

Sexual/aggressive behavior of wild yak (*Bos mutus* Prejevalsky 1883) during the rut: influence of female choice

Paul J. Buzzard · Donghua Xu · Huan Li

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Abstract Wild yaks (*Bos mutus*) ranged across the Tibetan Plateau in large herds before being forced to remote areas of the plateau. Consequently, little has been published about their behavioral ecology. We present the first extensive study on wild yak behavior during the rut. We gathered data on activity budgets, aggressive/sexual behaviors, and the behavior of bulls inside and outside mixed groups during 11 days in 2010 and 9 days in 2011. Yaks ate less and were more social during the rut than during summer. Males ate less than females and socialized more during the rut. We observed yaks for 234.25 h and recorded 2,078 aggressive/sexual behaviors. Yak bulls inspected and tended cows showing off their profiles during lateral displays, the most common type of indirect aggression. Yak bulls inside mixed sex groups rested less and socialized more than bulls outside. Females initiated intense intra-sexual competition and led at least 25 bulls on chases. Females then incited fight frenzies of numerous bulls from inside and outside the groups before copulations, and fights could be intense. We discuss female choice selecting for large size and fighting ability in males, the similarity of yak and bison (genus *Bison*) behavior, and conservation implications.

Keywords *Bos mutus* · Wild yaks · Mating behavior · Female choice · Behavioral ecology

1 Introduction

In the past, wild yaks (*Bos mutus* Prejevalsky 1883) ranged across the Tibetan Plateau of China in large numbers and often associated in herds of hundreds and even thousands [1, 2]. The worldwide yak population has been greatly reduced, however, to as low as 10,000 because of competition with livestock and loss of habitat, and they are classified as vulnerable on the IUCN redlist [3]. The remaining wild yaks have been forced to remote areas of the plateau, and consequently, there has been little information published on wild yak behavioral ecology and almost nothing published on their behavior during the rut [4]. In this paper, we provide the first extensive study of the sexual and aggressive behavior of wild yak during the rut to contribute to the understanding of yak behavioral ecology and ungulate mating systems.

Traditionally, studies of sexually selected behaviors in ungulates and other mammals have focused on intra-sexual male competition [5, 6]. The mating systems of ungulates are characterized by resource defense polygyny, female defense polygyny, and more rarely lekking and monogamy [7, 8]. Recently, however, there has been much interest in the importance of female choice as well as cooperative and competitive interactions between and within the sexes for a complete understanding of ungulate mating systems [9]. Female choice can be for the stamina and competitive ability of males as well as auditory or olfactory status signals [6]. For example, pronghorn (*Antilocapra americana* Ord 1815) females test the stamina of males and incite fights among them, while red deer (*Cervus elaphus* Linnaeus 1758) and fallow deer (*Dama dama* Linnaeus 1758) do prefer higher roaring rates of stags [10–13].

Wild cattle (genus *Bos*), bison (genus *Bison*), and buffaloes (genera *Syncerus* and *Bubalus*) of the tribe Bovini

P. J. Buzzard (✉) · D. Xu · H. Li
China Exploration & Research Society, Hong Kong, China
e-mail: pbuzzard@dzs.org

D. Xu
e-mail: Xdh7561@sina.com.cn

(subfamily Bovinae family Bovidae) generally use a tend-bond mating system in mixed sex herds where bulls guard or tend cows for varying periods of time with indirect and direct aggressive behaviors [14–16]. In these mixed sex herds, there is often much sexual dimorphism, and fighting ability is related to the number of copulations with a great skew in mating success. For example, in American bison (*Bison bison* Linnaeus 1758), male/female body weight ratios range from 1.6 to 1.8 [16–18], and high-ranking bulls sire at least 70 % of calves [19].

Despite the prevalence of intra-sexual competition and mating skew among Bovini bulls, female choice also occurs. For example, American bison cows approach high-ranking bulls and run to incite chases and fights among bulls [16]. Cows most often end up with higher ranking bulls after the runs and run more often if challenging bulls have a higher rank than the tending bull. Thus, it seems that female choice and potential cooperation with high-ranking males have been a strong evolutionary force in American bison favoring large body size, fighting ability, and stamina in this tend-bond mating species.

