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## Anatomical investigation on the bones of the pectoral limb of glossy ibis (*Plegadis falcinellus*)

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### Abstract

Glossy ibis is one of the three species of ibises found in India. They are highly migratory water birds with long neck, long curved bills, lengthy wing span and long legs, which attribute their flying ability and feeding behaviour. The bones of the forelimb especially the pectoral girdle represents the evolutionary development and adaptation. An adult glossy ibis carcass which was found on the road side and recovered for this study. The bones of the ibis were collected by natural maceration and further processed using 3 percent sodium hydroxide. The bones of the pectoral girdle were relatively longer for adaptation to flight and large wing span. Clavicle was distinctly 'U' shaped and hypocleidium was absent. Humerus was shorter than the forearm bones. Shaft of ulna showed scaly projections for the attachment of wing feathers. Radial carpal was quadrilateral and ulnar carpal was U shaped with one long limb. Carpometacarpus was composed of three fused metacarpals. There were three number of digits comprised of two phalanges in II digit and one phalanx in I and III digit. The autopodium was longer than the humerus while shorter than the radius and ulna.

**Keywords:** Glossy ibis, pectoral girdle, gross morphology, autopodium, wing bones

### Introduction

The glossy ibis is a widely distributed, water bird belonging to the family of *Threskiornithidae*, which includes ibises and spoon bills. Among the ibises, the Oriental White ibis (Black headed ibis), Indian black ibis and the Glossy ibis are the three species recorded in India (Ali *et al.*, 1983) [2].

This cosmopolitan bird commonly inhabitates large lakes, river banks, grasslands and paddy fields. Glossy ibis is the rarest among the other three species found in India (Alfred *et al.*, 2001) [1].

Glossy ibis is usually a highly migratory and nomadic bird, observed in flocks of 40 to 50 numbers and they are also colonial nesters commonly found associated with egrets and herons (Thirumalai and Radhakrishnan, 2005) [13].

Glossy ibises are medium sized birds of their family measures about 55 - 65 cm in length with a wingspan of 85 - 100 cm. Breeding adults have reddish brown bodies with shiny bottle-green wings. These birds have long slender neck, curved long bills and long legs. They feed on aquatic invertebrates, small fish, frogs and small snakes.

Glossy ibis species is the least common to nest in the South Indian region compared to other species. It was found to be nested in only two places of Tamil Nadu, Koonthakulam and Vedanthangal (Subramanya, 2005) [12]. This study was undertaken to fill up the lacunae in the availability of literature on the skeletal anatomy of glossy ibis.

### Materials and Methods

The current study was conducted on a adult male glossy ibis, which was found dead by natural causes on the road side The carcass was recovered and the viscera were removed. The feathers were removed and the carcass soaked in water to allow for natural biological maceration for about two weeks. Later the bones were collected and soaked in 3 percent sodium hydroxide to clean the residual tissue debris from the bones (Onwuama *et al.*, 2012) [9].

The cleared bones were sun dried and used for the study of pectoral girdle and bones of wings of the glossy ibis.

### Results and Discussion

#### 1. Bones of the Pectoral Limb

The pectoral limb of glossy ibis was composed of a well-developed pectoral girdle which was

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made up of scapula, clavicle and coracoid bones (Fig.1); Then distally the wing was formed by humerus, radius and ulna, radial carpal, ulnar carpal, carpometacarpus and phalanges (Fig.2) similar to that of most avian species as mentioned by Sisson *et al.* (1975) <sup>[11]</sup>.

## 2. Scapula

The scapula of glossy ibis was a flattened, sabre shaped bone, which extended with coracoid cranio-caudally, clavicle anteriorly and humerus laterally. Indu *et al.* (2012) <sup>[5]</sup> reported that the scapulae of green winged macaw and peahen were short and stout whereas it was long and narrow in glossy ibis. The pointed posterior extremity lied over the rib cage, parallel to the vertebral column as mentioned by Usende *et al.* (2017) <sup>[14]</sup> in the barn owl.

The anterior extremity had a wide facet laterally which formed the glenoid cavity along with the facet on the coracoid for the head of the humerus. Antero-dorsally it presented a acromion process (Nickel *et al.*, 1977) <sup>[8]</sup>. The lateral surface of the scapula was slightly convex and curved and this surface possessed sharp ridge for the muscular attachment.

