

Original Research Article

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## Gross and Morphometrical Studies on the Sternum of Blue Bull (*Boselaphus tragocamelus*)

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### ABSTRACT

The present study was carried out on the sternum of adult Blue bull (*Boselaphus tragocamelus*) of either sex. It was found that the sternum was a long plate of osteo-cartilagenous structure that was located at the mid-line of the floor of the thorax. It was made up of seven segments or sternbrae and was found to be wider, flatter and relatively longer than in the horse. The cranial end was formed by a wedge shaped and laterally compressed manubrium sterni that had extensive facets dorso-laterally for articulation with the first pair of costal cartilages. The manubrium sterni was followed by six similar segments, the sternbrae that were much longer than broad. The body of the sternum was flat and thick. It widened towards the caudal aspect, but became narrower behind the last pair of costal facets. The dorsum of the body had the impression of superior or dorsal sternal ligament. The ventral surface became more prominent on the second and third sternbrae and was concave further back. The lateral borders of the sternum were thick, notched that provided passage for the blood vessels. The lateral borders accommodated seven pairs of sternal facets on either side of the intersternal junctions. The eighth pair costal cartilages joined the sternum between 6<sup>th</sup> and 7<sup>th</sup> sternbrae along with the seventh pair costal cartilages. Biometrical observations on different parameters reflected significance ( $P < 0.05$ ) differences between the sexes of this species.

#### Keywords

Blue bull, Costal facet, Sternebrae, Sternum

#### Article Info

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### Introduction

The Blue bull (*Boselaphus tragocamelus*) is known to be one of the biggest antelopes in Asia. They are usually seen in day times in the meadow pasture, timberland areas and agricultural land area. It prefers mostly plain or grassy plain and low hilly areas with shrubs, small bushes, scrub forests with scattered trees and does not usually found inside dense forest areas, dense compact

wood, etc. Blue bull is considered sacred as per Hindu religion since Vedic period (1500-500 BC) and it is considered as religious. The Blue bull belongs to the family Bovidae and comes under the genus *Boselaphus*. The German Zoologist Scientist Peter Simon Pallas explained this species for the first time in 1766. English Zoologist Scientist Philips for the first time in 1833 narrated the binomial combination of the Blue bull. It is quite prevalent in northern and central parts of India

especially in foothills of Himalayas, eastern part of Pakistan and southern part of Nepal, but has vanished from Bangladesh. The adult male appears like ox and so called as Blue bull. The Blue bulls are safeguarded beneath the IUCN since 2003 and also under safeguard of 'Schedule III' of the Indian Wildlife Protection Act, 1972 (Bagchi *et al.*, 2004). The Blue bull is safeguarded in various parts of India such as Gir National Park (Gujarat), Kumbhalgarh Sanctuary (Rajasthan) and Panchamarahi Biosphere Reserve, India. The massive body of the Blue bull can be attributed to the large skeleton of the antelope. Further, the skeleton comprises of large and massive bones of axial and appendicular skeleton that not only protects the viscera, but also provides shape and support to the heavy musculature of the Blue bull. The present osteo-morphological study developed a baseline data on the sternum of adult Blue bull that would immensely help the wild life anatomists and Veterinarians in species identification and solving forensic and vetero-legal cases as no previous work has been done in this field on the Blue bull.

### **Materials and Methods**

The present study was carried out on the sternum of six specimens of adult Blue bulls (*Boselaphus tragocamelus*) of either sex. The permission for the collection of bones was acquired from the Principal Chief Conservator of Forests (PCCF), Government of Rajasthan. The bones were possessed from the Jodhpur zoo, Rajasthan getting authentic confirmation from the Principal Chief Conservator of Forests (PCCF), Government of Rajasthan vide letter no. F, 3(04) Tech-II/CCF/2013/2077, dated 12.12.2014, Chief Conservator of Forest (CCF) vide letter no. F, 3(04) Tech-11/CCF/2013/2326, dated 12.01.2015 and subsequently from the Deputy Conservator of Forest (Wildlife), Jodhpur s.n./sam/388-90, dated 22.01.2015. The

skeletons were taken out from the burial ground that was located in the premises of the office of the Deputy Conservator of Forest Wildlife (WL), Jodhpur. Afterwards, the specimens were processed as per standard technique given by (Choudhary *et al.*, 2013). The gross study was conducted under the supervision of the Zoo Authority, Jodhpur, India. The different parameters of sternum was measured and subjected to routine statistical analysis (Snedecor and Cochran, 1994) and independent samples t-Test with Systat Software Inc, USA and SPSS 16.0 version software.