To provide more insight into female and male sexually selected behaviors, it is necessary to study more species, especially those in different ecological environments [9]. The environment of the wild yak is particularly harsh in terms of high altitude and a short growing season providing just such an opportunity. Wild yak sexes are primarily segregated with bulls living alone or in bachelor groups and joining groups for the rut in September [1, 4]. Domestic yaks used indirect threats such as lateral displays with males standing broadside showing off their profiles and direct aggression such as charges and horn-to-horn fights that lasted 15 min [20]. Aggression is likely more intense in wild herds. For example, many wild yak bulls have been observed with scars, injuries, and horn damage [1]. Other yak behaviors during the rut include wallowing in dust accompanied with urinating/defecating, bellowing, and horning the ground [4].

In this paper, we describe the timing, changes in activity budgets and group compositions for wild yak during the 2010 and 2011 ruts. Data on activity budgets are important for understanding the ecological influences on social behavior [21], and we compare activity budgets over the course of the rut with data from summer 2004. We also provide data on aggressive/sexual behaviors during the rut. We predicted that in mixed sex groups, wild yak bulls would tend cows and intensely guard them from other bulls as implied by the large degree of sexual dimorphism (male/female body weight ratios ranging from 1.6 to 2.7) and preliminary observations on social grouping and male injuries [1, 4]. We also observed yak bulls in and outside of mixed sex groups to determine if group bulls would engage in more activity behaviors (standing, walking, and social)

and less comfort behaviors (lying and feeding) than bulls outside of mixed sex groups as in bison [22].

2 Materials and methods

2.1 Study area

Arjinshan Nature Reserve (ANR), Xinjiang is a national-level reserve and one of the largest nature reserves in China (45,000 km², Fig. 1). ANR is on the northern edge of the Tibetan Plateau, and there are steppes at 4,000–4,600 m and mountains with permanent snow above 5,500 m. The climate is continental, dry, and cold. During the winter 1999 expedition, the average daily maximum temperature was $-9\text{ }^{\circ}\text{C}$ ($n = 11$, overall maximum $-5\text{ }^{\circ}\text{C}$), while the average minimum was $-26\text{ }^{\circ}\text{C}$ ($n = 11$, overall minimum $-31\text{ }^{\circ}\text{C}$). Precipitation is rare and sparse, and frequently falls as snow or sleet even in summer [23].

ANR protects a unique ecosystem in transition from plateau to desert. In addition to wild yak, other ungulates include Tibetan antelope (chiru, *Pantholops hodgsonii*), Tibetan wild ass (kiang, *Equus kiang*), Tibetan gazelle (*Procapra picticaudata*), blue sheep (*Pseudois nayaur*), argali (*Ovis ammon*), and goitered gazelle (*Gazella subgutturosa*). Potential predators include wolves (*Canis lupus*), snow leopards (*Panthera uncia*), brown bears (*Ursus arctos*), lynx (*Felis lynx*), and dholes (*Cuon alpinus*).

2.2 Behavioral sampling

The largest concentration of wild yak in ANR is in the northeast [24]. From September 11–21, 2010 and September 20–28, 2011, we observed several mixed sex groups of wild yak at a small herder community of Yishakipati and at a camp 15 km to the southeast of Yishakipati in ANR



Fig. 1 Arjinshan Nature Reserve, Xinjiang and its position in China

(Fig. 1). We defined a group as >1 animal that was estimated to be ≤ 75 m from one another and tended to move as a cohesive unit. Group membership was variable especially with regard to bulls, because they would often range just outside groups and join groups in the evenings.

We observed yaks generally from dawn (07:30) until dusk (20:30) from a distance of 0.5–2 km with a 20–60 \times spotting scope and 25–40 \times binoculars. Even from this distance, the large body size of the yaks allowed us to observe yak behavior. We conducted scan samples every half hour beginning at the hour or half past the hour, and between scans, we conducted all occurrence focal scans for 10 min [25]. If we did not conduct focal scans, then we monitored the group between scan samples to record ad libitum all sexual/aggressive behaviors. From September 16–20, 2010 and September 20–26, 2011, two observers recorded behaviors concurrently in the mornings (07:30–10:30) and evenings (16:30–20:30), because social behaviors were most common at this time. The observers usually watched different groups, but if observers watched the same large group (>100 animals), each observer monitored one half of the group spread and used local landmarks to demarcate the boundaries and ensure that behaviors were not double counted.

