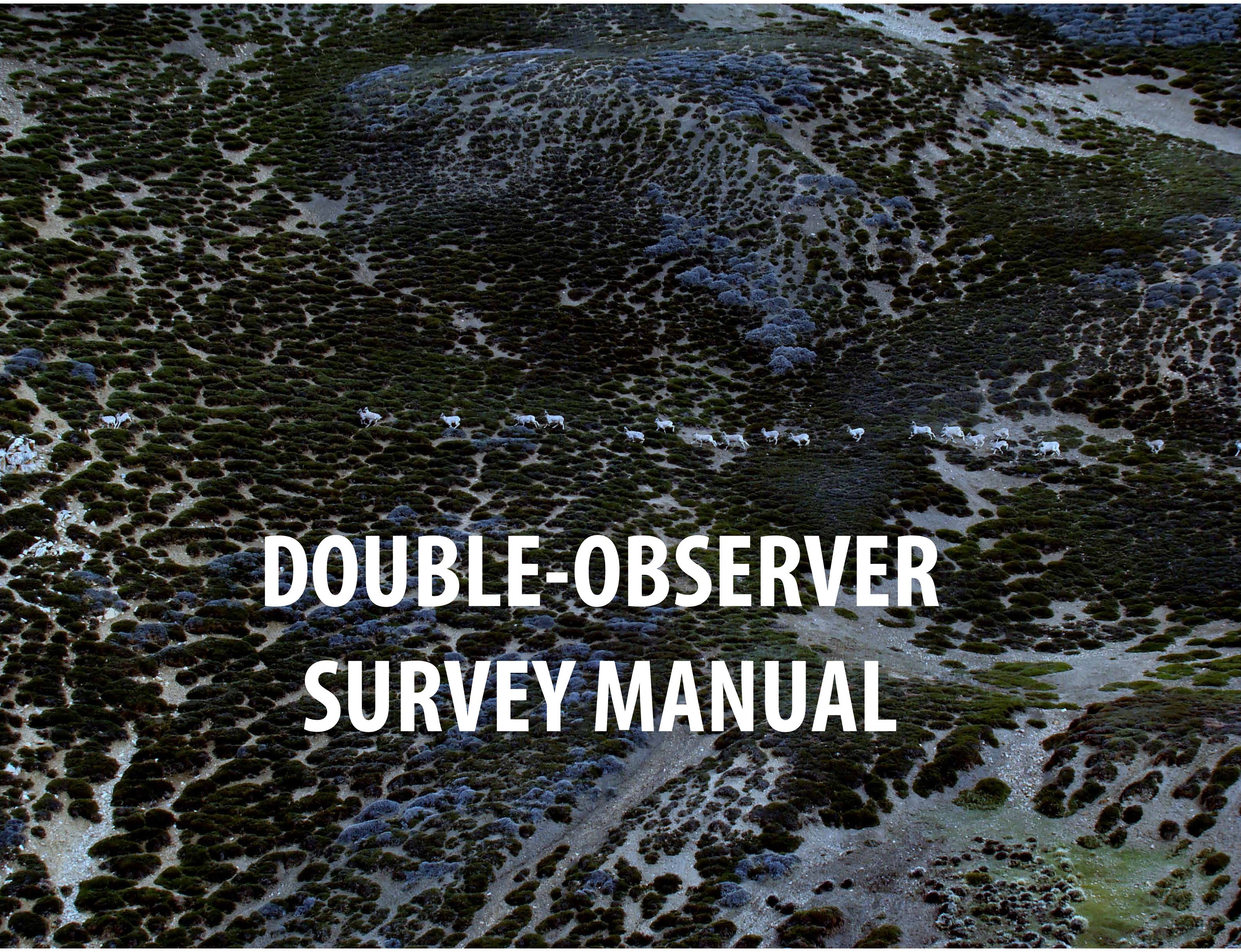

DOUBLE-OBSERVER SURVEY MANUAL

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Cover photo: Kulbhushansingh Suryawanshi

CONTENT

INTRODUCTION

This document provides guidance on how to plan, implement and analyse double observer surveys to estimate ungulate population abundance in mountainous terrain. Such population estimates are useful for the long-term monitoring of ungulate species. This document represents work in progress and will be regularly updated to take into account methodological advances and user comments. Please visit the online GitHub repository (https://github.com/kulbhushansinghs/Mountain-Ungulate-Double-Observer-Survey) for updated versions.

WHY MONITOR WILD UNGULATES?

Ungulates play a crucial role in maintaining ecosystems by influencing vegetation structure, plant species composition and nutrient cycling (Bagchi and Ritchie 2010). Wild ungulate prey availability is one of the most important determinants of large carnivore density (Karanth et al., 2004). The population of the rare snow leopard (Panthera uncia) is directly impacted by their mountain ungulate prey, even in livestock dominated systems (Johansson et al., 2015; Suryawanshi et al., 2017). Considering this, maintaining and monitoring ungulates populations are important objectives of conservation management.

Continual monitoring of a species helps assess its population status, can direct conservation action, and help evaluate effects of management actions. Data gained from such monitoring efforts helps establish baseline information that's often missing. This not only helps quantify changes in population over time, but also aids in framing conservation objectives, assess their feasibility, concentrate efforts, and define a time-period within which progress can be evaluated (Bull et al., 2014).

Beyond its direct benefits to conservation, continual monitoring can also help answer complex ecological questions related to the ecology of specific species.

METHODS FOR MONITORING

Several methods exist for monitoring ungulate and large herbivore populations. They include distance sampling using line transects or point counts (Burnham et al., 1980), strip transect (Eberhardt, 1978), track count (Sulkava and Luikko. 2007), and dung count (Laing et al., 2003). Most conventional monitoring methods remain challenging to implement robustly in mountainous areas and perform unsteadily with varying field conditions, (Singh and Milner-Gulland, 2011).

In mountainous terrain, logistical constraints are particularly important determinants of monitoring outcomes. Most mountain species are rare, occur in low densities with varying population sizes and may undertake altitudinal migrations. Almost always, mountain species are distributed non-randomly in the landscape. Additionally, high-altitude environments can be physically challenging, have unpredictable weather conditions and involve deceptive distances; adding to the complexity of monitoring. This is particularly the case during the birthing period (late spring), when females tend to conceal themselves (Singh & Milner-Gulland, 2011). These are some of the issues that need to be taken into account to ensure robust population monitoring of mountain ungulates.

Field challenges and logistic difficulty makes it very hard to conduct robust population assessments of mountain ungulates using methods such as distance sampling or dung count without violating their fundamental assumptions. For instance, distance sampling has been one of the most popular methods for assessing the density of large herbivores in tropical and temperate forests (Buckland et al. 2001). However, this method is subject to many assumptions that are hard to meet in mountainous landscapes (Singh & Milner-Gulland 2010): Accurate distance measures cannot readily be made as landscape features are rarely linear and sightings can be several kilometres away - undermining computing detection probabilities. Wingard et al. (2011) found distance sampling to be imprecise in estimating densities of argali *Ovis ammon* even in relatively accessible mountainous terrain in South-west Mongolia. They also discuss the difficulty in randomly sampling ungulates in mountain environments, accounting for their evasive movement and precisely recording perpendicular distances in mountainous terrain. On the other hand, Reading et al. (1997) successfully used distance sampling through aerial surveys to estimate density of argali in the Gobi Desert of Mongolia. However, the use of aerial surveys is expensive and sometimes dangerous in mountainous areas (Singh and Milner- Gulland 2010).