### **Results and Discussion**

The sternum of Blue bull was a long plate of osteo-cartilagenous structure placed at the mid-line of the floor of the thorax which was in line with Getty *et al.*, (1930) in ox. The average weight of the sternum in adult Blue bull was found to be  $510.37 \pm 1.67$  gm. Further, the average weight of the sternum in females was measured to be  $507.46 \pm 1.96$  gm, whereas in males it was  $513.28 \pm 1.28$  gm (Table 1). The average length of the sternum was found to be  $41.60 \pm 0.30$  cm in Blue bull. However, in females the average length was measured to be  $41.20 \pm 0.17$  cm, whereas in males it was  $42.00 \pm 0.50$  cm long. The sternum was comprised of seven segments or sternbrae (Fig. 1). It was found to be wider, flatter and relatively longer than in the horse. The manubrium was the first sternal segment and was almost a wedge shaped structure. It was laterally compressed. It had extensive facets laterally that articulated with the first pair of costal cartilages (Fig. 2). The manubrium formed a diarthrodial joint with the second sternbra. The other sternbrae were fused with each other. It was in agreement with Getty *et al.*, (1930) in ox, Grossman (1960) in camel, Mills (2003) in cattle, Dyce (2006) in ox, Frandson *et al.*, (2006) in cattle, Budras *et al.*, (2009) in horse and Akers and Denbow

(2013) in ruminants, but in contradiction to the findings of Leach (1946) in cat, Sebastiani and Fishbeck (2005) in cat and Hussain (2010) in goat. But contradictory to the findings of Duzler *et al.*, (2006) in avian species, Tomar *et al.*, (2011) in Pariah Kite, Satyamoorthy *et al.*, (2012) in Spot-billed pelican, Dewangan *et al.*, (2014) in pigeon, John *et al.*, (2014) in pigeon, crow and owl, Jayachitra *et al.*, (2015) in emu, turkey and duck, John *et al.*, (2015) in red wattled lap-wing, Sreeranjini *et al.*, (2015) in male Green-winged Macaw, Pathak *et al.*, (2017) in peacock and turkey and Wani *et al.*, (2017) in Common Moorhen. Sebastiani and Fishbeck (2005) reported that the sternum of cat was slim and elongated. It consisted of a series of articulated segments or sternebrae. Tomar *et al.*, (2011) stated that the sternum was quadrilateral plate like in Pariah Kite. The dorsal surface of the sternum was concave, whereas the ventral surface was convex. The carina was in the form of thin curved plate and projected ventrally. The cranial border of the sternum was triangular and had an elongated facet on either side for articulation with distal extremity of the coracoids bones. Satyamoorthy *et al.*, (2012) described that the sternum of Spot-billed pelican was large, broad and quadrilateral in shape. Dewangan *et al.*, (2014) described that the sternum of the pigeon was oval in shape. The carina was large and triangular. The pars cardiac was deep with a shallow pars hepatica. The sternum was divided in two equal halves by a shallow median groove on its dorsal surface. The apex of the sternum was blunt. John *et al.*, (2014) reported that the dorsal surface of the body of sternum was concave in pigeon, crow and owl. A single median pneumatic foramen was present in the cranial aspect in pigeon, whereas two lateral and a median pneumatic foramina were found to be present in crow and owl. The middle part of ventral lip presented a well-developed “Y” shaped structure in crow. The sternal crest was bifid cranially in owl. Jayachitra *et al.*, (2015) found that the sternum

was a large unsegmented bone located on the cranio-ventral aspect of the body cavity in emu, turkey and duck. It was bowl-shaped in emu, whereas triangular and rectangular in turkey and duck respectively. The ventral surface was devoid of keel in emu, but a prominent keel was present in the ventral surface of sternum of turkey and duck. John *et al.*, (2015) observed that the sternum was boat shaped in outline in red wattled lap-wing. The dorsal surface was smooth due to the presence of pneumatic foramen. The ventral surface presented a well-developed sternal crest. Sreeranjini *et al.*, (2015) reported that the sternum of an eight year old, male Green-winged Macaw was quadrilateral in shape. The dorsal surface was concave, whereas the ventral surface was convex. The dorsal surface had numerous pneumatic foramina, whereas a large, boat shaped keel was present in the ventral surface of the sternum. Pathak *et al.*, (2017) reported that the sternum was quadrilateral strongly concave plate like in peacock and turkey, whereas it was rectangular in shape in duck and white-breasted water hen. Wani *et al.*, (2017) stated that the dorsal view of sternal body in Common Moorhen was roughly pyramidal. The sternal keel was highly developed.

Biometrical observations revealed that the average length of the manubrium sterni in adult Blue bull was found to be  $5.23 \pm 0.08$  cm. Further, it was measured as  $5.07 \pm 0.03$  cm in females that was significantly lesser ( $P < 0.05$ ) than that of males, where it was found to be  $5.40 \pm 0.06$  cm (Table 1). The average widths of manubrium sterni at the cranial, middle and caudal aspects were found to be  $2.83 \pm 0.15$  cm,  $2.17 \pm 0.11$  cm and  $2.00 \pm 0.10$  cm respectively in adult Blue bull. Further, the widths at these specific sites were measured to be  $2.57 \pm 0.15$  cm,  $1.93 \pm 0.09$  cm and  $1.80 \pm 0.06$  cm respectively in females that were significantly lesser ( $P < 0.05$ ) than that of males, where they were measured as  $3.10 \pm 0.12$  cm,  $2.40 \pm 0.06$