We considered four age/sex categories of yak: females (>3 years old), males (>3 years old), young (calves less than 1 year old), and other (yearlings and unidentified individuals). We recorded six behaviors during scans: (1) feed, (2) lie down, (3) stand, (4) walk, (5) social behaviors, and (6) other. Walking individuals moved between feeding or resting places. The category social included aggressive or sexual behaviors between two individuals. The category other included additional behaviors such as reactions to a wolf in one case. We compared these scan data with scan samples collected by DX with the same methods from July 14–16, 18, 2004. We tested the frequencies of scan categories with G -tests [26].

We conducted focal samples on bulls in and outside mixed sex groups uniformly during the day. We recorded the time spent in the six behaviors from above during focal samples. We compared the average times that bulls performed these behaviors by first transforming the data with the arcsin function then performing z -tests of means after F tests confirmed the variances were comparable [27].

2.3 Behaviors related to the rut

Aggressive behaviors could be indirect or direct. Lateral displays were indirect aggressive displays where males showed off their profiles and stood within 5 m of each other oriented head-to-head or tail-to-tail [20]. Another indirect display, the “pass-by”, occurred when one male walked slowly in front of another male and passed within

1 m. Head-to-head face offs occurred when males stood directly opposite each other within 1 m. At this time, males sometimes rotated/shook their heads, and this often led to direct aggression in the form of horn-to-horn fights. Males charged toward other males in another show of direct aggression. Direct aggression was often indicated by males raising their tails. A “fight frenzy” was the engagement of at least 5 to 25 or more males in aggressive displays and fights [28]. Individuals rolled in dust during the wallow behavior, and before using wallows, they often pawed the ground with a front hoof or horned the ground.

Sexual behaviors included male inspection of females. During inspection, males smelled and at times licked the genital region of females often followed by the stereotypic lip curl or flehmen response [16]. If the female moved off, the males would often follow. Males also tended or guarded females from other males by standing next to them and blocking their escape. Males often reached back to make head-to-head contact with the female while tending the female. Mounts occurred within and between the sexes, and copulations lasted for at least 5 s.

2.4 Timing of the rut

On September 11, 2010 from 08:00 to 15:30, we observed a mixed sex group of ca. 200 individuals for 15 min every half hour. We observed a bull using the flehmen response indicating that the early rut had begun. On September 14, we observed for the first time a bull tending or guarding a cow from other bulls. We observed the first copulation on September 19, 2010 and observed bulls guarding cows from many other bulls until the end of September. Based on the behavior of bulls in 2010, we considered September 11–13 as the early rut, September 14–18 the mid-rut, and September 19–28 the main rut. In 2011, we could not begin observations until September 20th when we observed males guarding females; we observed fight frenzies and mounts starting on the 22nd. In 2011, we considered September 20–21 as the mid-rut and September 22–28 as the main rut.

3 Results

3.1 Activity budgets

We compared activity budgets for wild yak bulls, cows, and unknown individuals during the whole rut period to activity budgets from summer 2004. We found that during the summer, yak ate more than during the rut while lying down, socializing, and walking less (Table 1; $G = 155$, $P < 0.001$). We then compared the activity budgets of yak bulls and cows during the rut. We found that bulls fed less

Table 1 Comparison of activity budgets for (a) wild yak bulls, cows, and unknown individuals from scans during summer 2004 versus the 2010 and 2011 ruts; (b) wild yak bulls and cows during the 2010 and 2011 rut; and (c) yak bulls during the early rut vs. the mid-rut vs. the main rut

(a)			
	Summer (<i>n</i> = 526)	Rut (<i>n</i> = 15,297)	
Feed	64 %	42 %	
Social	0.5 %	4 %	
Lie	25 %	36 %	
Stand	10 %	10 %	
Walk	0.5 %	8 %	
(b)			
	Bulls (<i>n</i> = 2268)	Cows (<i>n</i> = 3301)	
Feed	17 %	68 %	
Social	24 %	–	
Lie	17 %	10 %	
Stand	26 %	13 %	
Walk	15 %	9 %	
Other	1 %	–	
(c)			
	Early rut (<i>n</i> = 210)	Mid-rut (<i>n</i> = 750)	Main rut (<i>n</i> = 1308)
Feed	33 %	20 %	13 %
Social	6 %	24 %	28 %
Lie	23 %	10 %	19 %
Stand	21 %	28 %	26 %
Walk	13 %	17 %	14 %
Other	4 %	1 %	0.1 %

than cows during the rut while engaging in every other behavioral category more than cows (Table 1; $G = 2082$, $P < 0.001$). We then compared the activity budgets for yak bulls over the course of the rut from the early rut to the mid-rut to the main rut. The time spent feeding by bulls decreased significantly over the course of the rut, and the time spent in social activities increased (Table 1; $G = 161$, $P < 0.001$).