## 3. Coracoid

The coracoid was a short, thick bone, placed vertically between the clavicle and scapula proximally; sternum distally. The anterior and posterior surfaces of the shaft were smooth and rounded. Girgiri *et al.* (2022) <sup>[4]</sup> reported that the coracoid of black-crowned crane was small and elongated while it was short and broad in glossy ibis. Coracoid of peahen was comparatively longer and narrower (Indu *et al.*, 2012) <sup>[5]</sup>.

The proximal extremity on its upper most end presented a large supracoracoid process. Laterally there was a large facet for humerus, and below it was a small facet for articulation with scapula. These observations were in compliance with Kigir *et al.* (2022) <sup>[7]</sup> in helmeted guinea fowl.

The medial border had a hook like process on its upper third, namely the procoracoid process. There was a large pneumatic foramen noticed below the procoracoid process. This foramen was not present in red-wattled lapwing (John *et al.*, 2015) <sup>[6]</sup>.

Clavicle articulated at the medial aspect of the coracoid by means of ligament. Scapula and clavicle articulated with coracoid and formed a foramen of canalis triosseum for passage of tendon of muscle (Rezk, 2015) <sup>[10]</sup>. The distal extremity of the coracoid was expanded and flat, articulated with the facet on the sternum (Nickel *et al.*, 1977) <sup>[8]</sup>.

## 4. Clavicle

The clavicle was a single bone of the pectoral girdle and the two sides of clavicle were composed of fat curved bones fused distally. The clavicle was “U” shaped and it lacked the distal hypocleidium; instead, a small median projection was observed. The clavicle was “Y” shaped in Japanese quail (Kigir *et al.*, 2022), chicken (Nickel *et al.*, 1977), peahen (Indu *et al.*, 2012) <sup>[7, 8, 5]</sup>, whereas it was an “U” shaped furcula in red-wattled lapwing (John *et al.*, 2015) and green-winged macaw (Indu *et al.*, 2012) <sup>[6, 5]</sup>.

Hypocleidium was present in the clavicle of peahen (Indu *et al.*, 2012), barn owl (Usende *et al.*, 2017), helmeted guineafowl (Kigir *et al.*, 2022) <sup>[5, 14, 7]</sup>, while it was absent in red-wattled lapwing (John *et al.*, 2015), black-crowned crane (Girgiri *et al.*, 2022) and green-winged macaw (Indu *et al.*, 2012) <sup>[6, 4, 5]</sup>.

## 5. Humerus

Humerus of glossy ibis was a strong, tubular long bone and

pneumatic in nature (Nickel *et al.*, 1977) <sup>[8]</sup>. The shaft of the humerus had two surfaces which were smooth and rounded. The medial border was slightly concave, while the lateral was convex.

The proximal extremity was composed of a head, two tubercles, two crests and a fossa. The head was rounded and prominent, which articulated with the glenoid cavity formed by scapula and coracoid. A small lateral tubercle was present and it continued downward by a wide and sharp deltoid crest (Rezk, 2015) <sup>[10]</sup>.

The medial tubercle was larger and was separated from the head by a deep sulcus capitis. The medial tubercle also continued further by a bicipital crest. Similar observations were noticed by Kigir *et al.* (2022) <sup>[7]</sup> in Japanese quail. Anteriorly, below the medial tubercle and crest, there was a deep pneumo tricipital fossa, which bore one large and multiple small pneumatic foramina. Usende *et al.* (2017) <sup>[14]</sup> reported that there was only a single large pneumatic foramen in the humerus of barn owl.

The distal extremity of humerus was comprised of two condyles; larger lateral condyle for the ulna and a smaller medial one for the articulation with radius and ulna. The two condyles were separated by a narrow intercondylar notch. The condyles were dorsally bound by medial and lateral epicondyles which enclosed a shallow, wide olecranon fossa on the posterior aspect of the distal extremity of humerus (Rezk, 2015) <sup>[10]</sup>.

## 6. Radius and Ulna

A large thick ulna and a slender rod like radius constituted the bones of the forearm in the glossy ibis. The two bones articulated on either extremities enclosing a wide interosseous space. The radius and ulna were relatively (1.2 times) longer than the humerus similar to that of the forearm of pigeon, while radius and ulna were shorter than the humerus in chicken (Nickel *et al.*, 1977) <sup>[8]</sup>.

