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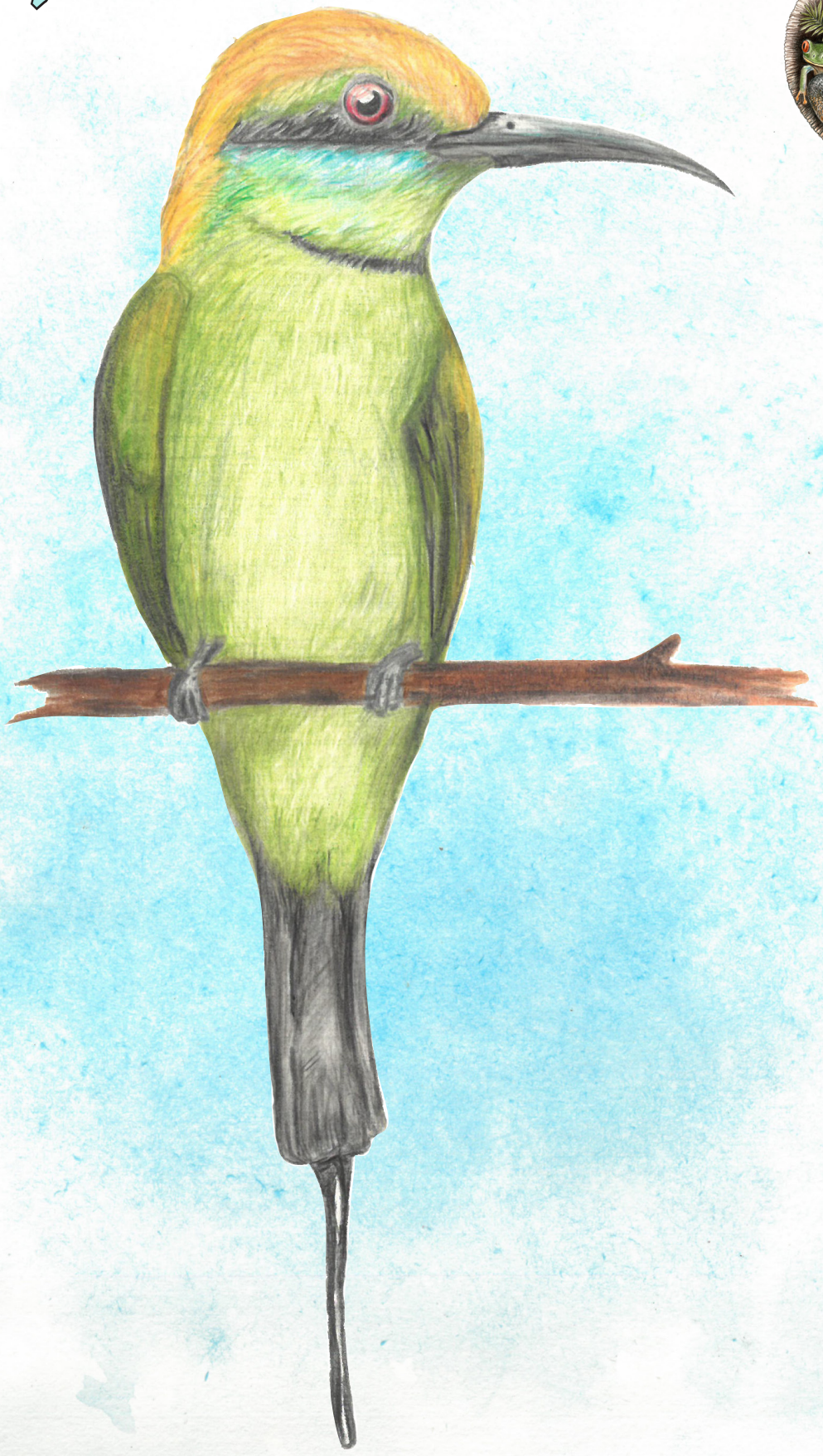

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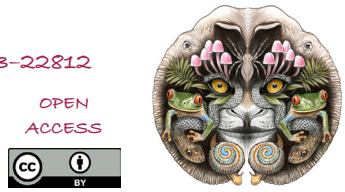

COMMUNICATION

An update on the conservation status of Tibetan Argali *Ovis ammon hodgsoni* (Mammalia: Bovidae) in India