3.2 Group compositions

We observed much variety in the sizes of mixed sex groups within and between days. During the early and mid-rut, we observed groups of 15–205 individuals with an average of 73.1 ± 52.1 ($n = 17$). The largest groups formed during the main rut especially on days with fight frenzies when small groups joined together; we observed groups of 9–283 individuals with an average of 105.1 ± 70.6 ($n = 17$). Because of topography and observation distance, it was

often difficult to obtain robust counts of age/sex classes. During the early and mid-rut, groups had from 2 to at least 25 calves which were 6 %–27 % of group totals and 7 %–54 % of cows/others (Fig. 2a). During the main rut, groups had from 2 to at least 28 calves which were 15 %–27 % of group totals and 20 %–44 % of cows/others (Fig. 2b). During the early and mid-rut, groups had 3–21 bulls (8 %–26 % of group totals, Fig. 2a), and during the main rut, groups had 2–15 bulls (9 %–22 % of group totals, Fig. 2b).

3.3 Behaviors related to the rut

We observed the yaks for 234.25 observer-hours and observed 2,078 aggressive/sexual behaviors. Aggressive behaviors typically occurred between bulls. The most common indirect aggression was the lateral display ($n = 196$) followed by pass-bys ($n = 34$). Direct

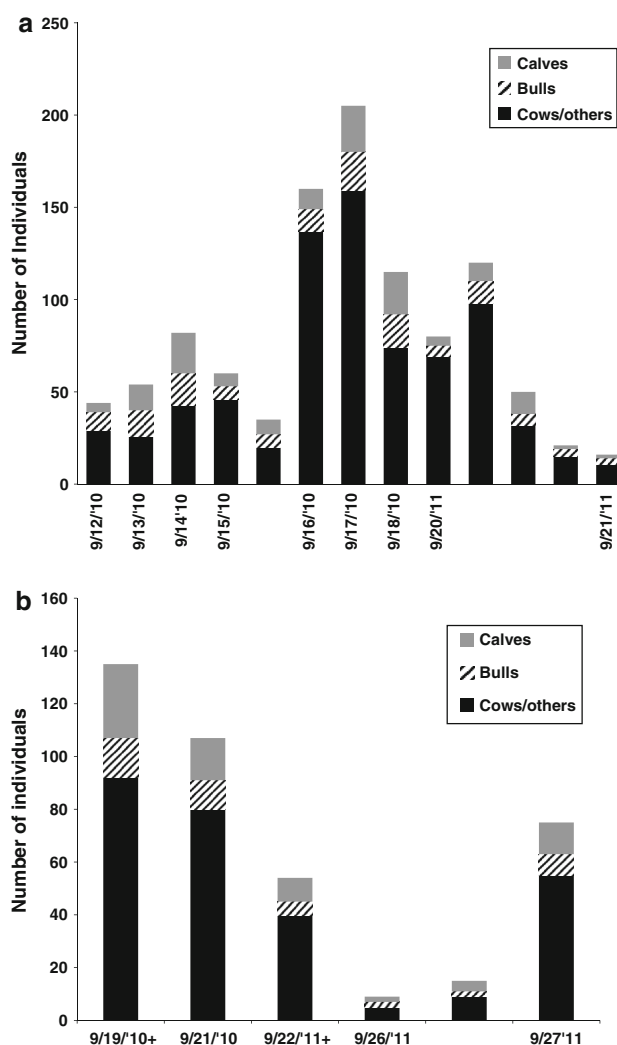


Fig. 2 The number of calves, bulls and cows/others for wild yak groups (a) during the early and mid-rut and (b) during the main rut. “+” indicates fight frenzy

aggression occurred in the form of charges ($n = 43$) and horn-to-horn fights ($n = 151$). Fights lasted from 15 s to over 20 min. Fights varied in intensity from long bouts (>20 min) of low intensity sparring among small bulls to more intense fights between large bulls at times forcing each other to the ground. We could not confirm any injuries. We also observed one brief fight between cows. We also observed several mounts within the sexes.

