvillei, 1817), Macapá/AP. A nearly complete carcass was found in a local forest. Information about the killing was collected through community reports. After collecting bones and information, the carcass was taken to the Laboratory of Zoology at the Federal University of Amapá for cleaning and examination. The cleaning process was carried out following the step-by-step maceration protocol and measurements of bones were taken with a measuring tape (2 m) and ruler (50 cm), except for cervical vertebrae, which were measured with a caliper (15 cm). To find the limbs in the carcass, an identification guide and a bone chart of aquatic mammals were used. Based on the observed data, the animal was a female, determined by the genital cleft. Examination of the occipital bone revealed an adult with complete bone fusion, obliterated sutures on the external surface of the

*Corresponding author: E-mail: paolafeioo@gmail.com;

skull. The carcass was nearly complete, with the entire face measuring 55 cm. Further studies are needed on environmental education about cetaceans, local awareness with the assistance of inspectors and competent authorities for the conservation of freshwater dolphins in the region and studies on carcasses for the maintenance of the species.

Keywords: Red dolphin; skull; skeleton; vertebrae.

1. INTRODUCTION

The Amazon river dolphin, *Inia geoffrensis* (Blainville, 1817) is one of the largest freshwater dolphins in the world, measuring approximately 2.5 m in length and reaching 160 kg. Sexual dimorphism of adults is characterized by males being pinker, larger and more robust than females [1]. This species belongs to the order Cetartiodactyla, suborder Odontoceti, family Iniidae, genus *Inia* [2,3].

Inia geoffrensis occurs in coastal fluvial-marine transition environments, where individuals are found in mangrove areas, and is listed as “data deficient” by the Red List of Threatened Species [4,5]. The observation and record of river dolphins in northern Brazil are limited to two species: the Amazon river dolphin *Inia geoffrensis* and the tucuxi *Sotalia fluviatilis* Gervais, 1853 [6].

Osteological studies can have implications that allow direct biological inferences, such as locomotion, and indirect ones, such as the distribution, evolution and ecology of a species [7]. They provide important information for taxonomic studies, since the skeleton has been the most used system to demonstrate phylogenetic relationships among chordates [8,9].

Carcasses of freshwater dolphins are found with marks of fishing nets and harpoons or signs of negative interactions with fishermen, and sometimes animals die when accidentally caught entangled in fishing nets [10,11]. Osteological studies of dolphin carcasses, however, are still scarce. This study was aimed at describing some osteological features of *Inia geoffrensis* (Order: Cetacea) in the state of Amapá, eastern Amazon.

2. MATERIALS AND METHODS

The record of a carcass of the Amazon river dolphin *I. geoffrensis* was carried out in the community of the District of Ariri, located 40 km

from Macapá/AP in August 2016. A standard measuring tape was used (2 m) to take measurements of the animal. In order to describe how the animal was killed, interviews with local residents were carried out and their reports were used as source of information; the carcass was also collected. The bones were found, approximately 20 minutes into the forest located in the community of Ariri/AP. Photographic cameras was also used to document the process.

After collecting the bones and information, the carcass was taken to the Zoology laboratory at the Federal University of Amapá, where the bones were cleaned and counted. The cleaning process was carried out following the step-by-step of the maceration process and bones were measured with a measuring tape (2 m) and ruler (50 cm), except for cervical vertebrae, which were measured with a caliper (15 cm) [12].

To find the limbs in the carcass, an identification guide and an osteological chart of aquatic mammals were used, provided by the Amazonian Aquatic Mammals Study Group [12]. For the analysis and classification of the age of the animal, the following standards were used [13]:

Calf: no fusion, absence of apparent suture at the margin of bones and presence of fontanelle;
Juvenile: no apparent fusion on the external surface of the skull, bone margins show visible sutures;
Subadult: visible partial fusion on the external surface of the skull;
Adult: complete bone fusion, sutures obliterated on the external surface of the skull. of Dentition was described with the aid of the Whale, Porpoise, and Dolphin Identification Guide [14,15,13].