cm and  $2.20 \pm 0.06$  cm respectively (Table 1). Pandey *et al.*, (2013) reported that the average length of first sternebra in tiger was  $8.28 \pm 0.19$  cm and the average widths at the anterior, middle and posterior aspects were  $2.30 \pm 0.04$  cm,  $1.23 \pm 0.08$  cm and  $2.10 \pm 0.04$  cm respectively. The average length of the 2<sup>nd</sup> sternebra in adult Blue bull was found to be  $2.95 \pm 0.12$  cm. Further, it was measured to be  $2.73 \pm 0.12$  cm in females that was significantly lesser ( $P < 0.05$ ) than that of males, where it was found to be  $3.17 \pm 0.09$  cm (Table 1). The average widths of 2<sup>nd</sup> sternebra at the cranial, middle and caudal aspects were found to be  $2.00 \pm 0.10$  cm,  $2.83 \pm 0.07$  cm and  $3.13 \pm 0.08$  cm respectively in adult Blue bull. Further, the widths at these specific sites were measured to be  $1.80 \pm 0.06$  cm,  $2.70 \pm 0.06$  cm and  $3.00 \pm 0.06$  cm respectively in females, where the cranial and middle widths were significantly lesser ( $P < 0.05$ ) than that of males. In males, these widths were reported to be  $2.20 \pm 0.06$  cm,  $2.97 \pm 0.07$  cm and  $3.27 \pm 0.09$  cm at the cranial, middle and caudal aspects respectively (Table 1). Pandey *et al.*, (2013) reported that the average length of second sternebra in tiger was  $4.13 \pm 0.04$  cm and the average widths at the anterior, middle and posterior aspects were  $2.17 \pm 0.04$  cm,  $1.27 \pm 0.04$  cm and  $2.00 \pm 0.00$  cm respectively. The average length of the 3<sup>rd</sup> sternebra in adult Blue bull was found to be  $4.13 \pm 0.04$  cm. Further, it was measured as  $4.07 \pm 0.03$  cm and  $4.20 \pm 0.06$  cm in females and males respectively. The average widths of 3<sup>rd</sup> sternebra at the cranial, middle and caudal aspects were found to be  $3.70 \pm 0.06$  cm,  $3.88 \pm 0.09$  cm and  $4.22 \pm 0.06$  cm respectively in adult Blue bull. Further, the widths at these specific sites were measured to be  $3.63 \pm 0.07$  cm,  $3.73 \pm 0.09$  cm and  $4.10 \pm 0.06$  cm respectively in females, where the caudal width was significantly lesser ( $P < 0.05$ ) than that of males. In males, these widths were reported to be  $3.77 \pm 0.09$  cm,  $4.03 \pm 0.09$  cm and  $4.33 \pm 0.03$  cm at the cranial, middle and caudal aspects respectively (Table 1). Pandey

*et al.*, (2013) reported that the average length of third sternebra in tiger was  $3.90 \pm 0.04$  cm and the average widths at the anterior, middle and posterior aspects were  $2.06 \pm 0.00$  cm,  $1.43 \pm 0.04$  cm and  $1.93 \pm 0.00$  cm respectively. The average length of the 4<sup>th</sup> sternebra in adult Blue bull was found to be  $4.38 \pm 0.09$  cm. Further, it was measured to be  $4.23 \pm 0.09$  cm and  $4.53 \pm 0.09$  cm in females and males respectively. The average widths of 4<sup>th</sup> sternebra at the cranial, middle and caudal aspects were found to be  $4.27 \pm 0.07$  cm,  $4.43 \pm 0.09$  cm and  $4.87 \pm 0.11$  cm respectively in adult Blue bull. Further, the widths at these specific sites were measured to be  $4.13 \pm 0.07$  cm,  $4.30 \pm 0.12$  cm and  $4.63 \pm 0.09$  cm respectively in females, where the cranial and caudal widths were significantly lesser ( $P < 0.05$ ) than that of males (Table 1). In males, these widths were reported to be  $4.40 \pm 0.06$  cm,  $4.57 \pm 0.09$  cm and  $5.10 \pm 0.06$  cm at the cranial, middle and caudal aspects respectively. Pandey *et al.*, (2013) reported that the average length of fourth sternebra in tiger was  $3.97 \pm 0.04$  cm and the average widths at the anterior, middle and posterior aspects were  $2.23 \pm 0.00$  cm,  $1.50 \pm 0.04$  cm and  $1.87 \pm 0.04$  cm respectively. The average length of the 5<sup>th</sup> sternebra in adult Blue bull was found to be  $5.02 \pm 0.07$  cm. Further, it was measured as  $4.93 \pm 0.09$  cm and  $5.10 \pm 0.12$  cm in females and males respectively. The average widths of 5<sup>th</sup> sternebra at the cranial, middle and caudal aspects were found to be  $4.63 \pm 0.07$  cm,  $5.07 \pm 0.08$  cm and  $5.38 \pm 0.09$  cm respectively in adult Blue bull. Further, the widths at these specific sites were measured to be  $4.50 \pm 0.06$  cm,  $4.90 \pm 0.06$  cm and  $5.20 \pm 0.06$  cm respectively in females, which were significantly lesser ( $P < 0.05$ ) than that of males. In males, the average widths of 5<sup>th</sup> sternebra at the cranial, middle and caudal aspects were found to be  $4.77 \pm 0.07$  cm,  $5.23 \pm 0.03$  cm and  $5.57 \pm 0.07$  cm respectively (Table 1). Pandey *et al.*, (2013) reported that the average length of fifth sternebra in tiger

was  $3.93\pm 0.08$  cm and the average widths at the anterior, middle and posterior aspects were  $2.13\pm 0.00$  cm,  $1.63\pm 0.04$  cm and  $1.87\pm 0.04$  cm respectively.