Wallowing occurred 156 times in both aggressive and sexual situations and up to 7 times in one 10-min focal sample. During wallows, primarily bulls rolled in sandy patches usually after pawing and/or horning the ground. Bulls most often wallowed during aggressive situations such as lateral displays, before fights, or when alone but with tail up in an aggressive posture (65 %, $n = 155$). When wallowing alone with or without tail up, they wallowed at a prominent position often higher in elevation than most other group members. Rarely, bulls wallowed while interacting with females (5 %, $n = 155$). We only observed a female wallowing once, and this occurred before fighting with another female.

Indirect aggressive behaviors between bulls were more common than direct aggressive behaviors and wallowing during the early and mid-rut of both years (Fig. 3a, b). On the first day of the main rut in 2010 (9/19), there was a large fight frenzy with a lot of lateral displays, and indirect aggressive behaviors were more common than direct aggressive behaviors and wallowing, but on the next day, there was another fight frenzy where direct aggression in the form of fights and chases was higher than indirect aggression and wallowing (Fig. 3a). In 2011, direct aggressive behaviors were also the highest after the start of the main rut (9/22/2011) on days with fight frenzies (Fig. 3b).

The most common behavior we observed between the sexes was when males smelled/inspected the genital region of females ($n = 901$) often leading to female urination. After the urination and at other times, males often performed the flehmen response ($n = 123$). After smelling and inspecting the female, the male would often stand next to and tend the female guarding her from 1 to 10 other males ($n = 477$). This guarding often had males reaching back and touching the head of the female while standing next to her.

The three most common intersexual behaviors (inspecting or smelling females, guarding or standing by females, as well as following females) were most common during the main rut and most common during the days with a fight frenzy (Fig. 4a, b). In both years, bulls more often inspected cows during the early and mid-rut and more often guarded and followed cows as the rut progressed (Fig. 4a, b).

3.4 Female choice

After males smelled the females, the females left 233 times and allured males to follow (26 %, $n = 901$). For another

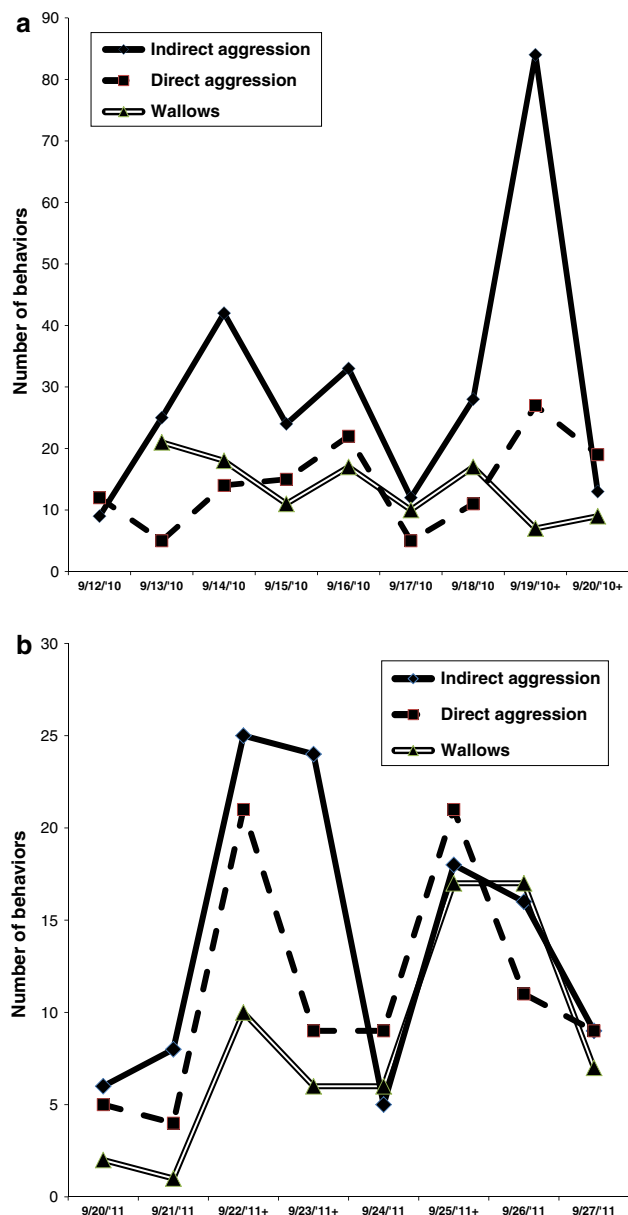


Fig. 3 The number of indirect aggressive behaviors (lateral displays and pass-bys), direct aggressive behaviors (fights and charges) and wallows during (a) the 2010 rut and (b) the 2011 rut. “+” indicates fight frenzy