The shaft of the ulna was smooth on all surfaces except on the ventral surface, it presented small raised projections throughout the length of the bone. Rezk (2015) <sup>[10]</sup> reported in cattle egret that those structures were the papillae remigales ventralis, which were the demarcation of origin of the secondary follicles of wing feathers. These projections were absent in barn owl (Usende *et al.*, 2017) <sup>[14]</sup>.

The proximal extremity of the ulna presented a prominent olecranon process and two articular facets. The lateral facet articulated with lateral condyle of humerus and the medial facet articulates with the medial condyle of humerus and proximal extremity of radius.

The distal extremity of ulna was in the form of an oblique condyle. The lateral ridge was larger and prominent while the medial one was small. The condyle articulated with ulnar and radial carpal bones below. Medially there was a facet for articulation with the distal end of radius.

The radius was a very slender rod like bone with a slightly curved shaft. The proximal extremity had two facets for the ulna and distal extremity articulates with radial carpal bone and ulna. The proximal end of the radius possessed an articular facet for distal extremity of humerus (Kigir *et al.*, 2022) <sup>[7]</sup>.

## 7. Carpals

In glossy ibis, the proximal row of carpals composed of radial and ulnar carpal bones. Similar observations were recorded in barn owl (Usende *et al.*, 2017) and black-crowned crane (Girgiri *et al.*, 2022) <sup>[14, 4]</sup>.

Radial carpal was irregularly quadrilateral, articulated with distal end of radius and ulna and with proximal end of carpometacarpus. The radial carpal was rectangular in cattle egret (Rezk, 2015) [10], whereas triangular in barn owl (Usende *et al.*, 2017) [14]. Ulnar carpal was 'U' shaped with one long and one short limbs. This observation was similar in barn owl (Usende *et al.*, 2017) and cattle egret (Rezk, 2015) [14, 10]. Ulnar carpal articulated with distal end of ulna and proximal end of carpometacarpus.

### 8. Carpometacarpus

The distal row of carpal bones were fused with the proximal ends of metacarpus during the embryonic development to form the carpometacarpus in birds (Nickel *et al.*, 1977) [8]. The carpometacarpus of glossy ibis was relatively longer when compared to other domestic birds, because of the larger wing span specific to long-legged aquatic birds.

The metacarpus was comprised of large IInd metacarpal bone and a much slender IIIrd metacarpal bone, separated by a wide intermetacarpal space. A prominent projection from proximal extremity of the IInd MC was considered to be the Ist MC bone or the os metacarpale alulare. The alular metacarpal had an extensor process for muscular attachment (Girgiri *et al.*, 2022) [4]. The proximal extremity of the carpometacarpus possessed a large carpal trochlea cranially and a fossa caudally for articulation with the proximal row of carpal bones. There was a small pisiform process below the level of trochlea for the passage of tendon of deep digital flexor muscle (Baumel, 1993) [3].

The intermetacarpal process was absent in carpometacarpus of glossy ibis, similar to that of cattle egret (Rezk, 2015) [10], while it was present at about the middle of IInd MC overlapping posteriorly in carpometacarpus of domestic fowl, turkey and pigeon (Nickel *et al.*, 1977) [8].

Below the alular metacarpal was the alular process containing facet for the first phalanx of I digit. The distal extremity of carpometacarpus had two articular facets for the II and III digits.