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Abstract: Mountain ungulates are important for alpine ecosystem ecology, yet are understudied, particularly in Asia. Tibetan Argali *Ovis ammon hodgsoni* occurs across Tibet, with Trans-Himalayan India forming the edge of its distribution. We studied their conservation status in India. We compiled published data and secondary information about the occurrence of argali. We then focused on Ladakh, the remaining stronghold of argali in India. Based on literature from Ladakh and after consulting key-informants, we delimited two major populations of argali and estimate population density and demography using the double-observer method. We found 27 studies on argali in India. Studies covered four major themes: records (n = 12), conservation (n = 7), ecology (n = 7), and evolution (n = 1), with studies increasing after 2000. Estimated argali density in Tsaba was 0.34 argali km^{-2} (0.32–0.40) and in Chushul-Mirpal Tso was 0.15 argali km^{-2} (0.12–0.30). Both populations had comparable demography including age-sex ratios. We need to urgently consider argali as a priority species for conservation in India particularly as threats—including transboundary concerns, lack of coordinated conservation across the international border, anthropogenic disturbances, competition & disturbance from livestock grazing, and habitat loss—are a reality. Towards that, we delimited knowledge gaps and set robust population baselines for the two important argali populations in India. As the Tibetan Argali here co-occur with people, it will be crucial to ensure conservation is done in partnership with local communities.

Keywords: Changthang, double observer survey, Mountain ungulate, occurrence, population, Tibet, Trans-Himalayan India.

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Author contributions: MK, RD, SL and KS did the field surveys. KRS conceived the study. MK analyzed the data and wrote the first draft with help from KRS. All author commented and revised subsequent versions. All authors agreed upon the final version.

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INTRODUCTION

Wild ungulates are key determinants of large carnivore populations whilst also playing an important role in ecosystem function including affecting vegetation composition and nutrient cycling (Karanth et al. 2004; Bagchi & Ritchie 2010; Suryawanshi et al. 2017). Ungulates typically from the sub-family Caprinae are adapted to live in the high mountains and are referred to as mountain ungulates. The mountain ecosystems of southern and central Asia are home to a diverse community of mountain ungulates (Schaller 1977). Because of the remoteness of their landscape and associated logistical challenges, studying mountain ungulates in Asia has seen considerable difficulty (Singh & Milner-Gulland 2011). This has hindered the understanding of their conservation status and limited conservation efforts in the region.

The argali is the world's largest wild sheep and occurs across large tracts of mountainous central and southern Asia. Various subspecies of argali are found across 11 central and southern Asian countries and is classified as 'Near Threatened' by the IUCN Red List (Reading et al. 2020) with their populations occurring in small and fragmented populations across their distribution range (Ekernas et al. 2016). Globally, argali populations are seeing a decreasing population trend, with a continuing decline in the population of mature individuals (Reading et al. 2020).

The Tibetan Argali *Ovis ammon hodgsoni* is found in parts of the Tibetan Plateau and its marginal mountains (Shackleton 1997). While this is a seemingly large area, its population is highly fragmented throughout this vast range (Fox et al. 1991; Schaller 1998; Namgail et al. 2009). Alongside, there is a great deal of uncertainty and varying reliability around numbers of Tibetan Argali (Reading et al. 2020). During an extensive survey of the Tibetan Plateau, argali were the least encountered wild ungulate (Schaller 1998). In India, the status of the Tibetan Argali is precarious. They are known to occur in the trans-Himalayan region of Sikkim and Ladakh, with sporadic sightings in Himachal Pradesh and Uttarakhand. Chanchani et al. (2010) estimated c. 177 individuals from Sikkim. Estimates from Ladakh have ranged from c. 200 individuals (Fox et al. 1999) to c. 360 individuals (Namgail et al. 2009). With c. 10,988 km^2 of potential Tibetan Argali habitat, Ladakh perhaps is the last remaining stronghold of argali in India (Chundawat & Qureshi 1999). Nonetheless, more recent surveys have found argali to be absent from large tracts of their potential habitat (Bhatnagar & Wangchuk 2001; Namgail et al. 2009).

Hunting for trophy and meat have been noted to contribute to a drastic decline of Tibetan Argali in Ladakh through the latter part of the 20th century (Ward 1924; Fox et al. 1991a; Namgail et al. 2004). Surveys by Namgail et al. (2009) suggested there was no substantial change in argali population in Ladakh since early 1980s, even though hunting of argali has been banned since then. The Tibetan Argali in fact are fully protected (Schedule 1) species under the Indian Wildlife Protection Act of 1972 and are also listed on Appendix 1 of CITES. Recovery of Tibetan Argali population in Ladakh might be hindered by exploitative and interference competition by livestock that is found throughout their presumed range, although more in-depth research is needed to determine this (Namgail et al. 2007).

Given this background, we compiled published data and gathered secondary information about the occurrence and abundance of argali in India. We then focused our work in Ladakh, as it is arguably the last remaining stronghold of Tibetan Argali in India (Namgail et al. 2007). Based on available literature from Ladakh and after consulting key-informants, we delimited two major populations of Tibetan Argali to estimate population density and population parameters using double observer surveys (Forsyth & Hickling 1997; Suryawanshi et al. 2012). The major goal of this work was to provide an update on the status of argali in India in order to inform regional and global assessment of conservation status of argali.