3. RESULTS

According to accounts, the animal was captured in the Matapí River, Ariri District, by community residents in August 2016. The decomposing

animal was found with its snout removed and was identified as a *I. geoffrensis* female based on the genital cleft (Fig. 1). Only on November 29, 2016, during fieldwork to record the frequency and behavior of the dolphins in the Matapí River, the carcass of the Amazon river dolphin *I. geoffrensis* was found in the forest of the community of the Ariri District. The carcass was clean, but reports by residents describe that the event had taken place four months before (August, 2016) the carcass was found.

The hypothesis for the animal's death is that a fisherman/community resident was fishing and saw the animal tear the fishing net. The fisherman then pulled the animal onto the boat and cut its snout. The animal was found later floating in the Matapí River and the local residents dragged it into the forest. The exact size or age of the animal is unknown; however, the snout-tail length measured was approximately 175 cm.

The animal was identified as a female, based on the *Illustrated Guide of Identification of*

Cetaceans and Sirens of Brazil ICMBio/CMA that describes the sexual identification of cetaceans, differentiating the sexes according to external traits such as mammary slits and a shorter distance between the genital cleft and anus when compared to males that lack slits and longer distance between the anus and genital cleft.

Examination of occipital cranial traits revealed an adult with complete bone fusion, obliterated sutures on the external surface of the skull (Fig. 2). The carcass was nearly complete, with the entire face measuring 55 cm (Fig. 3a, 3b).

The dentition of the animal revealed 42 upper teeth, but lacked four conical anterior teeth and six molariform posterior teeth; and 44 lower teeth, with the absence of four conical anterior teeth and five molariform posterior teeth (Fig. 4a, 4b). If all teeth were present, the animal would have a total of 105 teeth. In the upper rami, each ramus had 26 teeth and in the lower rami, one rami had 26 and the other, 27 teeth.

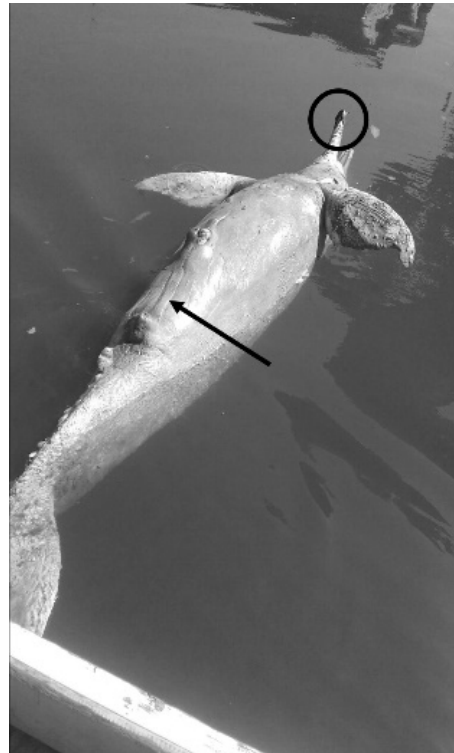


Fig. 1. Registration of the female red dolphin (*I. geoffrensis*) undergoing decomposition. Genital cleft represented by the black colored arrow. Cut snout indicated by the black colored circle

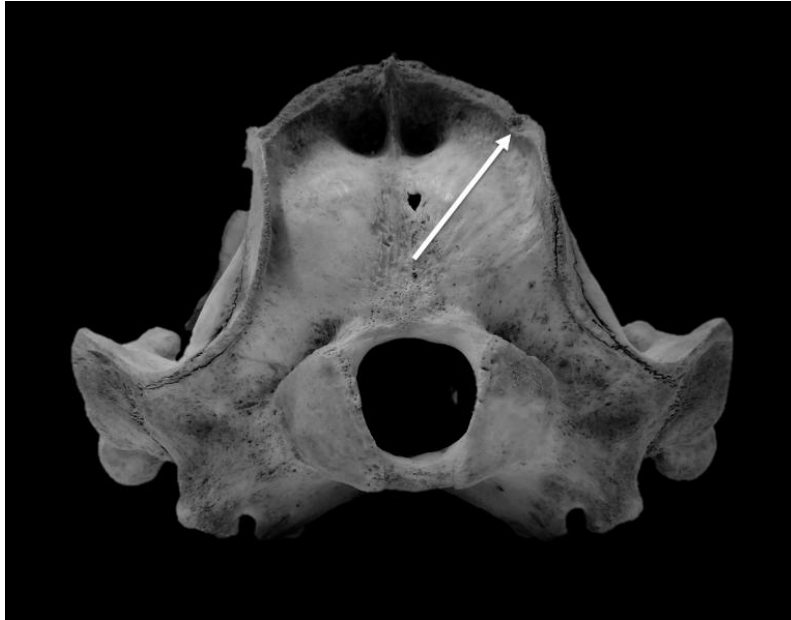


Fig. 2. Adult skull with complete bone fusion; arrow: obliterated sutures on the external surface of the skull of *I. geoffrensis*. scale: 3 cm