### 9. Digits

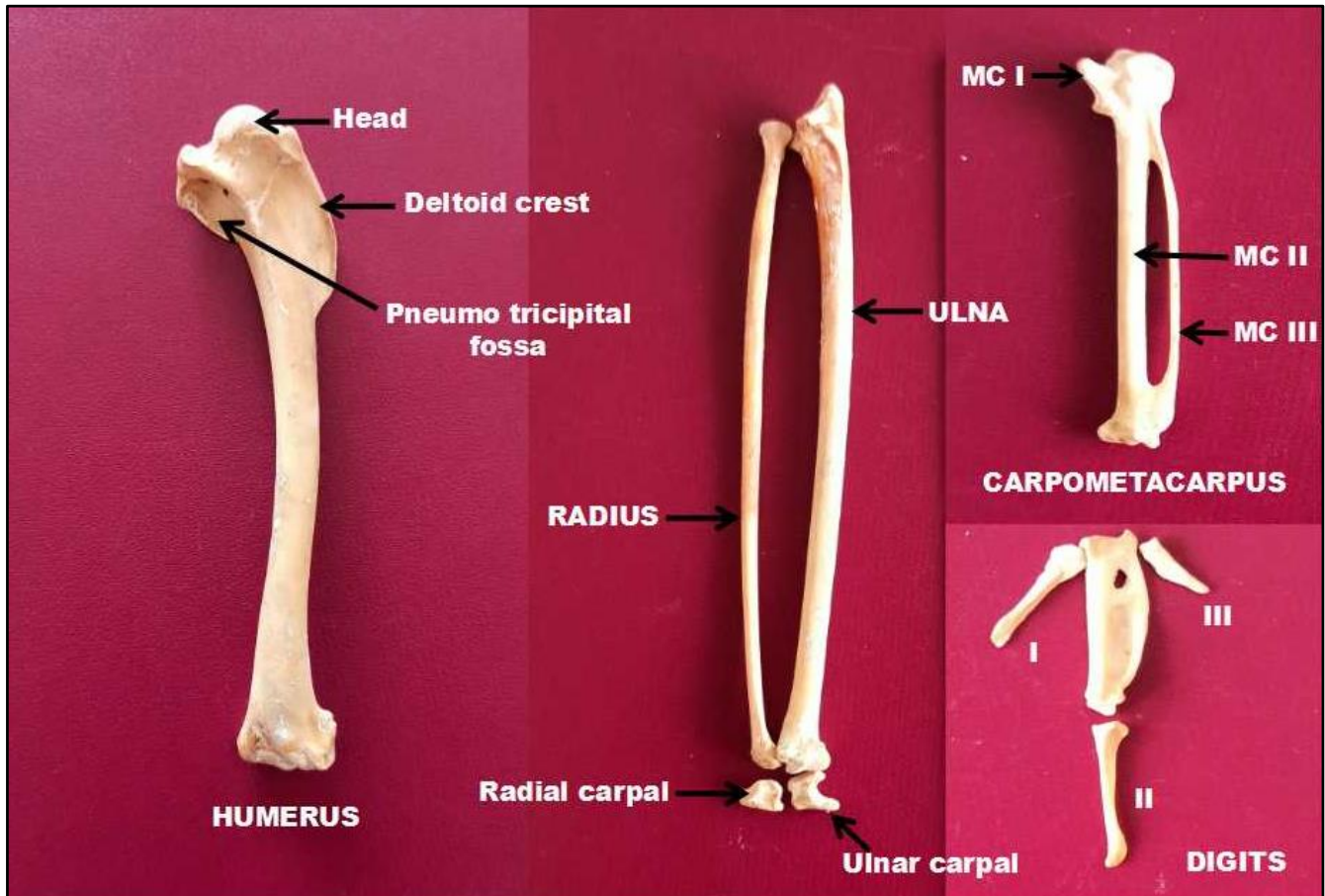
The wing of the glossy ibis was composed of three digits. The I digit had one phalanx, articulated with the alular process of I MC. It was in the form of pointed long claw. The II digit had two phalanges. The first phalanx was large and plate-like. The body of the first phalanx was thick, rod like, with a sharp convex edge. It presented a thin bony plate, sometimes perforated into foramen (Usende *et al.*, 2017) [14]. The second phalanx of II digit was in the form of pointed long bone. The III digit composed of one phalanx which was claw like and articulated with the distal end of III MC.

The length of the autopodium (carpals, metacarpals and digits) was longer than the upper arm, but shorter than the lower arm. In pigeon, autopodium was longer than the upper arm, but almost equal to lower arm (Nickel *et al.*, 1977) [8]. The autopodium exceeded the length of both upper and lower arm in duck and goose (Nickel *et al.*, 1977) [8], while it was comparatively shorter in black crowned crane (Girgiri *et al.*, 2022) [4].



**Fig 1:** Bones of the pectoral girdle of glossy ibis - scapula, coracoid and clavicle





**Fig 2:** Bones of the wing of glossy ibis - humerus, radius & ulna, carpals, carpometacarpus and digits with phalanges

### Conclusion

The pectoral limb of the glossy ibis had a strong pectoral girdle composed of scapula, corocoid and clavicle. Corocoid possessed procorocoid and supracorocoid processes. Clavicle was distinctly 'U' shaped which lacked the hypocleidium. Humerus had deltoid crest and bicipital crest. Radius and ulna were longer than the humerus. The wing region is formed by comparatively longer forearm bones and autopodium contributing the larger wing span. These findings on the morphological features of the forelimb bones of glossy ibis will pave way for further understanding of the flight characteristics and migratory adaptation of this species.

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