MATERIALS AND METHODS

Literature review

We conducted a scoping review of scientific literature on argali in India. Using structured search terms (India OR Ladakh OR Sikkim OR Himachal Pradesh OR Uttarakhand OR Himalaya*) AND (Argali OR "Ovis ammon") for abstracts, title or keywords. This was done to capture literature focused on argali in India. Searches were conducted in English only and were done in Web of Science (all findings) and Google Scholar (first 10 pages). Beyond this, additional searches were conducted by consulting the reference list of the literate from the structured search in November 2011. This also allowed us to capture potential multi-species study (e.g., Chanchani et al. 2010) that included argali. We used the flowchart provided in Haddaway et al. (2017) to organize our search. This included reading title and abstract of each publication, and if they didn't directly pertain to

argali research in India, then they were excluded from the review. Duplicates were removed as well.

Post this first round of screening, all the applicable publications were downloaded and read in full. Information including location of the study, year, publication type, and main theme of publication (see Table 1) were recorded. The literature review was conducted to construct a knowledge of base available for argali in India and identify key gaps.

Table 1. Major themes of publication.

Theme	Definition
Records	Only presence of argali from locations is reported
Ecology	Studies that investigate how argali interact with their surroundings
Conservation	Studies that explicitly investigate conservation threats to argali and their potential solutions. These studies can have policy relevance
Evolution/ Phylogenetic	Studies that relate to the evolutionary development and diversification of argali
Other	None of the above theme are directly applicable.

Field surveys, study area and data collection

In India, Tibetan Argali are known to occur primarily across the Changthang region of Ladakh (Namgail et al. 2009; Reading et al. 2020). This falls within the Leh district of the Union Territory of Ladakh. This area is an arid and cold high elevation desert with low rainfall and low primarily productivity (Chundawat & Rawat 1994). The vegetation of Ladakh is classified as 'Dry Alpine Scrub' (Champion & Seth 1968). Temperature can vary from summer highs of 30^{0}C to below -35^{0}C in the winters. This cold desert is characterized by dry plateau of rolling hills. Average elevation in Changthang is 4,500 m, ranging between 4,000–6,500. Apart from the Tibetan Argali, Changthang is home to sizeable population of other ungulates including Blue Sheep *Pseudois nayaur* and Tibetan Wild Ass *Equus kiang*. Beyond these, small groups of Tibetan Antelopes *Pantholops hodgsonii*, Tibetan Gazelle *Procapra picticaudata*, and Wild Yak *Bos grunniens* are also found in remote regions of Changthang. Main predators in this region are Tibetan Wolves *Canis lupus chanco*, Snow Leopard *Panthera uncia*, and Eurasian Lynx *Lynx lynx*.

These wildlife populations are spread across the landscape and not confined to protected areas. Albeit with low densities, human populations live in this low-productivity, highly seasonal landscapes. They have evolved a distinct lifestyle and culture, and have traditionally been pastoralists and agro-pastoralists. One of the mainstay of the local culture and economy is rearing of *Changra* goats that yield 'pashmina', i.e., cashmere (Singh et al. 2009).

We compiled published data and gather secondary information about the occurrence and abundance of argali across Ladakh (assisted by the literature review). To do the latter, we visited local herders in the Tsokar basin, Sumdoo TR, Korzok, Nyoma, Gya-Miru, Kharnak, Chumur, Hanle, Chushul, Tsaga, Man-Merak, Tangtse, Kuyul-Demchok, Tukla, and Himya and asked if they had seen Tibetan argali (locally known as 'Nyan' for males and 'Nyanmo' for females) in their vicinity in the past two years. The population in Hemis National Park is well documented in different studies and reports and hence we did not do secondary surveys in this region. A total of 30 key-informants were engaged (i.e., two key-informants per village). Alongside, we spoke to five knowledgeable wildlife protection department officials to gain further information. Given that argali are known to be migratory, information on potential migratory routes was noted in an attempt to delimit potentially separate populations.

Upon finishing the secondary surveys, the team identified two relatively large populations of Tibetan argali in Tsaba valley (within the Gya-Miru region) and around Mirpal Tso (near Chushul village). In March 2020, we used the mark-recapture theory based double-observer method (Forsyth & Hickling 1997; Suryawanshi et al. 2012) to survey both these areas. Individually identifying ungulates is challenging given their similarities in appearance across age and sexes. Nonetheless, ungulate groups can be identified due to peculiarities such as their size, age-sex composition and location; albeit temporarily. During the surveys the units being "marked" and "recaptured" are ungulate groups. This is done by two teams surveying for and enumerating animals either simultaneously or sequentially in the same area. They do so while strictly ensuring they don't influence each other on the animal detection. This method has been used to conduct reliable population estimation for several mountain ungulate species, including argali across central and southern Asia (Tumursukh et al. 2015; Chetri et al. 2017; Suryawanshi et al. 2020; Khanyari et al. 2021).