THE DOUBLE-OBSERVER SURVEY

The double-observer survey method is based on the principles of mark-recapture theory (Forsyth and Hickling 1997).

Broadly, the method involves **two observers** searching for and counting animals simultaneously, while ensuring they do not cue each other on the locations of the animals. Essentially, the two observers are conducting the survey as independent surveyors.

Its basic underlying idea is that while most mountain ungulates cannot be identified individually; groups can be identified due to characteristics such as group size, age-sex classification of the individual members in the group and the location of the group. Hence, an individual group of ungulates becomes the unit that is being "marked" and "recaptured" in double-observer technique.

The double-observer technique for population estimation was originally developed to estimate detection probabilities for aerial surveys of various taxonomic groups (Caughley 1974; Cook and Jacobson 1979; Graham and Bell 1989). Magnusson et al. (1978) modified the original equation proposed by Caughley (1974) to allow for differences between the two observers' ability to detect the target species. Forsyth and Hickling (1997) made an important contribution to the population estimation literature by applying the double-observer approach for estimating the abundance of Himalayan Tahr (*Hemitragus jemlahicus*) in New Zealand. Nonetheless, some aspects of this technique's applicability to mountain ungulates and associated assumptions remained untested. Suryawanshi et al. (2012) used field data and computer simulations to assess the general suitability and applicability of this technique for monitoring Central and South Asian mountain ungulates. Suryawanshi et al. (2012) then tested critical assumptions of the technique, modified and applied it to a problem situation and finally conducted an analysis to estimate its ability to detect actual population change. Their results confirmed the applicability of this method for monitoring mountain ungulates across the Central and South Asian mountains (see Suryawanshi et al. 2012).

The model is based on a set of basic ASSUMPTIONS:

1. Ungulate groups can be individually identified
2. Each observer has visual coverage of the entire survey area
3. Observations by Observer 1 and Observer 2 are independent of each other.

To meet the three key assumptions, the following conditions must be considered

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Key points to keep in mind for assumption 1: *Ungulate groups can be individually identified*

a) The observers should collect as much information as possible on the sightings of ungulate groups to be able to identify individual herds of ungulates based on age-sex composition of the herd, its location, and any other specifics that the observers can note (e.g., time of sighting; noticeable individual in the herd, e.g. the presence of an individual with only one horn).

b) This information helps identify individual groups. At the end of a day's survey, the two observers should reconcile collected information and assess if they have observed the same group or two different groups.

c) Uniquely identifying groups avoids double counting. Remember: it is the ungulate groups that are being recaptured in double-observer; NOT the individual ungulates. It is important to reconcile data within and between groups of observers to ensure that groups that moving between survey units aren't counted twice.

Key points to keep in mind for assumption 2: *Each observer has visual coverage of the entire survey area*

a) To ensure that the entire study area is surveyed, it should be further divided into survey units (blocks) of c. 20-30km^2 (depending on the landscape) which are small enough that the study species cannot spend an entire day in them and not be seen. Surveying the entire study area should be completed over a short period of time (suggested at a maximum 10 days).

b) This reduces the chances of animals moving in and out the study area or from one survey unit (block) into another between survey days.

Key points to keep in mind for assumption 3: *Observations by Observer 1 and Observer 2 are independent of each other*

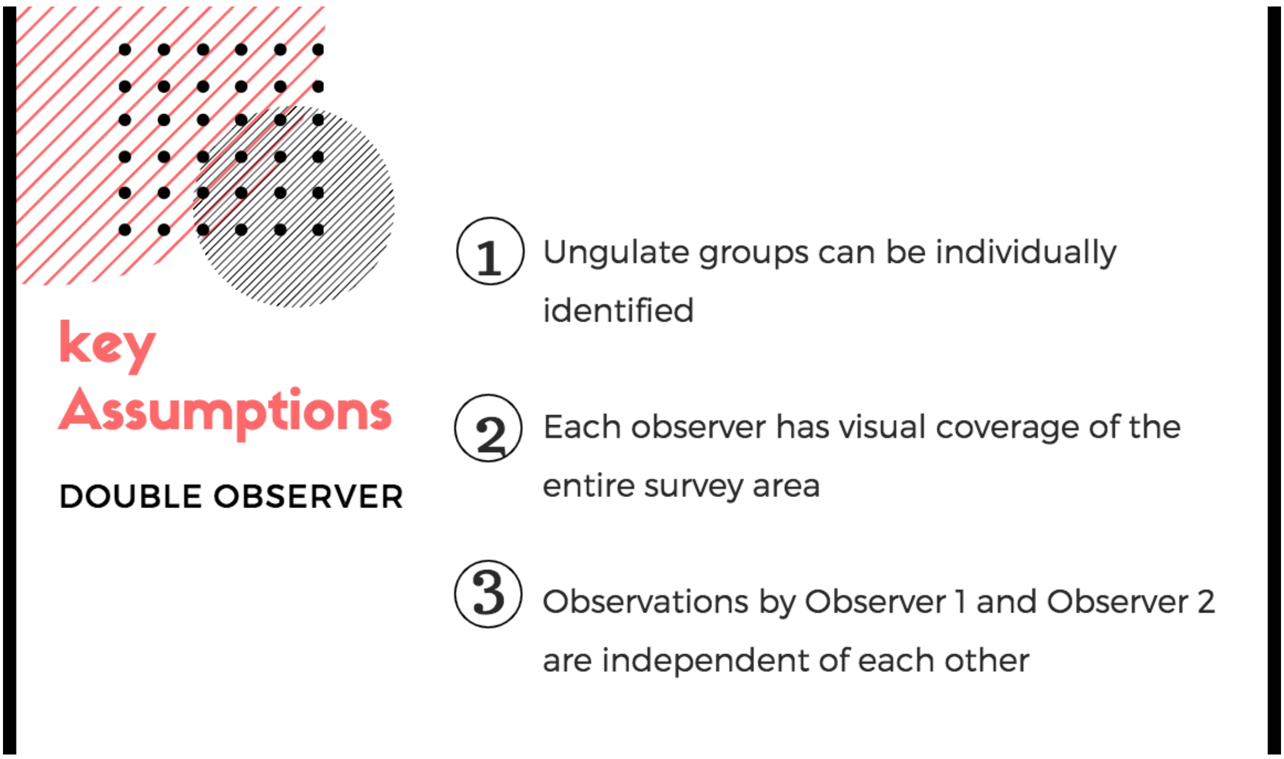
Two individual observers should survey each block independently. Generally, the first observer can start surveying 15-30 minutes before the second observer. Neither surveyor should cue the other on the ungulate sightings.

