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Assessment of Morphometric Indices Related to Vernal Flight in Migratory Buntings

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Abstract: Migratory songbirds fly over long distances to avoid adverse conditions at their breeding and wintering grounds, and this phenomenon is known as 'migration'. This migratory phenomenon is highly energy demanding. The present study was aimed to analyze the morphometric analysis of body mass, beak, wings, tail, and tarsus length of two migratory finches i.e., red-headed (RHB) and black-headed buntings (BHB) to investigate whether they showed differences in their morphological attributes. This observational study shows an understanding of the characterization of wing patterns and differences in the length of tarsus, tail, beak, and wings of both species. The size of the beak, tail, and wings of BHB is significantly different when compared to RHB. In addition, body mass was significantly high in BHB than that of RHB during their spring migration (preparatory phase). The above anatomical measurements conclude that the two species had differences in their anatomical attributes.

Keywords: Black-headed bunting, Migration, Morphometric analysis, Red-headed bunting, Songbirds

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Introduction

Migratory songbirds fly to breeding or overwintering grounds to avoid unfavorable environmental conditions (Rani *et al.*, 2006). These birds provide an excellent model, as they explore many locations on their way of journey and allowing us to observe evolutionary processes (Mathys *et al.*, 2018). Air travel is achievable only because of the wings and therefore it is needed to analyze the flight dynamic attributes and morphometric structures of the wings. The feather covering of the bird's body is classified into 3 classes: (a) The outside feather whether covering

the entire body or specialized as flight feathers (regimes) or as tail feathers (rectrices) known as Contour feather or pennae, (b) Down feather, hidden by the Contour feather, and (c) Filoplumes, associated with contour feathers (Ali, 1990).

For a life in the air, birds possess certain well-marked characteristics especially hollow bones and air sacs which principally function as accessory respiratory organs (Ali, 1990). As reported by Fitzpatrick (1997), the Palaearctic birds show more variability in the tail length than in wing and tarsus. Also, the birds' beaks show

ecological adaptation to diet which indicate their place of origin (Bright *et al.*, 2016).

Heim *et al.* (2018) revealed that stopover sites during the long migratory journey are crucial for migratory birds. They have investigated niche explored by 8 migratory and closely related *Emberiza* bunting species at a stopover site in Far East Russia and found that – (i) niche breadth and niche overlap differ between spring and autumn season, (ii) the higher overlap found during spring, and (iii) morphological differences are mostly related to the overall size and wing pointedness. Moreover, they concluded that buntings can use available resources opportunistically during a stopover while trying to follow a precise schedule to avoid competition and to ensure individual fitness.

The present study demonstrates the morphometric analysis of red-headed (RHB) and black-headed buntings (BHB) (Fig. 1). These species were selected because both are long-distance night migratory songbirds, are closely linked sister species that share their overwintering places and inhabit overlapping breeding places. The previous finding described that both the birds are narrowly related passerine species that were reported to meet in a hybrid zone, southeast of the Caspian Sea, Iran, over 70 years ago. Evidence suggested that the hybrid zone has expanded westwards in recent decades and that the BHB is being replaced by the RHB in a westward movement. They assumed that due to variation in climatic circumstances, a westward expansion in the breeding distribution range of the RHB is more likely than an eastward expansion of the BHB. Consequently, the essential conclusion is that interspecific interactions may be climate-dependent (Gholamhosseini *et al.*, 2017). Buntings belong to the family *Emberizidae*, order-*Passeriformes*, and class *Aves*. Their breeding grounds are located (~ 40° N) in East Europe, Palestine, Syria, Upper Mesopotamia, and Persia. They breed during the summer months. They leave their breeding grounds in late summer.

Their wintering grounds are in India (~ 25° N) in the western and central parts including Rajasthan, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra and Karnataka. They return to their breeding grounds in the spring, around April i.e., spring migration. It is expected that they spend about 90 days (45 days each way) of the migratory journey around 7,000 km both ways, about 90 days at their breeding grounds, and the remaining almost half of the year they spend at their wintering grounds. Buntings are sparrow size finches. Males are brightly colored, and recognized by black (BHB) or red (RHB) crown on their head. They have a conical bill and a visible forked tail. BHB is somewhat bigger and differences are noticeable during migratory and breeding seasons when they store heavy fat deposition (Ali and Ripley, 1974).