The average length of the 6<sup>th</sup> sternebra in adult Blue bull was found to be  $5.58\pm 0.09$  cm. Further, the average length of 6<sup>th</sup> sternebra in females was measured to be  $5.40\pm 0.06$  cm which was significantly lesser ( $P<0.05$ ) than that of males, where it was  $5.77\pm 0.07$  cm long. The average widths of 6<sup>th</sup> sternebra at the cranial, middle and caudal aspects were found to be  $6.27\pm 0.06$  cm;  $6.42\pm 0.07$  cm and  $7.20\pm 0.05$  cm respectively in adult Blue bull (Table 1). Further, the widths at these specific sites were measured to be  $6.17\pm 0.09$  cm,  $6.30\pm 0.06$  cm and  $7.13\pm 0.09$  cm respectively in females, whereas in males they were  $6.37\pm 0.03$  cm,  $6.53\pm 0.09$  cm and  $7.27\pm 0.03$  cm in length respectively. Pandey *et al.*, (2013) reported that the average length of sixth sternebra in tiger was  $3.93\pm 0.08$  cm and the average widths at the anterior, middle and posterior aspects were  $2.00\pm 0.04$  cm,  $1.53\pm 0.04$  cm and  $1.73\pm 0.00$  cm respectively. The average length of the 7<sup>th</sup> sternebra in adult Blue bull was found to be  $7.83\pm 0.09$  cm. Further, the average length of 7<sup>th</sup> sternebra in females was measured to be  $7.67\pm 0.09$  cm which was significantly lesser ( $P<0.05$ ) than that of males, where it was  $8.00\pm 0.06$  cm long (Table 1). The average widths of 7<sup>th</sup> sternebra at the cranial, middle and caudal aspects were found to be  $5.62\pm 0.10$  cm,  $3.53\pm 0.10$  cm and  $2.32\pm 0.13$  cm respectively in adult Blue bull. Further, the widths at these specific sites were measured to be  $5.43\pm 0.07$  cm,  $3.37\pm 0.09$  cm and  $2.07\pm 0.07$  cm respectively in females, where the caudal width was significantly lesser ( $P<0.05$ ) than that of males. In males, the average widths of 7<sup>th</sup> sternebra at the cranial, middle and caudal aspects were found to be  $5.80\pm 0.12$  cm,  $3.70\pm 0.10$  cm and  $2.57\pm 0.15$  cm respectively (Table 1). Pandey *et al.*, (2013) reported that the average length

of seventh sternebra in tiger was  $3.87\pm 0.08$  cm and the average widths at the anterior, middle and posterior aspects were  $2.23\pm 0.00$  cm,  $1.53\pm 0.04$  cm and  $1.93\pm 0.08$  cm respectively. Dewangan *et al.*, (2014) recorded the length and width of sternum of Blue rock pigeon as 5.9 cm and 2.4 cm respectively. John *et al.*, (2014) reported the average length of sternum were  $6.73\pm 0.08$  cm,  $6.02\pm 0.04$  cm and  $4.69\pm 0.01$  cm in pigeon, crow and owl respectively. They further reported that the average anterior widths of sternum were  $2.54\pm 0.02$  cm,  $3.2\pm 0.03$  cm and  $3.32\pm 0.02$  cm in pigeon, crow and owl respectively. The average posterior widths of sternum were found to be  $1.52\pm 0.02$  cm,  $2.02\pm 0.02$  and  $3.18\pm 0.04$  cm in pigeon, crow and owl respectively.

The body of the sternum was flat and thick. It widened towards the caudal aspect, but became narrower behind the last pair of costal facets. The dorsum of the body had the impression of superior or dorsal sternal ligament. The ventral surface became more prominent on the second and third sternebrae and was concave further back. The lateral borders of the sternum were thick, notched that provided passage for the blood vessels. The lateral borders accommodated seven pairs of sternal facets on either side of the intersternal junctions (Fig. 3). The first pair of facets was located on the dorso-lateral surface of the manubrium sterni. The eighth pair costal cartilages joined the sternum between 6<sup>th</sup> and 7<sup>th</sup> sternebrae along with the seventh pair costal cartilages. It was in agreement with Getty *et al.*, (1930) in ox, Mills (2003) in cattle, Dyce (2006) in ox, Frandson *et al.*, (2006) in cattle and Hussain (2010) in goat.