12 follows, it was unsure if the males smelled and/or inspected the females first. In both years, the follows increased as the rut progressed (Fig. 4a, b). At times, there was an extended sequence where males would smell then females would leave. Males would then follow the females who would stop. The males would smell again, and this could go on for several more times. Nine times we saw females fight with males to elude guarding males or attempted mountings.

All seven copulations were brief (<10 s) and occurred after females left a guarding male instigating chases and

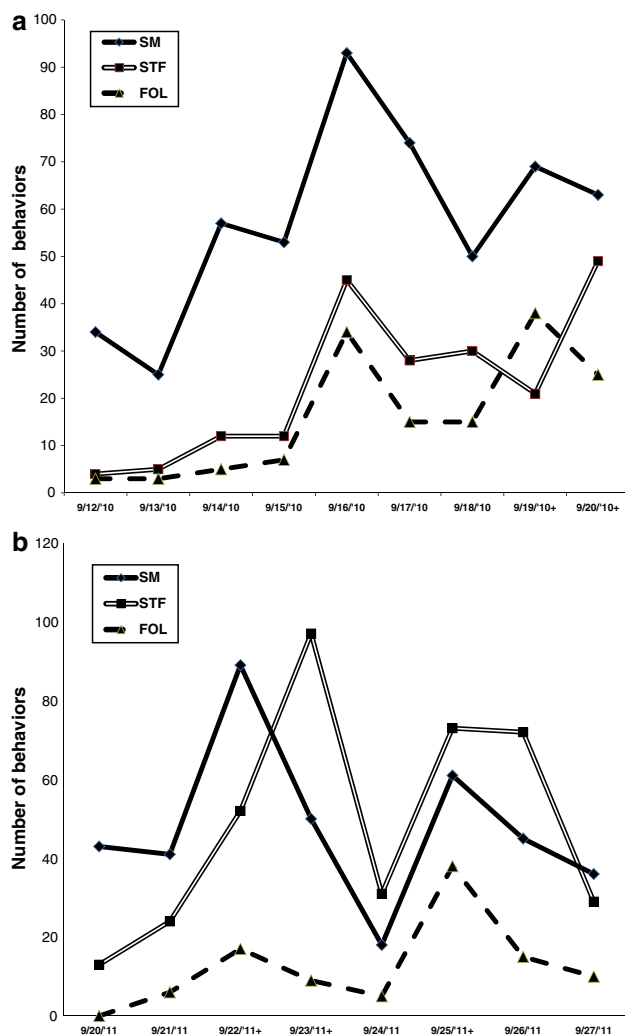


Fig. 4 The number of inter-sexual behaviors: SM (inspecting or smelling females), STF (tending or standing by females) and FOL (following females) during (a) the 2010 rut and (b) the 2011 rut. “+” indicates fight frenzy

fight frenzies. For example, males would guard a female from at least 10 other bulls for several hours. Then the female would lead the males on a chase, and they were joined by at least 15 other males. At least 50 other individuals from the group sometimes joined to watch or engage in the fight frenzy. Large males from outside the group would then join, leading to intense fights and copulations.

3.5 Comparison of group and outside bulls

Bulls in mixed sex groups socialized more and rested less than bulls outside mixed sex groups (Fig. 5). Group bulls spent on average 4.1 ± 1.5 min ($n = 64$) in social behaviors during 10-min focal samples compared to an average of 0.4 ± 1.1 min ($n = 83$) for bulls outside mixed sex groups (z test = 9.4, $P < 0.01$). Group bulls spent on average 0.7 ± 1.6 min ($n = 64$) resting during focal