Both the survey area, Tsaba valley and Chushul-Mirpal Tso were further divided into smaller blocks that could be visually covered by a team of observers on a survey occasion. The terrain and logistics determined the shape and size of these survey blocks. Each block was surveyed keeping three assumptions in mind: 1) each block had entire visual coverage, 2) areas within blocks were surveyed independently by two teams

who were separated by time (15 minutes), 3) ungulate groups could be individually identified based on the age-sex composition of the herd, location and any other noticeable peculiarities. The data collected included group size and group detection/non-detection by each observer team. The 'mt' model with a uniform prior was fitted using the function BBRecap to estimate number of argali groups (Ĝ) in each site. "mt" is the standard temporal effect with no behavioral effect. Owing to the fact that these were first attempted double observer surveys in the sites, we used uninformed uniform priors. We carried out 10,000 mcmc iterations with 1,000 burn in.

In Tsaba valley, we covered 6 blocks along 62 km survey trails (31 km for each observer) while in Chushul-Mirpal Tso we six blocks along 51 km survey trails (25.5 km for each observer). In both sites, each team used a pair of binoculars to scan and classify ungulate groups. Topographic maps of the areas and local knowledge of herders and wildlife protection department officials was used to determine survey trails. To account for the effect of activity patterns (if any) on sightings of the study species, we started all surveys just post sunrise (Fattorini et al. 2019). Each team had one or two trained persons. Same number of observers per team per surveys was kept to standardize effort. Overall, six observers were involved in the surveys.

Data analysis

For the literature review and the secondary surveys in Ladakh, we used descriptive statistics to display the data. For the population estimation, we used the Bayesian framework in "BBRecapture" package to estimate total number of argali groups (Fegatelli & Tardella 2013; R Development Core Team Version 3.3.4 2020). Number of groups was the unit of analysis as recommended by Suryawanshi et al. (2012). A group was coded '11' if both teams observed it, '10' if only the first team observed it and '01' if only the second team observed it.

The detection probability for observer teams one and two was interpreted from the estimated detection probability by model 'mt' for occasion one and two. The total population (Nest) for each landscape was estimated as a product of the estimated number of groups (Ĝ) and the estimated mean group size (μ). In order to estimate the confidence intervals of the population using both the mean group size and estimated number of groups, we generated a distribution of estimated group size by bootstrapping 10,000 times with replacement. A distribution of estimated population (Nest) was generated by multiplying 10,000 random draws of estimated number of groups (Ĝ), weighted by the posterior probability and draws of mean group size (μ). The estimated population (Nest) was the median of the resultant distribution while the 2.5 and 97.5 percentiles were used as the confidence intervals.

Density was obtained by dividing the estimated abundance by the total area sampled, which was obtained by summing areas of all the surveyed blocks. We demarcated and obtained areas of blocks on Google Earth Pro post the survey. These included areas that were visible from the trails.

Additionally, we conducted 10,000 bootstraps to assess the 95% confidence intervals of the proportion of individuals of different age-sex classes (adult male, adult female, and young) using herd as the sampling unit. The median values were used as the estimates, while the 0.025 and 0.975 quartiles were used as 95% confidence intervals.

RESULTS

Literature review

We found 27 studies on Tibetan Argali in India. These included 19 peer-reviewed scientific papers, seven reports and one book chapter. Majority of the studies were conducted in Ladakh (n = 19), followed by Sikkim (n = 4), Himachal Pradesh (n = 2) and Uttarakhand (n = 1). Overall studies covered four major themes: records (n =

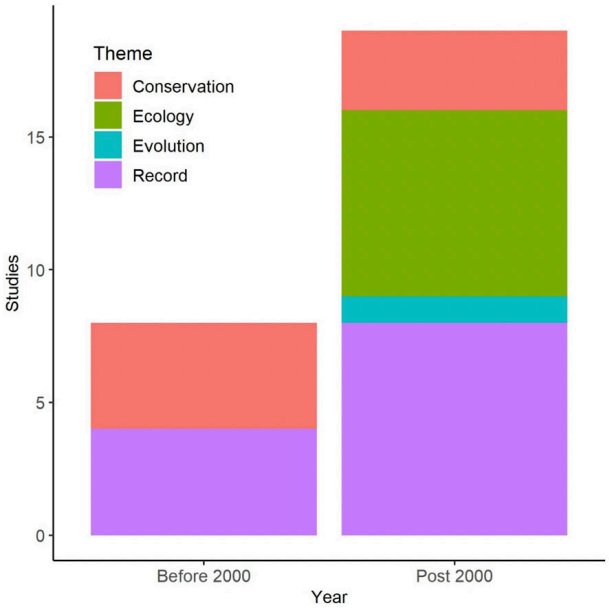

Figure 1. Stacked bar graph displaying split of research themes in publications before and post 2000.