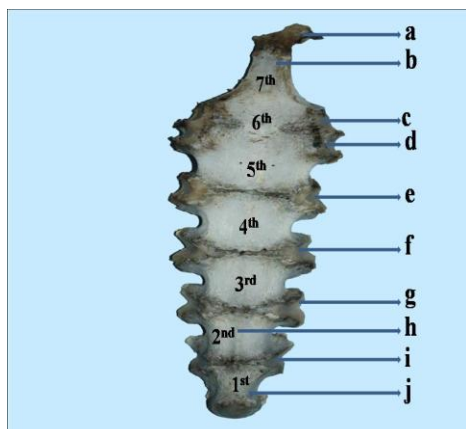
Biometrical observations revealed that the average dorso-ventral and longitudinal diameters of the first pair of costal facets were found to be  $1.57\pm 0.03$  cm and  $0.66\pm 0.01$  cm respectively in adult Blue bull. Further, the



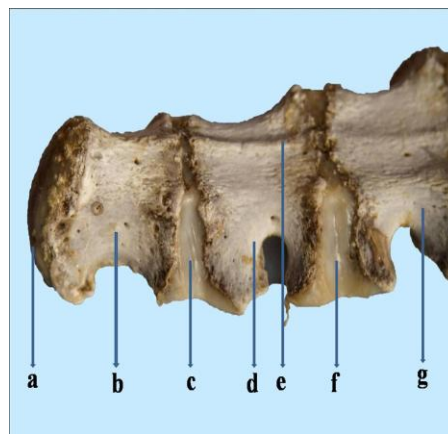
average diameters in females were measured to be  $1.55\pm 0.04$  cm and  $0.65\pm 0.01$  cm respectively, whereas they were found to be  $1.58\pm 0.01$  cm and  $0.68\pm 0.01$  cm respectively in males. The average dorso-ventral and longitudinal diameters of the second pair of costal facets were found to be  $1.90\pm 0.01$  cm and  $0.70\pm 0.01$  cm respectively in adult Blue bull. Further, the average diameters in females were measured to be  $1.88\pm 0.01$  cm and  $0.68\pm 0.01$  cm respectively, which were significantly lesser ( $P<0.05$ ) than that of males, where they were found to be  $1.93\pm 0.01$  cm and  $0.73\pm 0.03$  cm respectively (Table 1). The average dorso-ventral and longitudinal diameters of the third pair of costal facets were found to be  $2.56\pm 0.02$  cm and  $0.84\pm 0.03$  cm respectively in adult Blue bull. Further, the average diameters in females were measured to be  $2.53\pm 0.03$  cm and  $0.82\pm 0.04$  cm respectively, whereas they were found to be  $2.59\pm 0.04$  cm and  $0.86\pm 0.02$  cm respectively in males. The average dorso-ventral and

longitudinal diameters of the fourth pair of costal facets were found to be  $2.42\pm 0.01$  cm and  $0.97\pm 0.01$  cm respectively in adult Blue bull. Further, the average diameters in females were measured to be  $2.39\pm 0.01$  cm and  $0.93\pm 0.01$  cm respectively, which were significantly lesser ( $P<0.05$ ) than that of males, where they were found to be  $2.45\pm 0.01$  cm and  $1.01\pm 0.03$  cm respectively (Table 1).

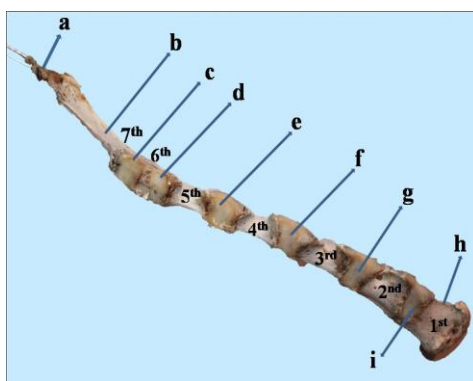
The average dorso-ventral and longitudinal diameters of the fifth pair of costal facets were found to be  $2.29\pm 0.02$  cm and  $1.20\pm 0.04$  cm respectively in adult Blue bull. Further, the average diameters in females were measured to be  $2.25\pm 0.03$  cm and  $1.16\pm 0.06$  cm respectively, whereas they were found to be  $2.33\pm 0.05$  cm and  $1.24\pm 0.07$  cm respectively in males. The average dorso-ventral and longitudinal diameters of the sixth pair of costal facets were found to be  $2.06\pm 0.05$  cm and  $1.76\pm 0.08$  cm respectively in adult Blue bull.



**Fig.1** Dorsal view of Sternum of adult male Blue bull (*Boselaphus tragocamelus*) with all seven sternebrae showing a) Remnant of xiphoid cartilage, b) Xiphoid process, c) Facet for seventh and eighth costal cartilages, d) Facet for sixth costal cartilages, e) Facet for fifth costal cartilage, f) Facet for fourth costal cartilage, g) Facet for third costal cartilage, h) Impression of dorsal sterna ligament, i) Facet for second costal cartilages and j) Facet on manubrium sterni for first costal cartilage



**Fig.2** Dorso-lateral view of sternebrae (1 – 3) of adult female Blue bull (*Boselaphus tragocamelus*) showing a) Manubrium sterni, b) Facet on manubrium sterni for first costal cartilage, c) Facet for second costal cartilage, d) Second sternebra, e) Impression of dorsal sternal ligament, f) Facet for third costal cartilage and g) Third sternebra



**Fig.3** Dorso-lateral view of sternum of adult female Blue bull (*Boselaphus tragocamelus*) with all seven sternebrae showing a) Remnant of xiphoid cartilage, b) Xiphoid process, c) Facet for seventh and eighth costal cartilages, d) Facet for sixth costal cartilage, e) Facet for fifth costal cartilage, f) Facet for fourth costal cartilage, g) Facet for third costal cartilage, h) Facet on manubrium sterni for first costal cartilage and i) Facet for second costal cartilage