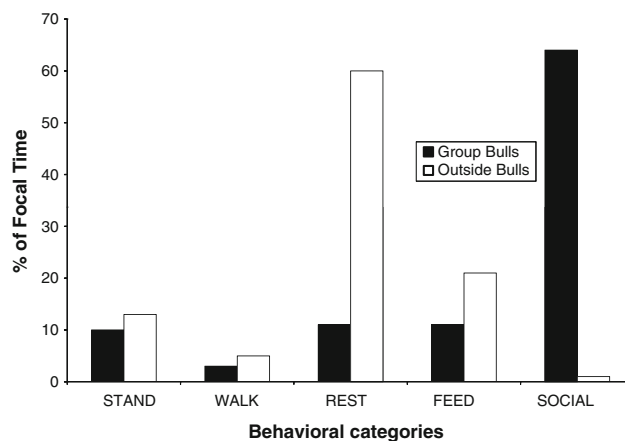


Fig. 5 The percent of time that bulls inside and outside mixed sex groups performed different behaviors during focal samples

samples compared to an average of 3.2 ± 1.9 min ($n = 83$) for bulls outside groups (z test = 5.7, $P < 0.01$). Feeding, walking, and standing rates were similar for bulls inside and outside groups (Fig. 5).

4 Discussion and conclusions

The timing of the wild yak rut and group compositions was generally consistent with previous reports [1, 4] who noted that the rut occurred mainly in September and from mid-August through September, respectively. Although we could not determine precise timing of the rut, late September was the peak in both years. Because of the observation distances and topography, it was difficult at times to obtain robust counts of age/sex classes, but it was still clear that during the rut wild yak bulls tended females primarily within large, mixed sex herds as predicted.

Bulls became more social and fed less as the rut progressed, and bulls inside mixed sex groups were more social and rested less than bulls outside the groups. The same has been found in American bison and Cape buffalo (*Syncerus caffer* Sparrman 1779) where males leave herds to recover [22, 29]. For both yak bulls and cows, the costs and benefits during the rutting season were substantial. First, the costs to the yak bulls could be large given the intense fights and scarring [this study; 1]. Likewise, the benefits are large because wild yak cows in estrus are particularly valuable; yak cows breed every 2 years or longer [30], and estrus can be very short. In domestic yak, estrus can last from only 0.5–6.5 h, and it mostly lasts less than a day [30]. As for wild yak cows, they were guarded by multiple bulls for much of the day, and this coercion was likely as costly as it is for other females [31].

Female choice, potentially in cooperation with high status males [9], seemed to be an important factor in wild yak selecting for large body size and fighting ability in this tend-bond mating species. In both years, we observed yak cows being tended or guarded for hours and then chased by over 25 bulls. We more often observed females eluding males than copulating with them, and we only observed copulations during or after large fight frenzies with intense fights involving large males who often came from outside the groups. These chases and frenzies together with cows resisting bulls emphasized the potential importance of intra-sexual competition mediated by female choice. The benefits of female choice can be direct or indirect; however, it can be difficult to distinguish female choice from intra-sexual male competition [6, 9]. Females incite male competition in a variety of animals, and inter-sexual choice, intra-sexual competition, and inter-sexual coercion must be considered together [9, 16, 32–35]. It is necessary for long-term studies on wild yak groups with individual identification to obtain data on the length of male tenures in and out of groups and to clarify the costs and benefits of female and male mating strategies.

It was suggested that yak behavior is intermediate between bison and wild cattle [20]. Our data, however, showed that yak behavior during the rut more closely resembled the behavior of bison. For example, males-tending females are an important part of yak as well as American and European bison behavioral repertoires during the rut. Feral cattle, banteng (*Bos javanicus* d'Alton 1823), and gaur (*Bos gaurus* Smith 1827) males compete for access to females, but there is no extended tending [36–40]. In addition, wild yak used wallows during the rut like bison and unlike cattle [4], but there were important differences in context. Yak wallowing was used more during intrasexual aggressive contexts, for example, with the tail raised before broadside displays and fighting. Bison wallowing, on the other hand, often followed urination in the wallow pits and was used primarily for scent marking and linked more to courtship behavior [14, 41, 42]. We did not observe wild yaks urinating in the wallows, but we were likely too far. This behavior has been observed in domestic yak [20]. We were also too far to hear bellows which are important in bison [16, 28].

Our behavioral data support genetic and morphologic studies that show yak is closer to bison than cattle [43–47]. Behavioral characters can be very valuable for determining phylogenetic relationships [48], and more extensive behavioral studies can help clarify the phylogenetic position of wild yak.

Wild yak at ANR is globally important [24] and understanding their mating behavior can benefit yak management and conservation. When populations become fragmented, effective management, and long-term

conservation must be based on knowledge of mating systems and the reproductive variation that occurs within the sexes [28].

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