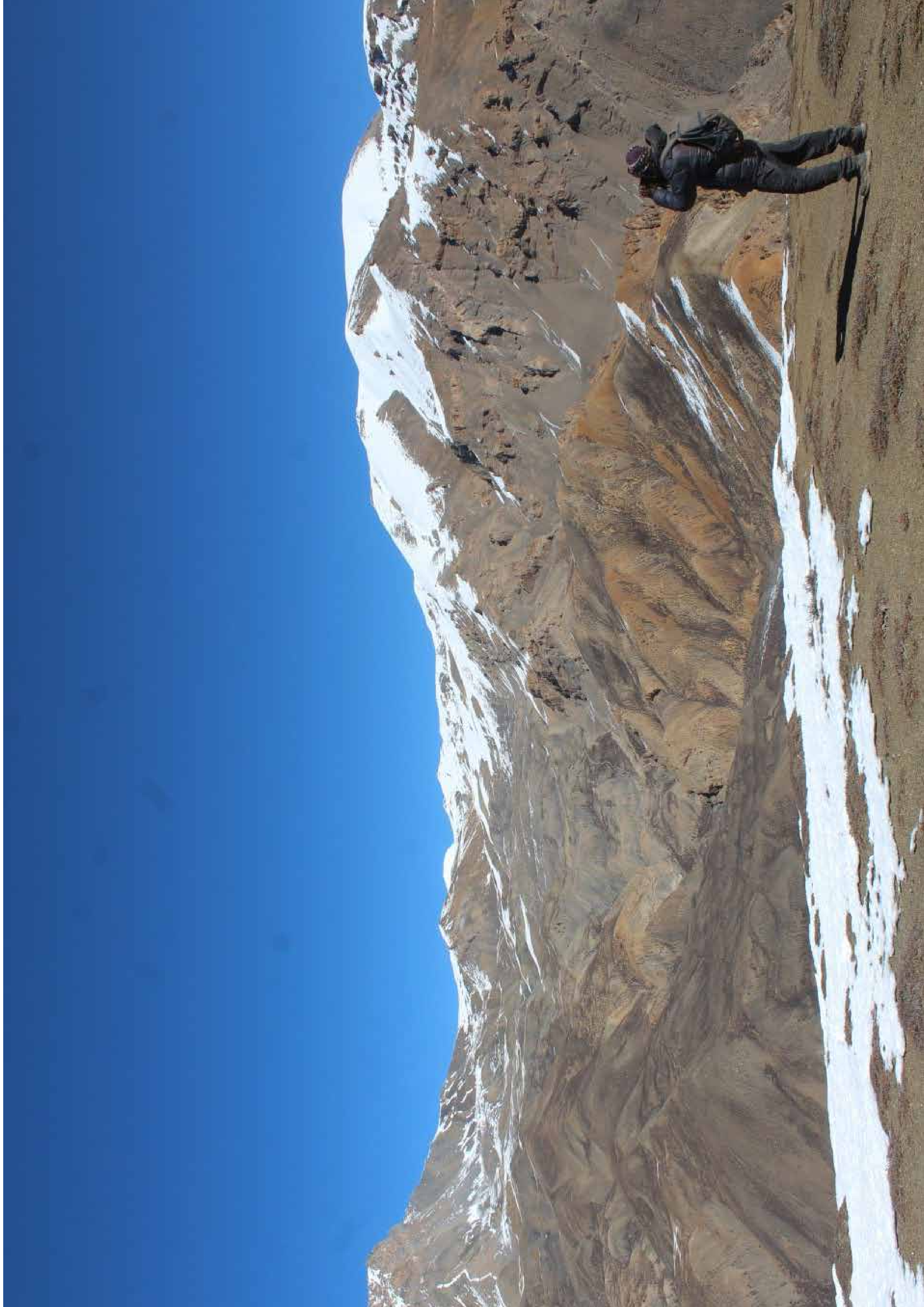
All blocks within a study area must be surveyed by both observers.

Depending on the landscape and the species being surveyed, the presence of observer 1 may result in evasive behaviour of the species, which will impact the detections of observer 2. In this case, the time separation between observers can be minimized and/or survey can be started simultaneously from two ends of the transects. A transect is the path chosen by the observer to survey their block. These can be pre-existing trails or an artefact of the observer's choice.

This is done so that both surveys represent simple random samples of the entire population.

Figure 1. Assumptions of Double-Observer Survey





PLANNING YOUR SURVEY

SURVEY TEAM SIZE

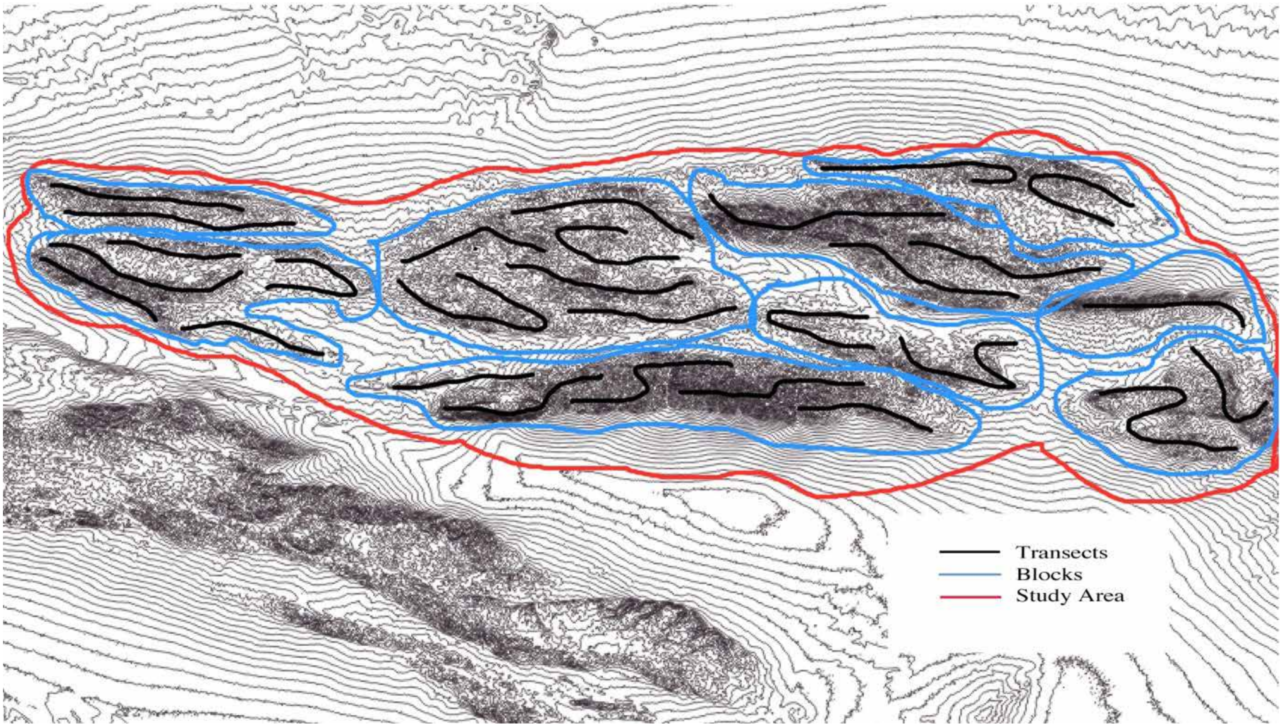
Ideally, six to eight trained observers are required for each survey. They will work simultaneously in the landscape.