**Table.1** The measurements of sternum of Blue bull in cm

Parameters			Mean	SD	SE	Female (Mean±SE)	Male (Mean±SE)
<b>Weight (gm)</b>			510.37	4.09	1.67	507.46±1.96	513.28±1.28
<b>Total length of sternum including xiphoid cartilage</b>			41.60	0.73	0.30	41.20±0.17	42.00±0.50
<b>Manubrium sterni</b>	Length		5.23	0.20	0.08	5.07*±0.03	5.40±0.06
	Width	Cranial	2.83	0.36	0.15	2.57*±0.15	3.10±0.12
		Middle	2.17	0.28	0.11	1.93*±0.09	2.40±0.06
		Caudal	2.00	0.24	0.10	1.80*±0.06	2.20±0.06
<b>2<sup>nd</sup> sternebra</b>	Length		2.95	0.29	0.12	2.73*±0.12	3.17±0.09
	Width	Cranial	2.00	0.24	0.10	1.80*±0.06	2.20±0.06
		Middle	2.83	0.18	0.07	2.70*±0.06	2.97±0.07
		Caudal	3.13	0.19	0.08	3.00±0.06	3.27±0.09
<b>3<sup>rd</sup> sternebra</b>	Length		4.13	0.10	0.04	4.07±0.03	4.20±0.06
	Width	Cranial	3.70	0.14	0.06	3.63±0.07	3.77±0.09
		Middle	3.88	0.21	0.09	3.73±0.09	4.03±0.09
		Caudal	4.22	0.15	0.06	4.10*±0.06	4.33±0.03
<b>4<sup>th</sup> sternebra</b>	Length		4.38	0.21	0.09	4.23±0.09	4.53±0.09
	Width	Cranial	4.27	0.18	0.07	4.13*±0.07	4.40±0.06
		Middle	4.43	0.22	0.09	4.30±0.12	4.57±0.09
		Caudal	4.87	0.28	0.11	4.63*±0.09	5.10±0.06
<b>5<sup>th</sup> sternebra</b>	Length		5.02	0.18	0.07	4.93±0.09	5.10±0.12

	Width	Cranial	4.63	0.18	0.07	4.50*±0.06	4.77±0.07
		Middle	5.07	0.20	0.08	4.90*±0.06	5.23±0.03
		Caudal	5.38	0.22	0.09	5.20*±0.06	5.57±0.07
<b>6<sup>th</sup> sternebra</b>	Length		5.58	0.22	0.09	5.40*±0.06	5.77±0.07
	Width	Cranial	6.27	0.15	0.06	6.17±0.09	6.37±0.03
		Middle	6.42	0.17	0.07	6.30±0.06	6.53±0.09
Caudal		7.20	0.13	0.05	7.13±0.09	7.27±0.03	
<b>7<sup>th</sup> sternebra</b>	Length		7.83	0.22	0.09	7.67*±0.09	8.00±0.06
	Width	Cranial	5.62	0.25	0.10	5.43±0.07	5.80±0.12
		Middle	3.53	0.23	0.10	3.37±0.09	3.70±0.10
Caudal		2.32	0.33	0.13	2.07*±0.07	2.57±0.15	
<b>Xiphoid cartilage</b>	Longitudinal Length		7.23	0.18	0.07	7.10*±0.06	7.37±0.07
	Transverse length		7.60	0.32	0.13	7.33*±0.09	7.87±0.09
	Thickness	Cranial	1.05	0.09	0.04	0.97*±0.02	1.12±0.02
		Middle	0.24	0.05	0.02	0.19*±0.01	0.28±0.02
Caudal		0.16	0.04	0.02	0.13*±0.01	0.19±0.01	
<b>Distance between xiphoid cartilage and 7<sup>th</sup> costal facet</b>			6.60	0.25	0.07	6.40*±0.06	6.80±0.05
<b>Diameter of costal facets</b>	1 <sup>st</sup>	Dorso-ventral	1.57	0.11	0.03	1.55±0.04	1.58±0.01
		Longitudinal	0.66	0.04	0.01	0.65±0.01	0.68±0.01
	2 <sup>nd</sup>	Dorso-ventral	1.90	0.03	0.01	1.88*±0.01	1.93±0.01
		Longitudinal	0.70	0.04	0.01	0.68*±0.01	0.73±0.03
	3 <sup>rd</sup>	Dorso-ventral	2.56	0.08	0.02	2.53±0.03	2.59±0.04
		Longitudinal	0.84	0.10	0.03	0.82±0.04	0.86±0.02
	4 <sup>th</sup>	Dorso-ventral	2.42	0.05	0.01	2.39*±0.01	2.45±0.01
		Longitudinal	0.97	0.05	0.01	0.93*±0.01	1.01±0.03
	5 <sup>th</sup>	Dorso-ventral	2.29	0.07	0.02	2.25±0.03	2.33±0.05
		Longitudinal	1.20	0.13	0.04	1.16±0.06	1.24±0.07
	6 <sup>th</sup>	Dorso-ventral	2.06	0.16	0.05	2.02±0.06	2.11±0.12
		Longitudinal	1.76	0.29	0.08	1.71±0.12	1.82±0.02
	7 <sup>th</sup>	Dorso-ventral	2.07	0.08	0.02	2.02±0.03	2.11±0.04
		Longitudinal	1.85	0.11	0.03	1.82±0.04	1.89±0.08
<b>Distance between the costal facets of same side</b>	1 <sup>st</sup> and 2 <sup>nd</sup>		3.57	0.22	0.06	3.42*±0.05	3.72±0.05
	2 <sup>nd</sup> and 3 <sup>rd</sup>		4.17	0.22	0.06	4.02*±0.08	4.32±0.04
	3 <sup>rd</sup> and 4 <sup>th</sup>		3.68	0.19	0.06	3.53*±0.06	3.83±0.06
	4 <sup>th</sup> and 5 <sup>th</sup>		3.80	0.15	0.04	3.70*±0.04	3.90±0.08
	5 <sup>th</sup> and 6 <sup>th</sup>		2.75	0.31	0.09	2.60±0.14	2.90±0.05
<b>Distance between the costal facets of sternebrae</b>	Manubrium sterni		3.33	0.18	0.07	3.20*±0.06	3.47±0.07
	2 <sup>nd</sup> sternebra		3.37	0.25	0.10	3.17*±0.09	3.57±0.07
	3 <sup>rd</sup> sternebra		4.10	0.13	0.05	4.00*±0.06	4.20±0.00
	4 <sup>th</sup> sternebra		5.48	0.21	0.09	5.33±0.09	5.63±0.09
	5 <sup>th</sup> sternebra		6.40	0.26	0.11	6.20*±0.06	6.60±0.12
	6 <sup>th</sup> sternebra		7.07	0.19	0.08	6.93±0.09	7.20±0.06
	7 <sup>th</sup> sternebra		6.73	0.22	0.09	6.60±0.12	6.87±0.09