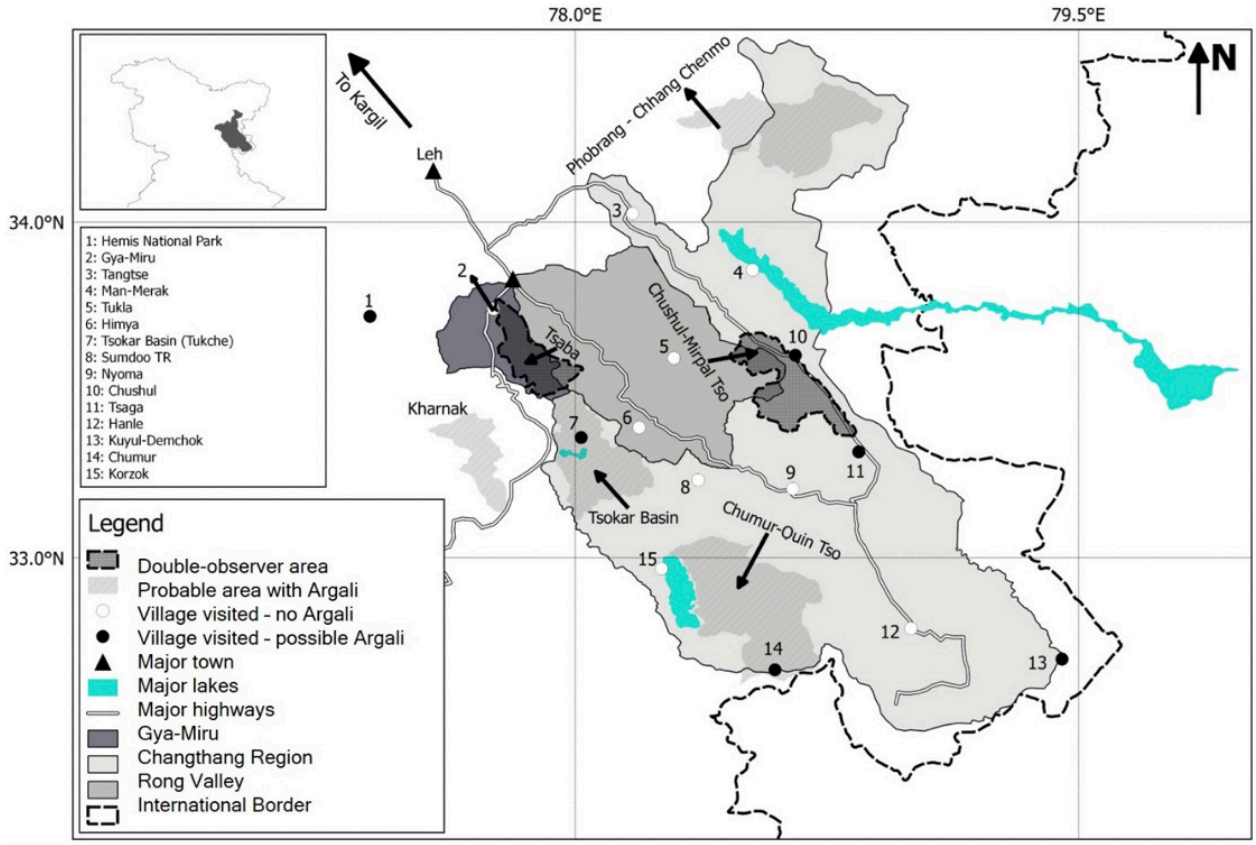

Figure 2. Map displaying the current distribution of Tibetan Argali within Ladakh. Probable areas were delimited by key-informants.

12), conservation (n = 7), ecology (n = 7), and evolution (n = 1). Interestingly, not only have the number of studies increased since 2000 (n = 19 compared to n = 8 before 2000), but researchers are also studying newer themes beyond just presenting records of Argali (Figure 1). Nonetheless, records have remained the major theme of study through time.

Tibetan Argali in Ladakh

Records of Tibetan argali in Ladakh based on compiling published data and secondary information are listed in Table 2 and displayed in figure 2. In Tsaba valley, the double-observer survey abundance of argali was 104 (98–123), whilst in Chushul-Mirpal Tso was 76 (57–148). The estimated density of argali in Tsaba was 0.34 argali km^{-2} (0.32–0.40) and in Chushul-Mirpal Tso was 0.15 argali km^{-2} (0.12–0.30) (Table 3 and Figure 3a). Table 3 summarises different parameters such as detection probabilities, estimated number of groups, mean group size, and age-sex ratios of each of the populations and species. The age-sex class proportion were comparable between Tsaba and Chushul-Mirpal Tso (Figure 3b).