HOW TO DELIMIT A STUDY AREA?

The **study area** should be delimited with landscape features and geographical barriers (eg. river valleys; ridgelines) in mind. Each study area is delimited with the idea that it is large enough to contain one or more population of our ungulate of interest.

Once delimited, the **study area** is first divided into defined **"blocks"** or survey units. Each is roughly 20-30 km^2 in size to allow for ease for survey. This allows each **block** to be surveyed within one day (Figure 2). Second, we identify the survey routes, called **"transects"** the observers follow within each **block**.

Figure 2: Delimit a Study Area into three levels; Study Area (red line), Blocks (blue line) and Transects (black line). Study Area size = large enough to support one or more populations of ungulates; Block size = c. 20-30 km^2; Transect = c.5-10 km.



The **blocks** are generally delimited prior to the field survey using geographic features such as valleys or ridgelines. Local knowledge on constraints of survey (for example accessibility) on maps should also be taken into consideration. However, it is recommended that a recce survey be conducted on the ground to plan the actual survey. It is critical that **blocks** be selected such that there is minimum movement of groups of ungulates between **blocks** during the survey period. Thus, natural geographic units such as individual mountain clumps, separated by secondary valleys (off the main river valley for instance), can be delineated as **blocks.**

Multiple **transects**, along which observers search for ungulates, are then defined within each block. Unless it is logistically impossible, ridgelines or valleys are generally preferred transects as they provide the best views. For ease, **transects** can follow the topography of the landscape and do not have to be straight lines. It is important however that the **transects** meet Assumption 2 by ensuring that the visual coverage of the area surveyed is maximized.

While starting a **transect** within a **block**, especially in new areas, it is important that the observer pair communicate with each other about logistics of the survey. They may e.g. break the **transect** into sections that are surveyed independently, with the pair meeting each other intermittently to ensure safety. If this is done, it is critical that surveyors don't discuss or cue each other to the ungulate sightings.

Each day, it is good practice to survey 3-4 adjacent **blocks** within the study area simultaneously, assigning one team of two observers to each **block** (if possible given the number of available observers and the landscape). This helps ensure that any movement of groups of ungulates between blocks is noted and accounted for at the end of the survey.

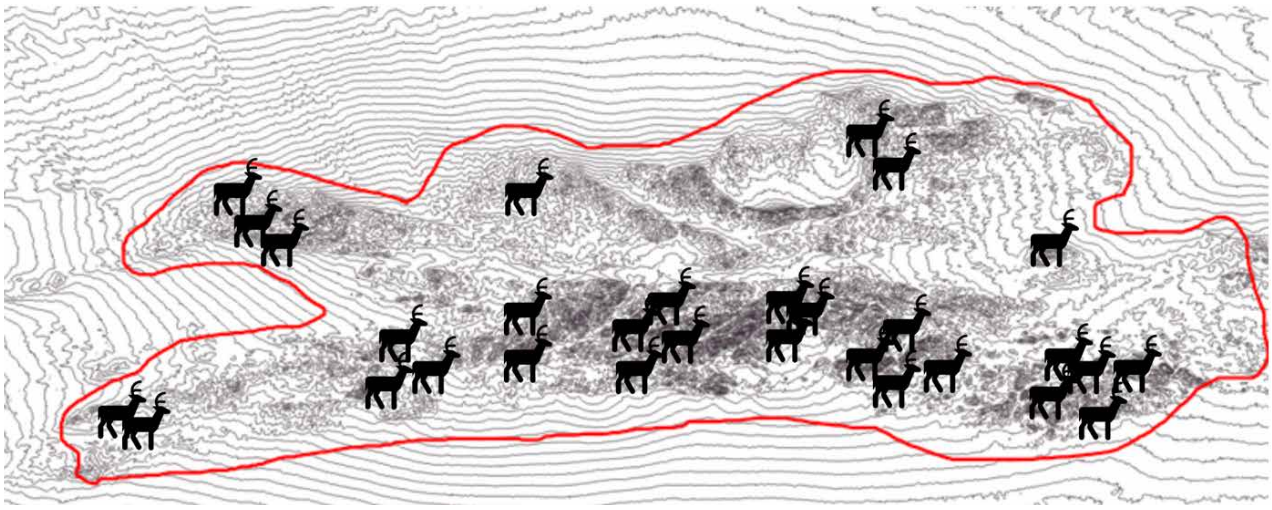
EXAMPLE FROM ALTAI MOUNTAINS 1 (TOST)

Step 1: Identify the **Study Area.**

Ask yourself: what is the target population for your survey? In Tost, Mongolia, there are two horizontal mountain chains running West-East on either side of our basecamp that we have chosen as area of interest. This is also the area where we place our camera traps for snow leopards. It is essential to note that mountain ungulates (Ibex and Argali in these areas) have a clumped distribution, as seen by Figure 3 (especially in the winter), hence it is necessary to cover the entire available habitat . This ensures that we don't underestimate the population numbers.

Note that in Tost, our total survey area (Figure 3) includes parts of the landscape that are not mountain ungulate habitat. This is because Tost is a Nature Reserve, and our survey needed to cover the entire reserve area. You may encounter similar situations, where the delimitation of your survey area has to take political or other non-ecological aspects into account. In this case, as we did in Tost, it's best practice to maximize the survey efforts in all potential habitats (mountain areas), while non-habitat areas may be part of the total study area, but will not be surveyed.

Figure 3: Identifying the Study Area of Tost. Ibex are likely to be distributed in a clump distribution.



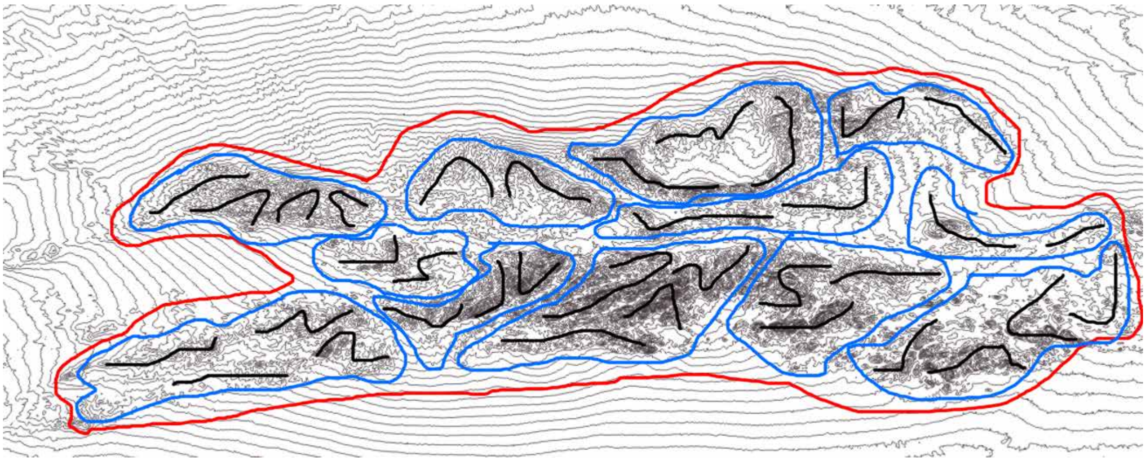
Step 2: Identify the survey **Block.**

After defining your study area, demarcate blocks (each roughly 20-30 km^2), seen in blue in Figure 4. Each block is demarcated keeping in mind assumptions of the double-observer method as stated above. Remember the aim is to survey each block within 1 day and to complete the entire survey within no more than 10 days (to meet Assumption 2).