Values bearing superscript (\*) differ significantly in column P< 0.05



Further, the average diameters in females were measured to be  $2.02\pm 0.06$  cm and  $1.71\pm 0.12$  cm respectively, whereas they were found to be  $2.11\pm 0.12$  cm and  $1.82\pm 0.02$  cm respectively in males. The average dorso-ventral and longitudinal diameters of the seventh pair of costal facets were found to be  $2.07\pm 0.02$  cm and  $1.85\pm 0.03$  cm respectively in adult Blue bull. Further, the average diameters in females were measured to be  $2.02\pm 0.03$  cm and  $1.82\pm 0.04$  cm respectively, whereas they were found to be  $2.11\pm 0.04$  cm and  $1.89\pm 0.08$  cm respectively in males (Table 1).

The average distance between the 1<sup>st</sup> and 2<sup>nd</sup> pair of costal facets was found to be  $3.57\pm 0.06$  cm in adult Blue bull. Further, the distance was measured to be  $3.42\pm 0.05$  cm in females that was significantly lesser ( $P<0.05$ ) than that of males, where it was found to be  $3.72\pm 0.05$  cm (Table 1). The average distance between the 2<sup>nd</sup> and 3<sup>rd</sup> pair of costal facets was found to be  $4.17\pm 0.06$  cm in adult Blue bull. Further, the distance was measured to be  $4.02\pm 0.08$  cm in females that was significantly lesser ( $P<0.05$ ) than that of males, where it was found to be  $4.32\pm 0.04$  cm (Table 1).

The average distance between the 3<sup>rd</sup> and 4<sup>th</sup> pair of costal facets was found to be  $3.68\pm 0.06$  cm in adult Blue bull. Further, the distance was measured to be  $3.53\pm 0.06$  cm in females that was significantly lesser ( $P<0.05$ ) than that of males, where it was found to be  $3.83\pm 0.06$  cm (Table 1). The average distance between the 4<sup>th</sup> and 5<sup>th</sup> pair of costal facets was found to be  $3.80\pm 0.04$  cm in adult Blue bull. Further, the distance was measured to be  $3.70\pm 0.04$  cm in females that was significantly lesser ( $P<0.05$ ) than that of males, where it was found to be  $3.90\pm 0.08$  cm (Table 1). The average distance between the 5<sup>th</sup> and 6<sup>th</sup> pair of costal facets was found to be  $2.75\pm 0.09$  cm in adult Blue bull. Further,

the distance was measured to be  $2.60\pm 0.14$  cm in females, whereas it was found to be  $2.90\pm 0.05$  cm in males.