Earlier studies, which were done in our laboratory showed that buntings differ in their migratory pattern. BHB showed robust and intense night-time migratory activity (*Zugunruhe*) as compared to RHB when caged. The IR motion sensor records the activity-rest pattern (locomotory activity) of each bird (Haustier PI-meldor; C and K Systems [Intellisense XJ-413T] Conrad Electronic, Hirschau, Germany) which is mounted on the activity cage. The sensor detects bird movement within the cage. The Chronobiology Kit program from Stanford Software System, USA was used for the calculation and analysis of the activity counts of the birds (Malik *et al.*, 2004). These movements were collected in 5-minutes bins in separate channels of the computerized data recording system. Here, we are showing only representative actograms of buntings just to make a distinction in the blueprint of their locomotor activity (Fig. 2). Besides the differences in their activity pattern, other seasonal differences like gain in body mass, increase in gonadal volume and fat deposition was observed in BHB as compared to RHB under natural day length (NDL) (Gupta *et al.*, unpublished). Thus based on our observations, we concluded that the

Body morphology and Geographical distribution of Bunting species

Figure 1: Body morphology and the range of distribution of bunting species (upper left to right: BHB, and RHB), (lower left to right: Distribution maps from e-Bird). Purple areas showing their distribution.

migratory phenologies in the two allied bunting species were different.

Therefore, in the present study, we studied the 'morphometric uniqueness' of RHB and BHB to investigate that whether their 'morphometric equipment' is also significantly dissimilar from each other or alike. Morphometric characters observed are - (i) the length of flattened wing and their patterns, (ii) beak length, (iii) tarsus length, and (iv) length of tail. Along with these characters, their body mass was also measured.

Materials and Methods

Species Studied and Ethics:

The present study was conducted in the month of February-April for two consecutive years i.e.,

2018-2019. The experiments were carried out as per approval of the Institutional Animal Ethics Committee (IAEC), Department of Zoology, University of Lucknow, Lucknow, India; Ethical permission to capture birds were obtained from the (protocol # LU/ZOOL/SM/SR/Ph.D./PG/08-2017).

Birds were captured from the wild and brought to the laboratory. Two species of male bunting were employed for the study: (a) RHB (*Emberiza bruniceps*, $n = 33$) and (b) BHB (*E. melanocephala*, $n = 28$). The birds were shifted to a large outdoor aviary ($3.0 \times 2.5 \times 2.5$ m) in the lab. Food (seeds of kakuni, *Setaria italica*) and water were available *ad libitum* and replenished once daily during the daytime. The Birds received antibiotics (Tetracycline hydrochloride,

Figure 2: Activity-rest pattern recording demonstration in buntings: activity cage equipped with IR sensor (a), activity-rest in BHB (b) and RHB (c) under different photoperiodic schedules during non-migratory (NM), pre-migratory (PM), and migratory (M) phases of their life history states.

Hoechst Roussel Vet. Ltd) for five consecutive days dissolved in water (Budki *et al.*, 2012). Also, a supplement food, rich in protein and vitamins was prepared by mixing bread crumbs, boiled eggs, crushed eggshells, cottage cheese, and multivitamins (Vimeral, containing vitamins A, D₃, E, and B₁₂, Virbac Animal Health India, Mumbai, India), was provided on alternate days. Birds were maintained in good health under captive conditions.

Measurement Methods:

The non-invasive measurements were made either by digital caliper or flat ruler in adult male birds of

both species. The measurement of bill and tarsus length were made by using a caliper to the nearest 0.1 mm, tail and wing length by ruler scale to the nearest 1 cm.

Body mass:

We recorded the body mass of an individual bird on a top pan balance with an accuracy of 0.1g. A bird was placed in a cotton bag that was initially weighed and tared (Kumar *et al.*, 2001).

Bill/Culmen length:

Bill/culmen length was measured by placing the caliper from the culmen base just inside the

Figure 3: Representative images are showing the measurement methods of tail (a), tarsus (b), wing (c) and bill length (d) in red-headed buntings.

feathers on the forehead to the bill tip. For this, the caliper is wide opened so that the opening between the outer and inner caliper is greater than the Culmen length of the bird (Fig. 3) (Cornwallis and Smith, 1960; Winker, 1998).