Step 3: Identify the survey **Transects.**

Once the blocks are identified it is good practice to map out possible transects in order to ensure full coverage of blocks. Figure 4 illustrates possible transects (in black) that the two observers can take to cover their respective blocks. It is important to note here that as long as visual coverage of the entire block is achieved by walking these transects, there is no need to walk to each corner of the block. Transects are the best to survey blocks. They are better than e.g. single high elevation points as they ensure larger visual coverage.

Figure 4: Identifying the blocks and transects of Tost. Blocks are each 20-30 km² and surveyed within one day. Transects ensure the full coverage of the area.



EXAMPLE FROM ALTAI MOUNTAINS 2 (NOYON)

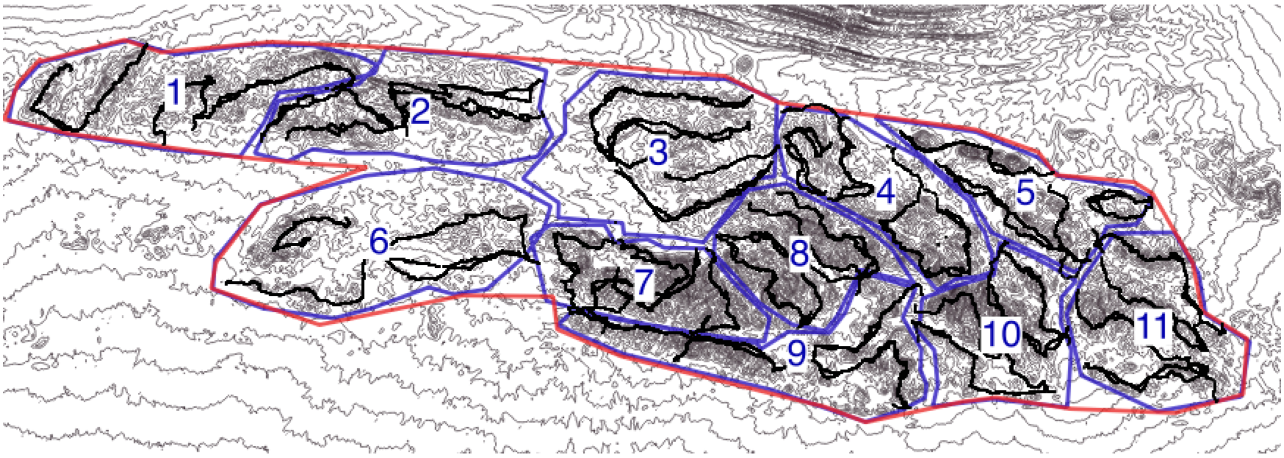


Figure 5. A contour map of Noyon with blocks (blue) and transects (black). The rationale behind choosing this as the survey area is similar to the one for Tost as seen previously

Figure 5 shows the survey transects within each block identified in the survey area. One good practice is to survey 3-4 adjacent blocks on a given day. For instance, with a team of 8 people (i.e. 4 survey teams) if logistics permit, one could do blocks no. 1, 2, 6, and 3 on day 1, then 7, 8, 4, and 9 on day 2 and 5, 10, 11 on day 3. Alternatively, one could do blocks 1, 2, 3, 4 on day 1, then 5, 11, 10, 8 on day 2, and 9, 7, 6 on day 3. These are just two of many choices one could make. These choices would need to be taken on the ground, depending on prior knowledge of species distribution and movement, topography and logistics of getting around.

EXAMPLE FROM HIMALAYA (SPITI)

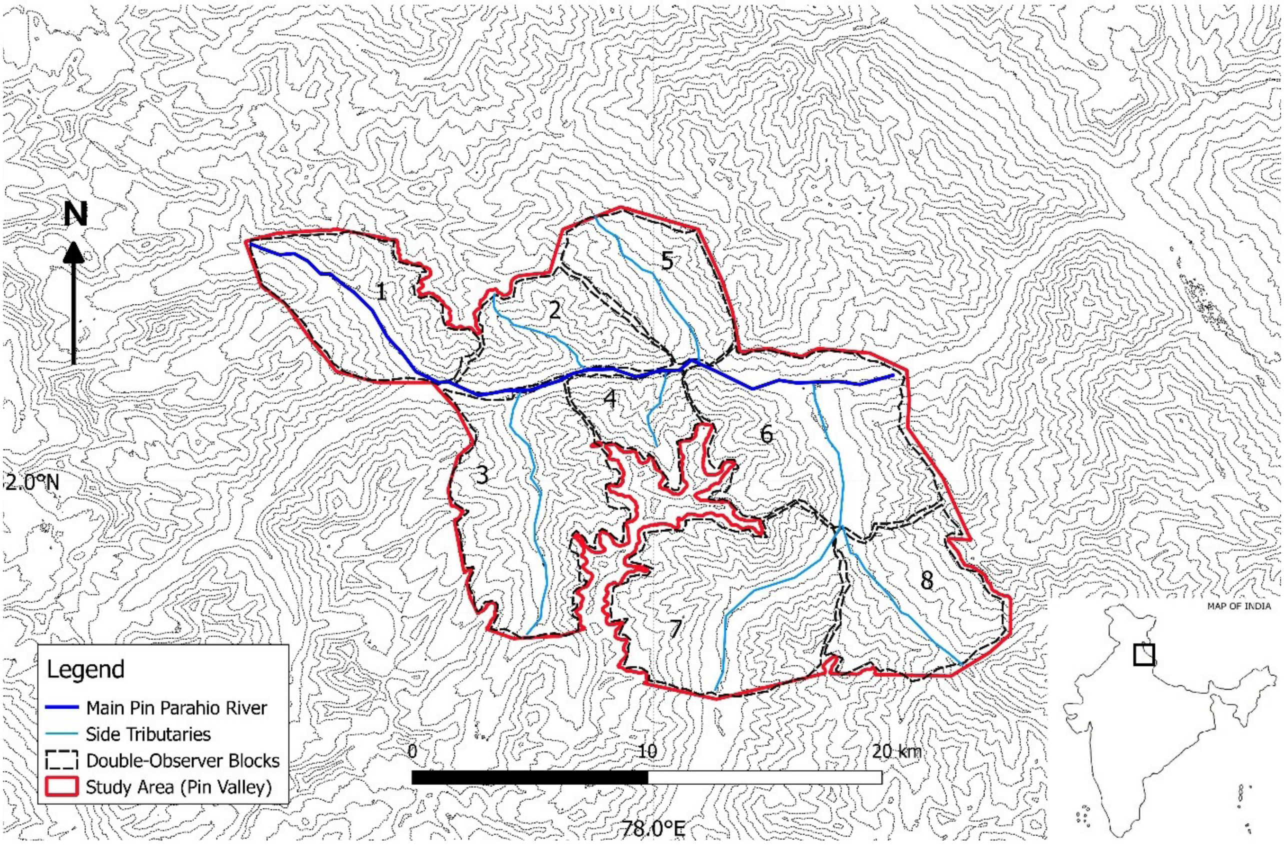


Figure 6. Map showing the survey area in Pin Valley, India. As can be seen from the contours, the valleys become higher and steeper (hence less accessible) away from the main river and its tributaries.