DISCUSSION

India forms the edge of the distribution for the Tibetan Argali (Image 1) and often it is such at range extremities that local population decline, leading to local extinctions as populations become fragmented and disconnected (Boakes et al. 2017). Added to this is the fact that Tibetan argali is known to be found in fragmented and disconnected groups across its range in India (Namgail et al. 2009; Chanchani et al. 2010). This is similar to many other ungulate species from the Indian Himalaya like the Kashmir Red Deer (Hangul) *Cervus elaphus hangul* (Ahmed et al. 2009). Our study shows that limited research has been conducted on Tibetan Argali in India (n = 27 studies). This is perhaps similar for other sympatric Caprinae species in the region such as Ladakh Urial, *Ovis orientalis vignei* (e.g., Khara et al. 2020), highlighting the need for focussed research on mountain ungulates across the country and the larger central and southern Asian Mountain ecosystem. The total number of studies might be an underestimate considering our search didn't extend beyond the English language, and likely missed studies in grey literature that are often not easily

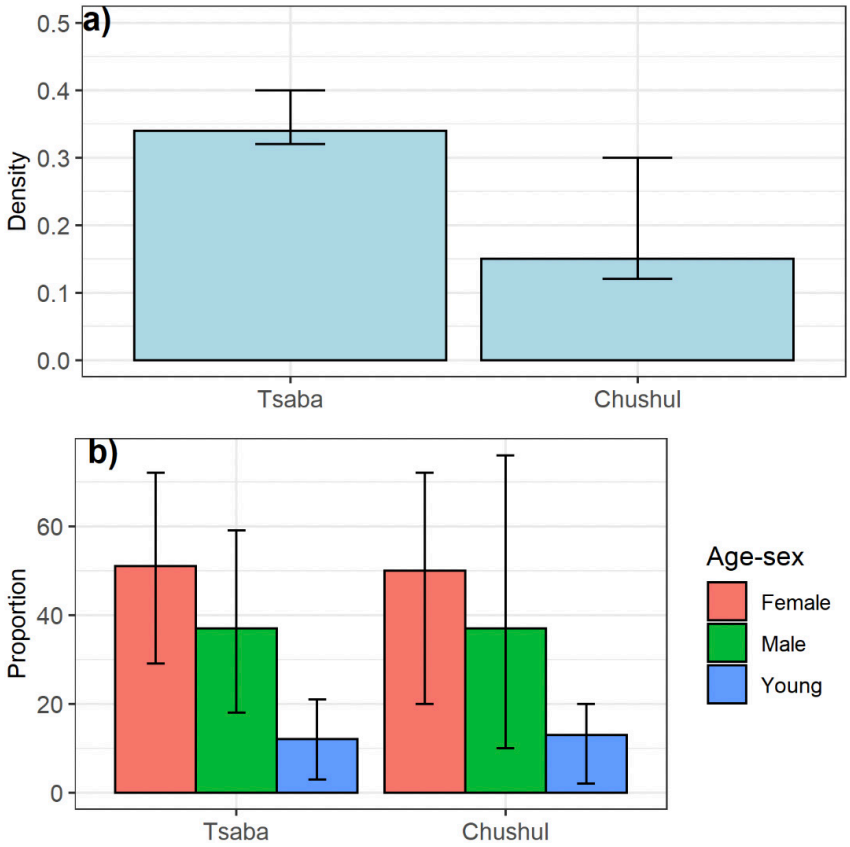

Figure 3. Panel graph showing a) density of argali and b) age-sex classes across Tsaba and Chushul. The estimated density of argali in Tsaba was 0.34 argali km^{-2} (0.32–0.40) and in Chushul-Mirpal Tso was 0.15 argali km^{-2} (0.12–0.30). The bars represent 95% confidence intervals.

Table 2. Records of Tibetan Argali in Ladakh.

Location	Occurrence and abundance*	Source of information	Notes
Hemis National Park	c. 20 argali	Namgail 2001	Interviews with wildlife protection department suggested this population persists and is likely to be resident. 3 adult males, 11 adult females, 1 yearling and 5 lambs
Gya-Miru region (Tsaba valley) and neighboring Tsokar basin	127 argali	Namgail et al. 2009	Survey area was 472 km^{-2} (0.3 argali km^{-2}) According to local knowledge this population of argali spend winter/ rutting in the Tsaba valley catchment (within Gya-Miru proposed Wildlife sanctuary) and migrate to the adjacent Tsokar Basin in the summer.
Kuyul-Demchok-Skagjung region	c. 30 argali near Demchok and Skagjung	Namgail et al. 2009, anecdotal observation of our field team and interviews with local herders.	Believed to be move between India and China. Anecdotal observation by our field team in November 2020 near Demchok (4 argali).
Phobrang- Chhang Chenmo	c. 100 argali	Namgail et al. 2009; Shawl et al. 2011 and our interviews	Interviews suggested argali are found in and around the Chhang Chhenmo valley throughout the year.
Quin Tso-Chumur	c. 10–15 argali	Namgail et al. 2009 and anecdotal sighting	At least 2 adult males, 3 adult females, 3 yearlings, 2 kids sighted in November 2020 Interviews with local herders confirmed atleast 30 Argalis in the area exhibiting movement between India and China.
Tsaga la region	Present	Interviews with local herders and confirmed by wildlife protection department.	Numbers are unknown but believed to be less than 20
Kharnak	c.75 argali	Interviews with local herders and anecdotal sights	2 groups of Argali were spotted by the field team. One of the groups had 29 argali (primarily consisting of females and yearlings) and 19 argali (primarily consisting of adult males). Herders in the valley confirmed that around 75 argali might inhabit this area and exhibit movement within the valley throughout the year.
Chushul – Mirpal Tso region	c. 70–100 argali	Interviews with local herders and confirmed by wildlife protection department and wildlife researchers	Local herders suggested that argali here move between Mirpal Tso region and Upper Yaya tso region depending on the season.