Wing length:

Flat rulers are generally appropriate for the direct measurement of the wing length of birds (Winker, 1998). We measured the length of the full stretched wing from the tip to the point of attachment of marginal covert (Fig. 3).

Tarsus length:

The length of the tarsometatarsal bone was measured by placing one arm of the internal jaw of the caliper in the notch of the intertarsal joint and the other arm at the lower edge of the bone before the toe diverge (Figure. 3) (Cornwallis and Smith, 1960; Muriel *et al.*, 2010).

Tail length:

The tail length was measured by placing a transparent flat ruler near the uropygial gland to

the longest feather (rectrices) of the tail (Fig. 3) (Cornwallis and Smith, 1960; Fitzpatrick, 1997).

Results

In both the bunting species comparison of various features such as morphometric character analysis of length of bill/culmen, flattened wing length, and the length of the tarsus and tail along with the body mass comparison of both species have been plotted (Fig. 4).

Mean and standard deviation of the length of tail, wings, tarsus, and bill were measured, calculated, and tested statistically (Unpaired students t-test, $p < 0.0001$). The results of the same are shown in Table 1.

Body mass:

Birds exhibited a significant difference in their body mass. The BHB weighed 31.56 ± 0.84 g on average, whereas the RHB weighed 24.88 ± 0.48 g. Both the buntings were in an unstimulated photosensitive phase (Fig. 4). There was a significant difference in their body mass (Unpaired students t-test, $p < 0.0001$) (Table 1).

Figure 4: (A) Comparative account of morphometric characters: beak size (a), tarsus length (b), tail length (c) and wing span (d) of black-headed (n = 23) (left panel) and red-headed bunting (n = 33) (right panel), X-axis shows scale of measurements in centimeters; and (B) Body mass of red-headed bunting (n=33), and black-headed bunting (n=28)

Table 1: Comparative analysis of morphometric attributes in buntings

S. No.	Morphometric attributes	<i>E. bruniceps</i>	<i>E. melanocephala</i>	Statistical analysis
1.	Body mass	24.88 ± 0.48 g	31.56 ± 0.84 g	P < 0.0001***
2.	Beak length	1.15 ± 0.02 mm	1.35 ± 0.02 mm	P < 0.0001***
3.	Wing length	10.68 ± 0.12 cm	11.30 ± 0.16 cm	P = 0.0005**
4.	Tarsus length	1.75 ± 0.02 mm	1.92 ± 0.02mm	P < 0.0001***
5.	Tail length	6.87 ± 0.07 cm	7.11± 0.04 cm	P = 0.0340**

Flight feathers:

The flight feathers (remiges) are long, stiff, asymmetrically shaped, but symmetrically paired pennaceous feathers on the wings of the bird. They are named as - Marginal Covert (Mac), Median Covert (Mec), Alula (Al), Carpal Covert

(CC), Greater Covert (GC), Primary Covert (PC), Tertiaries (T), Secondaries (S), and Primaries (P) (Table 2). The function of each wing feather is described in Table 2 (Cornwallis and Smith, 1960). (Fig. 5).

Figure 5. Topographical features of wing feather: Marginal Covert (Mac), Median Covert (Mec), Alula (Al), Carpal Covert (CC), Greater Covert (GC), Primary Covert (PC), Tertiaries (Ter), Secondary (Sec), Primaries (Pri)

Table 2: Wing feathers and their functions

S. No.	Wing feathers	Description
1.	Marginal Covert	These are small feathers that cover a small area of the anterior dorsal surface of the wing.
2.	Median Covert	These are a group of small feathers and not looked individually, placed above the greater coverts, 8-9 in number.
3.	Alula or bastard wing	Present on the upper leading edge of the wing attached to the pollex, the number varies but generally 3 in number.
4.	Carpal Covert	These are very small in size and arranged between the innermost primary and outermost secondary.
5.	Greater Covert	These feathers usually covering each secondary feather.
6.	Primary Covert	Each primary feather is covered by the primary covert.
7.	Tertiaries	These are the form of the inner three secondary which differ in shape, size, and color.
8.	Secondaries	Secondaries are those flight feathers that are attached to the ulna.
9.	Primaries	The flight feathers present on the outer part of the wing are marked as primaries.