Step 1: Identify the **Study Area.**

As seen in the above map, in Pin Valley, our survey area is the main Pin valley drained by the Pin Parahio River (full line in black). The Pin Valley is a well-defined system as the boundary is surrounded nearly on all sides by high elevation passes and glaciers which are 4500 m and higher, creating a clear border for the Asiatic ibex habitat (the sole mountain ungulate found here).

Step 2: Identify the survey **Blocks.**

After defining your study area, demarcate blocks keeping the assumptions of the method in mind. In this particular case, as we are surveying a water shed, the tributaries (dotted black) forking off the main Pin Parahio river form neat blocks (side valleys), each of about 30 km^2 to survey. The numbers given to blocks above in ascending order

(Figure 6) are one example of the sequence in which each block is surveyed. It is critical to note from the map that a large part of each demarcated block is high and steep (largely inaccessible). This is area > 4,500 m, generally inaccessible glaciers or mountain passes. These are an integral part of the landscape, so even though observers can't physically get into these areas, they are still surveyed by strategically placing transects to allow for visual coverage.

Step 3: Identify the survey **Transects.**

In the case of Pin valley and most Ibex habitats, the valleys, especially the relatively smaller side valleys, are really rugged and steep. This makes walking up to ridgelines and the top of valleys (normally considered good places to conduct the survey due to their enhanced visual coverage) dangerous and often unachievable. Therefore, we walk alongside the river (often upstream), observing both sides of the valley. The transects roughly follow the path of the side tributaries in each block.

CONDUCTING SURVEYS

STEP 1: FIELD SURVEY

The field double-observer survey needs to be done with the three key assumptions of the method in mind for it to provide us with robust ungulate population estimates. Two observers will walk the **SAME** transect, search for and count animals simultaneously (with a 15-30 minutes gap). To meet Assumption 1, it is important that the observers do not cue each other on the locations of the animals. The two should **NEVER** communicate their observations or cue each other about observations. Depending on the terrain, safety, knowledge, and experience of the observers, a 15-30 minute gap should be maintained between them while walking a transect. In some conditions, it might be safer to ensure that the 1st observer remains in sight of the 2nd observer at all times. However, caution needs to be taken in this instance so that observer 2 doesn't get cues from observer 1's behaviour (such as greater interest in a particular direction).

STEP 2: WHAT DATA TO COLLECT

Each time an Observer sights an animal of interest (e.g. ibex, blue sheep) they should record the following:

- GPS location of observer during sighting (Long and Lat)
- Species observed
- Age and Sex category of individuals observed: Young, Kid, Male Class 1, Male Class 2, Male Class 3, Male Class 4, Adult Female, Unclassified
- Behaviour: eg. Individuals moving south towards valley, individuals grazing on west slope.
- Location specific information: mountain name, sighting along ridge.
- Unusual features of individuals: missing or broken horns.

Please see Appendix 2 for an example of a field data collection sheet.

TIPS FOR AN EFFICIENT SURVEY

- Walk slowly and keep looking out for movement.
- Every 100m-200m, scan all sides with your binoculars. While scanning, take a section of the mountain and first scan it slowly from the left to the right and then do the same section from up to down to ensure effective scanning.
- Choose your route wisely. It isn't necessary that all blocks to be surveyed with two observers walking the transect in the same manner. Contingent on topography, behaviour of the animals (they might be very skittish for instances) the pair can have different tactics. For instance, one observer can start the survey from one side of the valley (for example the north) and the other observer can start the survey from the other side of the valley (for example the south) and they cross each other on the way to their respective ends. This is especially effective in dealing with skittish animals.
- For effective use of the method, adapting to the situation on the ground and incorporating local solutions and innovations is usually needed. Just remember to uphold main assumptions of the methods at all times. For example, in the example above from the Indian Himalayas (Spiti), there is minimal evasive movement of ungulate. Hence, we maintain about 30 minutes difference between the two observers. In the Altai Mountains on the other hand, (Tost and Noyon) both Argali and Ibex show evasive movement (perhaps due to the prevalence of hunting in this area). In this case, we reduce the separation between observers to 10-15 minutes.
- Unfavourable weather conditions or a lack of people can greatly affect the accuracy and efficiency of the surveys. In these circumstances, it is advisable to wait (even if it means a loss of a day of surveys), as it might be safer and yield better data.

STEP 3: OBSERVERS COMPARE SIGHTINGS AT THE END OF DAY

Recaptures of groups of animals can only be determined by comparing observers' sightings and information. When a transect has been surveyed entirely by a pair of observers, they should return to camp and reconcile their observations (groups seen by both observers and groups sighted by only one of the two) and record their data. Observers can individually identify groups using information on sex, age, location and group size recorded. Below is an example of how two observers can compare sightings to update the Master Data Sheet.

Table 1: Example of comparing observations

4	0	1	Observer 2
6	1	0	Observer 1
10	1	1	Both observers

Once each team (pair) of observers has reconciled their data amongst themselves, they should converse with other teams (especially ones whose blocks are adjacent) about potential double-counting and movement of groups between blocks or transects. This is to ensure that any such movement is recorded and taken into account. Then, the group can discuss what appropriate action can be taken while entering data. If two pairs of observers sighted the same ungulates, then only ONE pair should record it as their sighting in the Master Data sheet (this is to avoid double counting).

It is crucial that data is entered and updated each day. This is generally best done over a cup of tea at a campfire! The data should then be entered into the Master Data Sheet. Please see Appendix 2 for an example of the format. Additionally, check the quiz presentation on the GitHub repository (https://github.com/kulbhushansinghs/Mountain-Ungulate-Double-Observer-Survey) to get a better understanding of how to reconcile field survey data into a master data sheet.

WHAT EQUIPMENT IS NEEDED?