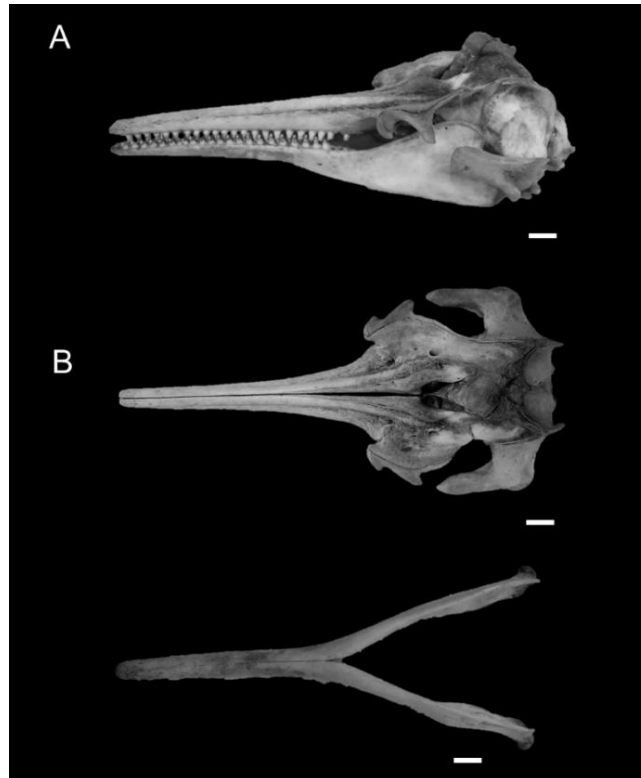


Fig. 3A. Face of *I. geoffrensis* with no prognathism in the mandibular portion. B. distribution of the upper and lower mandibular portion of *I. geoffrensis*. scale: 3 cm

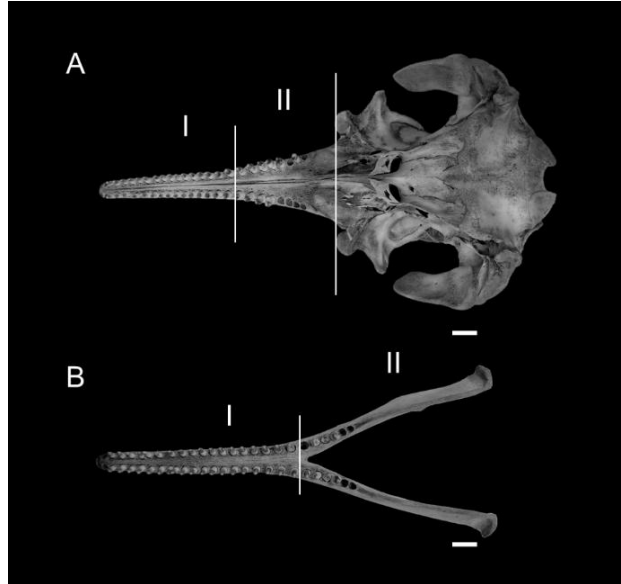


Fig. 4A. Mandibular portion of *I. geoffrensis* with conic (segment I) and molariform (segment II) division. B. maxillary portion of *I. geoffrensis* with conic (segment I) and molariform (segment I) division. Scale: 3 cm