Further, the average distance between the 1<sup>st</sup> pair of costal facets was found to be  $3.33\pm 0.07$  cm in adult Blue bull. However, the distance was measured to be  $3.20\pm 0.06$  cm in females, that was significantly lesser ( $P<0.05$ ) than that of males, where it was found to be  $3.47\pm 0.07$  cm (Table 1). The average distance between the 2<sup>nd</sup> pair of costal facets was found to be  $3.37\pm 0.10$  cm in adult Blue bull. However, the distance was measured to be  $3.17\pm 0.09$  cm in females, that was significantly lesser ( $P<0.05$ ) than that of males, where it was found to be  $3.57\pm 0.07$  cm (Table 1). The average distance between the 3<sup>rd</sup> pair of costal facets was found to be  $4.10\pm 0.05$  cm in adult Blue bull. However, the distance was measured to be  $4.00\pm 0.06$  cm in females, that was significantly lesser ( $P<0.05$ ) than that of males, where it was found to be  $4.20\pm 0.00$  cm (Table 1). The average distance between the 4<sup>th</sup> pair of costal facets was found to be  $5.48\pm 0.09$  cm in adult Blue bull. However, the distance was measured to be  $5.33\pm 0.09$  cm and  $5.63\pm 0.09$  cm in females and males respectively. The average distance between the 5<sup>th</sup> pair of costal facets was found to be  $6.40\pm 0.11$  cm in adult Blue bull. However, the distance was measured to be  $6.20\pm 0.06$  cm in females, that was significantly lesser ( $P<0.05$ ) than that of males, where it was found to be  $6.60\pm 0.12$  cm (Table 1). The average distance between the 6<sup>th</sup> pair of costal facets was found to be  $7.07\pm 0.08$  cm in adult Blue bull. However, the distance was measured to be  $6.93\pm 0.09$  cm and  $7.20\pm 0.06$  cm in females and males respectively. The average distance between the 7<sup>th</sup> pair of costal facets was found to be  $6.73\pm 0.09$  cm in adult Blue bull. However, the distance was measured to be  $6.60\pm 0.12$  cm and  $6.87\pm 0.09$  cm in females and males respectively (Table 1).

The cariniform cartilage was not found in the manubrium sterni of Blue bull. The xiphoid cartilage was present in the caudal aspect of 7<sup>th</sup> sternebra attached with the xiphoid process. It was a rounded thin plate like structure like that of the horse, but found to be smaller than the horse. The present findings were in agreement with Getty *et al.*, (1930) in ox, Mills (2003) in cattle, Dyce (2006) in ox, Frandson *et al.*, (2006) in cattle and Akers and Denbow (2013) in ruminants, but contradictory to the findings of Leach (1946) in cat, Grossman (1960) in camel, Sebastiani and Fishbeck (2005) in cat, Duzler *et al.*, (2006) in avian species, Budras *et al.*, (2009) in horse, Hussain (2010) in goat, Tomar *et al.*, (2011) in Pariah Kite, Satyamoorthy *et al.*, (2012) in Spot-billed pelican, Dewangan *et al.*, (2014) in pigeon, John *et al.*, (2014) in pigeon, crow and owl, Jayachitra *et al.*, (2015) in emu, turkey and duck, John *et al.*, (2015) in red wattled lap-wing, Sreeranjini *et al.*, (2015) in male Green-winged Macaw, Pathak *et al.*, (2017) in peacock and turkey and Wani *et al.*, (2017) in Common Moorhen.

Biometrical observations revealed that the average longitudinal length of the xiphoid cartilage was found to be  $7.23 \pm 0.07$  cm in adult Blue bull. Further, it was measured to be  $7.10 \pm 0.06$  cm in females that was significantly lesser ( $P < 0.05$ ) than that of males, where it was found to be  $7.37 \pm 0.07$  cm (Table 1). Similarly, the average transverse length of the xiphoid cartilage was found to be  $7.60 \pm 0.13$  cm in adult Blue bull. Further, it was measured to be  $7.33 \pm 0.09$  cm in females that was significantly lesser ( $P < 0.05$ ) than that of males, where it was found to be  $7.87 \pm 0.09$  cm. The average thicknesses of the xiphoid cartilage at the cranial, middle and caudal aspects were found to be  $1.05 \pm 0.04$  cm,  $0.24 \pm 0.02$  cm and  $0.16 \pm 0.02$  cm respectively in adult Blue bull. Further, the average thicknesses at these sites were measured to be  $0.97 \pm 0.02$  cm,  $0.19 \pm 0.01$  cm and  $0.13 \pm 0.01$

cm respectively in females that were significantly lesser ( $P < 0.05$ ) than that of males, where they were found to be  $1.12 \pm 0.02$  cm,  $0.28 \pm 0.02$  cm and  $0.19 \pm 0.01$  cm respectively (Table 1). The average distance between the seventh pair of costal facet and xiphoid cartilage was found to be  $6.60 \pm 0.07$  cm in adult Blue bull. Further, the distance was measured to be  $6.40 \pm 0.06$  cm in females that was significantly lesser ( $P < 0.05$ ) than that of males, where it was found to be  $6.80 \pm 0.05$  cm (Table 1).

The present gross and morphometrical study on the sternum of adult Blue bull revealed that the sternum was a long plate of osteo-cartilagenous structure that was comprised of seven segments or sternebrae. The cranial end was formed by a wedge shaped and laterally compressed manubrium sterni that had extensive facets dorso-laterally for articulation with the first pair of costal cartilages. The body was flat and thick.

It widened towards the caudal aspect, but became narrower behind the last pair of costal facets. The lateral borders were thick, notched that accommodated seven pairs of sternal facets on either side of the intersternal junctions. The eighth pair costal cartilages joined the sternum between 6<sup>th</sup> and 7<sup>th</sup> sternebrae along with the seventh pair costal cartilages. Biometrical observations reflected that the measured parameters were more in males that deferred significantly ( $P < 0.05$ ) from the females. There is no previous information on these parameters in the sternum of Blue bull, nor in any other domestic animals in India with which comparisons could be made. We therefore believe that the data presented above would form a baseline for further work especially comparability and compatibility are now desirable traits as efforts are geared up towards massive improvement in the livestock sector of the international economy.

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