1. Binoculars
2. Spotting scope (Optional; very good for open and rolling habitats)
3. GPS unit
4. Data collection sheet
5. Notebook and stationary
6. Good hiking shoes
7. Food and water

OTHER IMPORTANT ISSUES

A number of other important logistical issues need to be kept in mind while planning and conducting the survey:

- Permits may need to be obtained from various organizations, such as defence and wildlife authorities, for example when the survey is planned close to international borders.
- The time of year the survey is conducted is extremely important. Summers might be easier in terms of logistics of getting to places. However, ungulates may be located high up and in inaccessible places (i.e. birthing females, especially in Ibex and Markhor, tend to go to extremely rugged areas). This can affect the detection of the species. Young to female ratio right after the birthing period (generally June-July) is a better proxy for female fecundity compared the same ratio later in the year, when other factors such predation and winter mortalities will start affecting the ratio. (See section "Importance of Age-Sex Classification")
- Depending on the logistics, capabilities and requirements of the team, it is highly recommended that surveys be conducted at a similar time across multiple years.
- Generally, a team of c.7-9 people is efficient. 3-4 pairs can be surveying 3-4 blocks at a given time, with one person being the driver (if needed) and/or camp in charge. Training local rangers, villagers, herders, and other interested people (especially youth) is a great way to not only generate interest, but also ensure future sustainability of the work.

ANALYSIS

The data can be analysed using the mark-recapture framework in any software. We suggest using the Bayesian framework of the 'BBRecapture' package in R (version 3.2.3) (R Core Team, 2015). In this framework, detection is modelled as a function of the observer number (i.e. observer one and two). The population estimate (N-hat) is generated by multiplying the randomly picked estimate from the posterior distribution of estimated number of groups ($\hat{G}$) with a randomly picked estimate from the distribution of group size (μ). This is repeated 10,000 times to get a distribution of the population estimate (N-hat) as well as the confidence intervals.

Appendix 2 shows sample data sheets from the field with some key data collection tips. It also contains the master datasheet, which subsequently becomes the .csv file that is needed to analyse the data.

We have prepared a GitHub Repository which includes the R code, example data, and suggested papers under the following link:

https://github.com/kulbhushansinghs/Mountain-Ungulate-Double-Observer-Survey

GitHub is a web-based hosting service for version control. Information on setup to optimization and learning how to use GitHub can be found on

https://github.com/resources

It is important to note that this analysis will keep evolving with developments in the future. All of the developments can be tracked on the GitHub repository. For any questions, please contact Munib Khanyari at munib@ncf-india.org

WILD UNGULATE CLASSIFICATION

Below is a description of five of the most abundant and important wild ungulate species of the Central and South Asian mountains. They form the major source of diet for the rare snow leopard across its global range.

Age-sex classification of all five species can be presented as male (Class 1, 2, 3 and 4), female (sub-adult and adult females) and young (yearlings and kids).

Table 2: Age-sex classification description

Sex Class	Age Class	Description
Male	Class 1	2-3 year olds
	Class 2	4-5 year olds
	Class 3	6-7 year olds
	Class 4	Older than 7 years
Female	Sub- adult	2-3 year old that haven't started reproducing yet
	Adult	3 years or older. Generally breed and rear young
Male/Female	Kids	newest cohort
	Yearling	Born a year before the current birthing cycle

Note that for each species, there are variations in body size, colour, horn size and colour, and other morphological traits across their global ranges (especially for wide ranging species like the Ibex and Argali). These variations are not captured in the descriptions below, but one can find more detail in other literature, for example Fedosenko & Blank (2001) for Ibex and Fedosenko & Blank (2005) for Argali.

IMPORTANCE OF AGE-SEX CLASSIFICATION

Herd composition and age ratios can be used to assess status and demographic trends of ungulate populations (Hardy, 2002). Age-sex classifications, especially across multiple years, can be used to estimate age- and sex-specific mortalities and survival rates as well as age-sex ratios (Toigo & Gaillard, 2003). Robust count data will give us a sense of increase or decrease in ungulate populations, but age-sex classification can help us understand the mechanisms under which this change is occurring. This information is crucial for conservation managers, as certain factors such as disease or predation may disproportionately affect a certain age or sex, which, if not detected and acted upon, can cause a population decline over time.

Importance of age-sex classification for Double-Observer surveys

For the field survey, age-sex classification is a key piece of information to individually identify groups and assess if observations are recaptures between the two observers. Age-sex classification of a group is one of its key distinguishing factors. Information on group size, along with its age-sex classification, is one of the most robust ways to assess group recaptures. Without this information, there is little evidence to base recaptures on. It is therefore critical that all observers undergo training to be able to differentiate between the age-sex classes before field surveys.

Importance of age-sex classification beyond the surveys

In harvested populations (i.e., populations subject to hunting), male to female ratios can provide managers with information including (but not limited to) i) the maximum sustainable mortality rates for a population, ii) annual adult mortality rates, iii) adult sex ratios, iv) how much male or female mortality needs to be reduced to achieve a desired balance between sexes in the population (e.g. to ensure the population doesn't crash due to a lack of males in areas were illegal trophy hunting is targeting prime-aged males). Michel et al. (2015) suggest that a lower proportion of male Markhor (*Capra falconeri*) could be attributed to selective harvest of prime-aged males for trophies in hunting concessions of Tajikistan.

Young to female ratios are a proxy for birth rate and survival of the young, and hence for a population's reproductive performance (Mishra et al., 2001). Suryawanshi et al. (2010) found that blue sheep (*Pseudois nayaur*) young to female ratio was 3 times higher in areas without livestock grazing. This information can be used to investigate implications of livestock grazing (e.g. resource competition or disease transmission) on a wild ungulate population (which in this case seems to be affecting either young survival and/or female fecundity, hence impacting the populations negatively). Ekernas et al. (2016) suggest that argali populations with young to female ratios lower than 0.5

can be on a decreasing population trend. This however is sensitive to timing and is best evaluated in June/July, right after the birthing. An evaluation later in the year can result in confounding the impact of other factors such as predation of young on the ratio.

In summary, age-sex classification provides useful information to better understand the status of ungulate populations.

IBEX (Capra sibirica)

DESCRIPTION AND CLASSIFICATION

The bex is a large mountain goat that is characterised by its horn and beard. Both sexes have a dark dorsal stripe down the length of their back, and short, dark, furry tails. From autumn to spring, male are generally dark brown or black and have dull white saddle on their backs which is separated by the dorsal stripe. Sometimes, they have whitish patch at the base of their necks. In summers, they have dense coat that is generally brown.

Class 1 Male

Males have distinct, thick, scimitar-shaped horns that diverge from the middle of the head and curve backwards. The front side of the horn is flat and has thick horizontal ridges. Class 1 males are larger than females, with a small beard and short, spike-like horns. Class 2 are larger than class 1 and have roughly 6-7 ridges on their horns. Class 3 have the full adult pelage (dark brown), long beard and 8-9 ridges on the horn. Their horns start to have an inward curve towards the back of the animal's body. Class 4 males have large horns with more than 10 ridges and the horns have a more pronounced inward curve than class 3. They also have a characteristic white back (often seen clearly during the mating season) giving them the name "saddleback males". These are generally >7 year old males. Horns of the Central Asian sub-species are known to be thinner and grow longer than those of the southern sub-species.

Class 3-4 Male

Females are grey-brown with dark markings on their legs and less distinct white underparts (in comparison to males). Compared to males, they have thinner, shorter and parallel horns that are spaced wider apart at their base and don't diverge. The horns are of similar length as those of a class 1 male. Adult females are larger and have longer horns than sub-adult females.