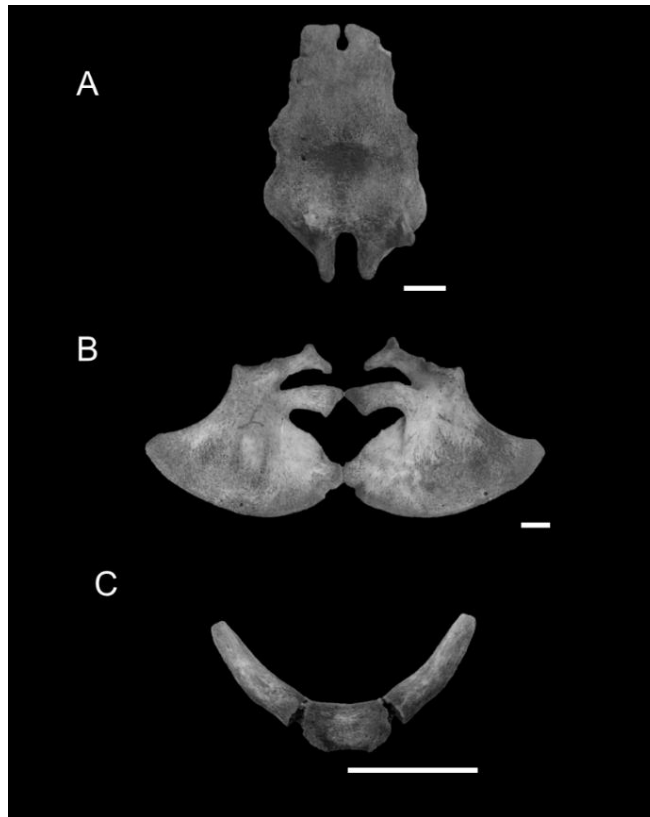


Fig. 5A. sternum of *I. geoffrensis*. B. scapulas of *I. geoffrensis*. C. hyoid of *I. geoffrensis*. scale: 3 cm (scapulas), Scale: 4 cm (sternum) and Scale: 3,8 cm (hyoid)

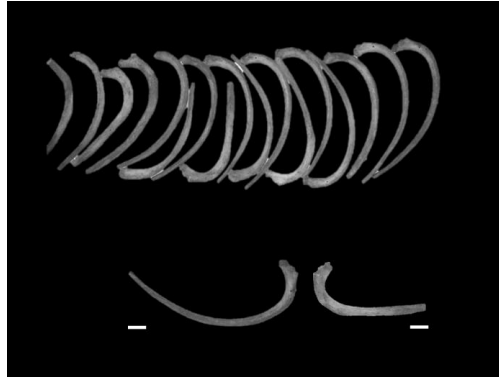


Fig. 6A. Partial sample of a total of 25 ribs collected. **B.** arger and smaller specimens checked for the collected ribs. Scale: 3 cm

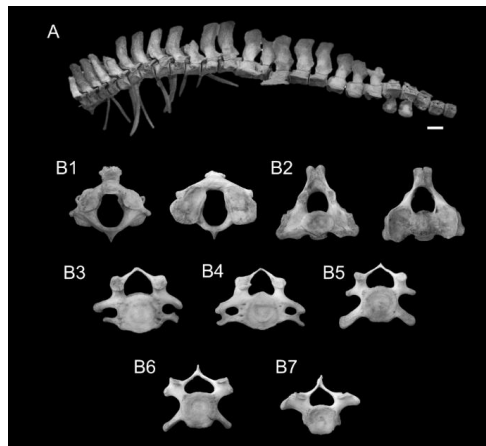


Fig. 7A. It represents 25 vertebrae, among them: 22 vertebrae distributed between thoracic and lumbar; 3 caudal vertebrae identified by similarity. **B.** it represents 7 cervical vertebrae, among them: **B1.** first cervical vertebrae of *I. geoffrensis* that merges with the skull. **B2.** second cervical vertebra of *I. geoffrensis*. **B3.** third cervical vertebra of *I. geoffrensis*. **B4.** fourth cervical vertebra of *I. geoffrensis*. **B5.** fifth cervical vertebra of *I. geoffrensis*. **B6.** sixth cervical vertebra of *I. geoffrensis*. **B7.** seventh and last cervical vertebrae of *I. geoffrensis*

Regarding other bones of the specimen, despite the lack of data about the bones of this cetacean, a sternum was identified, measuring 18x12 cm (Fig. 5a) as well as two scapulas with 21 cm (Fig. 5b); and a hyoid with 7.6 cm (Fig. 5c).