accessible through online web searches (Haddaway et al. 2017). Old hunting records (dating back to early 20th century) (e.g., Ward 1924) and government archives are potential repertoire of information on argali in India, albeit with varying difficulty in accessing its content. Nonetheless, it is encouraging to see increased research outputs post 2000, particularly covering various research themes. For effective conservation of argali to occur in India, it is critical to build a research base of robust and integrated information than helps conservationists not only understand the species better but also delimit conservation priorities and test their effectiveness (e.g., Williams et al. 2020).

Furthermore, our study provides an update on the status and distribution, along with providing robust population estimates and population parameters for two important populations of Tibetan Argali in Ladakh. While an in-depth and updated threat assessment is needed to understand contemporary threats to argali, our literature review highlighted majors conservation concerns to be: transboundary concerns (lack of coordinated conservation across the international border), and anthropogenic disturbances (competition and disturbance from livestock grazing and habitat loss) as the main threats to this region's argali populations. Based on our surveys and the secondary information collected, we estimate that the Tibetan argali population in Ladakh to be slightly higher than 300–360 as reported by Namgail et al. (2009). The bulk of the argali population seems to be present in the Tsaba-Tsokar, Chushul-Mirpal Tso, Phobrang-Chhang Chenmo, and Kharnak populations, although more research is needed to understand potential seasonal movement of argali to better delimit geographically separate populations. While there are signs of some increase in numbers (e.g., Namgail et al. 2009 report around 10–20 argali from Kharnak while our surveys suggest c. 75 argalis), there seems to be no substantial change in the population of argali in Ladakh since the late 1980s.

Nevertheless, several challenges remain while studying and attempting to conserve argali populations in Ladakh an India at large. For instance, due to their proximity to the Indo-Sino border, areas supporting population like the Phobrang-Chhang Chenmmo, Quin Tso-Chumur, and Chushul-Mirpal Tso often have restricted access. This is also true for the Tso Lhamo population in Sikkim (Chanchani et al. 2010). Volatility along the borders renders these population particularly vulnerable from a conservation point of view (Mendiratta et al. 2021). Additionally, due to its vast territory, the areas home to the Kharnak population proves to be a logistic challenge to survey; especially as large area remain inaccessible for nearly six months of including and either side of winter. As most of the migrating population of argali share pastures seasonally with various transhumance pastoral communities that have their social, cultural and political differences (Singh et al. 2013), conducting meaningful stakeholder meetings to then have effective on-ground action remains a huge challenge (Allen & Singh 2016).

Even though there has been a ban on hunting of Argali since the 1980s, Ladakh has seen substantial levels of socio-economic changes primarily due to expansion of defense, tourism and development infrastructure (Bhatnagar et al. 2006; Dollfus 2012). There is a possibility that these activities are limiting argali population recovery by negatively influencing habitat use. Alongside, the role of exploitative and interference competition from livestock grazing and collateral activities in hindering recovery of argali

Table 3. Information about Tibetan Argali populations in Tsaba Valley and Mirpal Tso-Chushul landscapes, Ladakh, India.

	Tsaba Valley	Chushul-Mirpal Tso
Area (km^2)	306	497
Minimum count (Obs 1 & 2 combined)	98	57
Estimated Population (95% CI)	104 (98–123)	76 (57–148)
Density	0.34 (0.32–0.40)	0.15 (0.12–0.30)
P1	0.74	0.60
P2	0.79	0.53
Obs 1 Total	89	47
Obs 1 group	13	7
Obs 2 Total	89	32
Obs 2 group	14	6
Common Groups	11	4
Total Groups	17	9
Range of Group Sizes	3–15	5–12
Mean Group Size	6.1	6.3
Prop Male	0.37 (0.18–0.59)	0.37 (0.10–0.76)
Prop Female	0.51 (0.29–0.72)	0.50 (0.20–0.72)
Prop Young	0.12 (0.03–0.21)	0.13 (0.02–0.20)
M:F	0.72	0.74
Y:F	0.24	0.26

Note table 2: detection probabilities (P1 = first observer; P2 = second observer), individual ungulates seen by each observer (Obs 1 total and Obs 2 total), Individual number of groups seen by each observer (Obs 1 groups and Obs 2 groups), number of groups seen by both, i.e. recaptures (Common groups), mean group size, proportion of male, female, and young with 95% confidence intervals. M:F and Y:F displays the male to female ratio and the young to female ratio respectively using the estimated proportional values for each age-sex class.