Figure 6: Tabular representation of feather characteristics of bunting species: feathers on wing and their observed characters (a), circular statistical graphs show observed characters of the feather in red-headed bunting (n=33), (b) and black-headed bunting (n=25), (c). The arc length of each portion is proportional to the quantity it represents.

Gross morphology of wings:

In the present study, we characterized the wings based on their morphology which are present on the feather tract: Marginal covert- yellow(A)/black centers (B), Medial covert-more (A)/less(B) light yellowish outer fringes, Alula (Al)- slightly (A)/more pointed (B), carpal covert

(CC)- broad (A)/pointed base (B), greater covert (GC)- slightly (A)/more pointed (B), primary covert (PC)- broad(A)/pointed base (B) and tertials (T)- broad (A)/pointed base (B), notched (A)/smooth edges (B) in secondary feathers. All the measured values presented in Figure 6 were plotted in percentage to illustrate a particular type

of wing variant in the two bunting species observed (Fig. 5).

Discussion

In passerine bird species, most of the feathers are contour feathers and form the surface plumage of the full-grown bird to give it shape and color. They are grouped in different tracts (pterylae) which cover about half of the skin surface. The areas in between (apteria) are devoid of contour feathers and are usually hidden by the feathers of the adjacent pterylae. Small body feathers cover the head and body, while the term flight feathers include the large feathers of the wing (primaries, secondaries, and tertials) and tail (rectrices). The wing coverts, the alula, and tail coverts are associated with the flight feathers and intermediate in structure. They are usually considered to be part of the small feather (Ginn and Melville, 1983).

In birds, the flight mechanism is a complex and most energy-demanding mode of animal locomotion. Documented literature shows that wing architecture has been associated with numerous aspects of avian ecology and life history-related events, together with migratory behavior and sexual selection. Up to now, analysis of the relationship between wing shape and flight style has been based on simple numerical indices derived from linear measurements of wing length, wing chord, aspect ratio, and wing pointedness (Wang and Clarke, 2015). In this study, we have found a different pattern of feather planning in both species during spring migration preparation (Fig. 6.). As morphometry of a bird's wing and its mechanical properties leads to an understanding of aerodynamic performance (Bhargavi *et al.*, 2017). So, in this regard, we argue that bunting's long migratory journey is supported by their sole wing pattern. Earlier we discussed that these migratory finches are able to spend a total of about 90 days on the way of covering their spring and autumn migratory flight.

According to Crandell and Tobalske (2011), the tip feathers of a bird's wing reduce the drag by allowing air to pass through and use tip reversal upstroke. Alula is used in slow flight with high angles of attack such as landing (Lee, 2015). In the present investigation alula is characterized by a slightly pointed or more pointed tip that might help in departure and landing decision during the migratory marathon (Fig.6.). It has been reported that the shortest coverts are seen in passerine birds and are associated with a flight style proposed to be distinctive in flap-gliding behaviors involving partially or fully flexed wings (Wang and Clarke, 2015). In our study, the total length of the wing of BHB is 11.30 ± 0.16 cm and that of RHB is 10.68 ± 0.02 cm.

The avian beak offers a standard paradigm of adaptation to feeding ecology and beak morphology is repeatedly considered to be a symbol of evolutionary adaptation for specialized trophic niches. The beak is often seen as the target of selection mechanisms closely linked to the feeding ecology of birds such as prey type, feeding style, etc. Evidence also suggests that beak morphology and variation may be constrained by many other factors, including evolutionary history and development on the parts of the entire skull (Bright *et al.*, 2016). Bunting feed on the ricks of the paddy, bajra etc. and our results suggested that how this beak size helps them during the journey. Black-headed possesses slightly bigger beak sizes ranges from 1.35 ± 0.02 mm and 1.15 ± 0.02 mm. Selection for the large variation in bill dimensions might produce a large variation in tarsus dimensions (Grant, 1971). We also found a positive correlation between the tarsus length and beak size i.e., 1.92 ± 0.02 mm in BHB and 1.75 ± 0.02 mm in RHB, respectively. The tail of birds has important aerodynamic functions. In many species, tails are elongated into shapes which increases aerodynamic costs. Tail shape may act in the natural and sexual selection by displaying strength (Fitzpatrick, 1997). In this study tail range of BHB is 7.11 ± 0.04 cm and that of RHB is 6.87 ± 0.07 cm.