Twenty-five ribs were also identified, the largest was 25.5 cm and the smallest, 20 cm (Fig. 6); as well as 32 vertebrae consisted (Fig. 7a) of 7 cervical vertebrae (Figs. 7b1, 7b2, 7b3, 7b5, 7b5, 7b6, 7b7), 22 thoracic and lumbar vertebrae, and 3 caudal vertebrae identified by similarity in sizes ranging from 16 cm (largest) and 3 cm (smallest). The expected number of ribs of *I. geoffrensis* is $n = 26$ pairs.

4. DISCUSSION

The Amazon river dolphin (*I. geoffrensis*) is considered a predator, essential for the regulation of ecosystems and that is adversely affected by the impact of humans on its habitat, including hunting [16,17]. *I. geoffrensis* was reported as the main species used as bait for piracatinga fishing (*Calophysus macropterus*) [18,19]. In this context, cetaceans have long attracted attention from humans [20].

It should be pointed out that in recent years, direct interactions between humans and cetaceans have increased as a result of fishing and tourist activities [21,22,23,24]. In the case of

fishing, the damage in fishing nets caused by dolphins results in losses and negative reactions from fishermen [25,26]. These adverse interactions can generate and condition aggressive behaviors among dolphins as well as dolphins and humans, while harmonious interactions are rarely reported in eastern Amazon [27,28]. These interactions can sometimes be harmful, such as the use of carcasses as bait, indiscriminate killing due to conflicts with fishermen and destruction of their habitat [29].

The species *I. geoffrensis* in the Tapajós River tends to interact with eight to 18-year-old youngsters because they offer fish to dolphins, while other results indicate playful behavior of children with dolphins [30]. Therefore, the reported negative interactions corroborate the results obtained in the study [25,26].

It should be pointed out that regarding sexual traits, *I. geoffrensis* is considered one of the most sexually dimorphic cetaceans. In addition to the previously described criteria, *I. geoffrensis* females differ from males by their grayish color and smaller size, supporting their dimorphism [26].

The size of adult animals ranges from 216 cm to 255 cm in length and 142 kg to 185 kg in weight, while for age, both *Sotalia spp.* and *I. geoffrensis* exhibit a darker color in the dorsal region that varies according to the individual's age [31,28]. Newborns and young animals are predominantly dark gray and as they get older, they become lighter, in part, because of marks of aggression caused by humans, and the scar tissue is pink [31]. In adults, pink is the prevalent color and is more intense in males than in females [32]. Although the specimen found had a snout-tail size smaller than that described by [31], the cranial examination carried out following [13] suggest the animal was an adult based on the fusion of skull bones.

Other characteristics were also observed in the individual examined, such as long and robust face, but absence of prognathism and deviation of the jaw.

As for dentition, according to [33], this species has 27-30 teeth, divided into anterior conical and posterior molariform teeth. [34] point out that *I. geoffrensis* has 25 to 29 teeth per ramus and a total of number of teeth varying between 96 and 140. The animal examined had a total of 105

dental alveoli, in agreement with the Identification Guide and [15].

Few studies are available on the morphology of *I. geoffrensis*, and the sizes and the exact number of ribs and vertebrae are unknown. However, when comparing the results obtained to those reported by [35], describing that the numbers of ribs must be divided into pairs, the number of ribs of *I. geoffrensis* was estimated to be $n = 26$ pairs, in agreement with the described by [36].

The information available in the literature on the following osteological structures - sternum, pair of shoulder blades, hyoid, ribs, and vertebrae is insufficient. However, [36,37] demonstrated a phylogenetic relationship between *Pontoporia blainvillei* and *Inia geoffrensis*, indicating polyphyly for genetic analysis and monophyly for morphological characters [37]. Therefore, [36] describes the osteological characteristics of *P. blainvilli* and compares them with those of *I. geoffrensis*. This study was used as a parameter for the examined specimen, since they are morphologically monophyletic and belong to the same subfamily Iniinae.

5. CONCLUSION

Information on *I. geoffrensis* carcasses for reporting and detailing this opportunistic collection was scarce. Further studies on this species are needed, such as bone and dental wear. In addition, environmental education about cetaceans and local awareness activities should be carried out with the assistance of inspectors and competent authorities, as well as more detailed studies on carcasses of *I. geoffrensis* in order to provide more information on its ecological role for the preservation of freshwater dolphins in the region.

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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