Image 1. Tibetan Argali *Ovis ammon hodgsoni*. © Rigzen Dorjay.

populations needs more research (Namgail et al. 2007; Butt & Turner 2012).

Therein is an urgent need to consider Tibetan argali as a priority species for conservation in India. As a first step towards that, we set robust population baselines for two remaining strongholds of argali populations in Tsaba and Chushul-Mirpal Tso. While we intended to do so, robust on ground surveys were not possible in Kharnak and Phobrang-Chhang Chenmo due to logistical and COVID-19 related constraints. Robust population estimates over time help in determining population trends (Mihoub et al. 2017). Conservation status assessment of any species requires rigorous monitoring of their abundances (Lindenmayer et al. 2013). An initial population reference can aid in framing conservation objectives by helping assess feasibility, concentrate effort, and define time period within which progress can be evaluated (Bull et al. 2014).

Our estimated argali densities for Tsaba and Chushul-Mirpal Tso are lower than many other sites across argali's central Asia range known to harbor good argali population (e.g., Wingard et al. 2011; Khanyari et al. 2021), while being comparable to estimates presented by Tumursukh et al. (2015) from the Tost mountains, in Mongolia. A factor driving lower densities of argali from our sites might be the clustering of groups within the study sites, driven primarily by forage availability, competition with sympatric livestock and wild ungulates and species natural history. This merits further research.

Additionally, both our argali populations were female-biased, like most mountain ungulate populations (Berger & Gompper 1999). Not only are males disproportionately predated upon, but in polygynous mating species like argali, males expend higher costs than females during rut which can lead to reduced mating male survival. This can be exacerbated in resource limited systems (Berger & Gompper 1999; Toigo & Gaillard 2003). Alongside, factors such as selective hunting of prime-aged males for trophy hunting or through poaching can further aggravate the female-bias. We also find low young to female ratio for both sites (Table 3). Ekernas et al. (2016) suggest that argali populations with young to female ratios <0.5 are potentially declining. Our surveys were conducted in March. To better understand the dynamics of this population, it would be important to conduct the surveys in summer, soon after the birth season.

Finally, it would be useful to update the conservation status of argali, not only throughout their range, but particularly Tibetan Argali in neighboring regions such as China and Nepal to get a an overall status in the region. Kusi et al. (2019) compiled historical data and their own observation data to discuss the present distribution of Tibetan Argali in Nepal. They also recommend management of livestock numbers, promotion of traditional grazing practices and raising conservation awareness as long-term conservation strategies for the species. The Tibetan plateau houses the largest known Tibetan Argali population, numbering into a few thousands. However they have seen recent declines primarily due to habitat loss and hunting (Harris 2010). Schaller (1998) provides a good overview of historic records, and although some early explorers seemed to find them common, most reported them as rare. Contemporary Chinese policy aims to conserve argali using two main strategies—nature reserves and international hunting areas (Harris 2010). Given the proximity of the India, Nepalese and Chinese population to their respective country borders, it is important to consider a transboundary strategy to conserve them.

CONCLUSION

Across India and larger central and southern Asian mountain ecosystem, it is important that more research is conducted on various conservation aspects concerning the Tibetan Argali and other Caprinae species. Specifically, in Ladakh, we recommend that continual monitoring of the Tsaba and Chushul-Mirpal Tso populations are done. Alongside continually monitoring these populations, in-depth threat assessment and stakeholder engagement, especially with the agro-pastoral communities that share their pastures with argali, is needed to delimit both contextually-appropriate and effective conservation interventions for argali in India.

Research ethics/best practice statement

Research conducted complied with the laws and regulation of India (Union Territory of Ladakh) where the study was performed. The required permission was obtained from the Ladakh Wildlife Protection Department. For the primary survey, none of the procedures performed involved any animal handling and were in accordance with the 1964 Helsinki declaration and its later amendments. For the secondary surveys, were made sure to obtain oral consent for all respondents – written consent was not possible as many respondents were not literate. We ensured all information provided by informants was anonymized and interviews were not conducted if the respondent did not feel comfortable. Interviews with individuals were only conducted after taking permission from village elders and the village headman. Ethics clearance was obtained from the research ethics committee from the University of Bristol.

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