Red-headed buntings, however, appear to be light weighted than black-headed buntings. For instance, a collection of BB weighed 31.56 ± 0.84 g on average compared to RB weighed 24.88 ± 0.48 g with unstimulated gonads in our sample.

Conclusion

In the case of bunting species, we have found a unique characterization of feather planning which forms a distinctive wing outline in both species during spring (vernal) migration. This unique wing characterization in bunting may be age-dependent. Thus, estimation of the wing shape may help assess the age of the birds.

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References

- Ali S. (1990) The books of the Indian birds. Oxford University Press, New York.
- Ali S and Ripley RD. (1974) Handbook of the birds of India and Pakistan. Oxford University Press, New York.
- Bhargavi S, Venkatesan S, Ramesh G and Kannan AT. (2017) Morphometrical analysis of the wing of the blue-and-yellow macaw (*Ara ararauna*) with reference to the aerodynamics. Int J Curr Microbiol App Sci. 6(8): 2707-2710.
- Bright JA, Lobónc JM, Cobbe SN and Rayfield EJ. (2016) The shapes of bird beaks are highly controlled by non-dietary factors. PNAS 113(19): 5352-5357.
- Budki P, Rani S and Kumar V. (2012) Persistence of circannual rhythms under constant periodic and aperiodic light conditions: Sex differences and relationship with the external environment. J Exp Biol. 215: 3774-3785.
- Cornwallis RK and Smith AE. (1960) The bird in the hand. British Trust Ornithology field guide no. 6.
- Crandell KE and Tobalske BW. (2011) Aerodynamics of tip-reversal upstroke in a revolving pigeon wing. J Exp Biol. 214: 1867-1873.
- Fitzpatrick S. (1997) Patterns of morphometric variation in birds' tails: length, shape and variability. Biol J Linn Soc. 62(1): 145-162.
- Gholamhosseini A, Aliabadian M, Darvish J, Töpfer T and Sætre GP. (2017) An expanding hybrid zone between Black-headed and Red-headed buntings in northern Iran. BioOne 105(1):27-36.
- Ginn HB and Melville DS. (1983) Moults in birds. British Trust for Ornithology. BTO GUIDE 19, ISBN: 9780903793025.
- Grant PR. (1971) Variation in the tarsus length of birds in island and mainland regions. Evolution 25: 599-614
- Heim W, Eccard JA and Bairlein F. (2018) Migration phenology determines niche use of East Asian buntings (Emberizidae) during stopover. Current Zool 64(6): 681-692.
- Kumar V, Singh S, Misra M and Malik S. (2001) Effects of duration and time of food availability on photoperiodic responses in the migratory male blackheaded bunting (*Emberiza melanocephala*). J Exp Biol. 204: 2843-2848.
- Lee S, Kim J, Park H, Jabłónski PG and Choi H. (2015) The function of the alula in avian flight. Scientific Reports 5: 9914. <https://doi.org/10.1038/srep09914>.
- Malik S, Rani S and Kumar V. (2004) Wavelength dependency of light-induced effects on photoperiodic clock in the migratory blackheaded bunting (*Emberiza melanocephala*). Chronobiol Intern. 21 (3): 367-384.
- Mathys BA and Lockwood JL. (2018) Contemporary morphological diversification of passerine birds introduced to the Hawaiian archipelago. Proc Royal Soc. B278 (1716): 2010.2302. doi.org/10.1098/rspb.2010.2302.
- Muriel R, Casado E, Schmidt D, Calabuig CP and Ferrer M. (2010) Morphometric sex determination of young Ospreys *Pandion haliaetus* using discriminant analysis. Bird Study 57: 336-343.

Rani S, Malik S, Trivedi AK, Singh S and Kumar V. (2006)
A circadian clock regulates migratory restlessness in
the blackheaded bunting, *Emberiza melanocephala*.
Curr Sci. 91: 8.

Wang X and Clarke JA. (2015) The evolution of avian

wing shape and previously unrecognized trends in
covert feathering. Proc Royal Soc. B 282 (1816):
2015.1935. doi.org/10.1098/rspb.c2015.1935.

Winker K. (1998) Suggestions for measuring external
characters of birds. Ornithol Neotrop. 9: 23-30.