Yearlings are newborns that survive their first winter and are a little larger than kids (but smaller than sub-adult females and class 2 males). Yearlings mostly look like adult females, but with much smaller body and horns sizes.

Kids are the newborn and lack horns. They are the smallest in size as well.

HABITAT

Asiatic Ibex primarily occupy mountainous regions between 1000-6000m, favoring rocky terrain and open alpine meadows. They seek out lower elevations during winter (Fedosenko and Blank 2001). They graze on alpine pastures and wet meadows, but are never far away from rocky, precipitous terrain. Their habitat use is positively associated with ruggedness (Menon 2003).

MARKHOR (Capra falconeri)

DESCRIPTION AND CLASSIFICATION

Markhor is the largest mountain goat in the world. They have long fur, a flowing beard, and corkscrew-like horns. Both sexes have dark brown muzzles, brown upper legs and a brown flank stripe. The belly, small rump patch and lower legs are white, with a dark patch between the knees. The tail is short and less bushy than that of the ibex. Subspecies have been separated on the basis of their horn shape, although there is much variation in this.


Class 2 & 4 Male

Males vary from iron-grey to off-white in winter, with hints of red-brown in the summer. Class 1 males are the size of females with a darker grey-brown pelage, horns up to 45 cm, and no ruff (white hair on chest and forelegs). They have thicker neck and darker pelage than females. Class 2 males have the beginning of the ruff and horns over 50 cm. Class 3 males have a big black beard, a light ruff on the neck and chest up to forelegs and a light patch on the thigh. A black fur streak on the shoulder and haunch starts upwards. Horns are big, with one-and-a half turns. Class 4 males have massive horns with two-and-a half turns of the corkscrews, voluminous ruffs and black faces.


Class 2 & 4 Male

Adult Female

Females are fawn in colour and are only about half the size of an adult male (Class 3-4). They lack a mane and generally have a very small beard. Their horns are thinner and more separated at the base than that of males, with one or one and a half turns.

Yearlings resemble females but are smaller in size, with slightly larger and broader horns. They also are darker in colouration. Kids are the smallest and lack horns, beards or manes.

HABITAT

Markhor are adapted to mountainous terrain with steep cliffs, generally between 600-4000m elevation. They prefer dense pine and fir forests, open, barren slopes, and grass glades, all near precipitous rocky cliffs (Menon 2003). Markhor rarely use high mountain zones above the tree line (Michel et al., 2015).

Adult Female

BLUE SHEEP (Pseudois nayaur)

DESCRIPTION AND CLASSIFICATION

Blue sheep at higher altitudes (trans-Himalayas and the Tibetan plateau) display a light, almost cream colouration, while those living at lower altitudes (i.e. greater Himalayas) are known to be darker. Their tails are short and dark, and the insides of their limbs and the rump patch are distinctly white.

Male horns are very characteristic and curve outwards, backwards and then downward in a crescent formation. The tips of the horns once again point upwards at the very end in prime males over eight years of age. Male horns are much thicker than female horns and diverge from a much closer base on the head of the individual. Class 1 males are as big as females with a horn size around 25 cm. Horn size reaches 35 cm in class 2, and over 40 cm in class 3 and 4 males (with an upward turn at the very end). Adult rams (class 2, 3, and 4 mostly) have dark brown to black markings on the neck, chest and legs, and a flank stripe that merges with the colour of the legs. Adult males have a slate-blue coat which is more pronounced in the winter, whereas in the summer it is much duller and more red-brown (females and young show this change more prominently, however).

Females are about one-third the size of males and have much shorter and thinner horns that diverge out (rather than in parallel) with a gap between them. They are dull shale in colour and have dark grey instead of black markings on their body. Sub-adult females are similar to adult females, but of smaller body size with smaller and thinner horns.

Sub Adult Female

Adult Female

PC: Munib Khanyari

Yearlings are roughly two-thirds the size of females, with horn sizes of around 15 cm. Their horns are smaller and thinner than that of the sub-adult females. **Kids** are the smallest in body size and lack horns.

HABITAT

Generally, blue sheep inhabit open grassy slopes in high mountains, from 2,500-5,500m. Though they prefer foraging in alpine pasture, they remain close to cliffs and crags to escape from danger. Found above the treeline, they like open-grassy or boulder-strewn ground and high cliffs (Menon 2003). They avoid forest cover.

Adult Female

Class 1 Male

Class 1 Male

ARGALI (Ovis ammon)

DESCRIPTION AND CLASSIFICATION

Argali are the world's largest wild sheep. Both the sexes have a rather grey-brown pelage in the summer, are darker along the back, with a white face, undersides and a white rump. A dark lateral line separates the dark upper sides from the light undersides. In the winter, the coat tends to become more white-grey. Their tails are short and black-tipped.

In comparison with female, **males** have larger and thicker horns that start off from a closer base on top of their heads then curve outwards and then back in, almost as concentric circles. Depending on the sub-species, the old age males (>8 years old) have horns that have two or multiple concentric curls or that curl outwards after forming the first concentric curl. Males are about three times the size of females and in the winter (depending on the sub-species) can develop a long creamy white ruff that ends on the grey-brown shoulders. Class 1 males have horns that have started to curve outwards from the top of the head, class 2 males have horns that have started to curve inwards

Class 3-4 Male

PC: Rigzin Dorjay

Class 3-4 Male


Class 3-4 Male

after the initial outward curl, class 3 males have the complete inwards curl, and class 4 males have the largest horns, with tips pointing outwards from the spiral and sometimes upwards as well. The horns can be so massive that they are often broken off near the tip on older males.

In comparison with males, **females** have shorter and thinner horns (almost knob-like) that emerge from the top of the head with more separation at the base between them. Their horns are much less ribbed and their rump patches are not as distinct as those in the rams, either. Sub-adult females are similar to adult females, but are smaller in body size and have smaller and thinner horns.

Kids are generally dark grey, are the smallest and have no horns. **Yearlings** start getting the adult pelage and have short stubble-like horns.

HABITAT

Argali inhabit mountains, steppe valleys and open deserts (Reading et al., 1997). Generally, Argali prefer open high rolling habitats, while they are rarely found in valleys or rugged areas and avoid cliffs and areas with more than 20cm of snow. Most argali live in alpine grassland between 3,000-5,500m. In some areas (Kazakhstan, Mongolia, especially) they are found at lower altitudes.


Class 3-4 Male

URIAL (Ovis orientalis)

DESCRIPTION AND CLASSIFICATION

Urial are very similar to argali but are much smaller; with shorter, thinner horns. Adult males tend to be reddish grey in winter with a piebald (white-black) ruff and saddle. The saddle patch generally is dark (black) in front and white at the back. They have a long black throat ruff that merges with a white chest ruff, both of which are lost in the spring. The ruff is only around the centre of the neck. A dark flank stripe separating the upper parts and the underparts, and dark hair above and below the knee are present in both sexes. Their face, bib, undersides and lower legs are white. The rump has a much smaller white patch than that of the argali.

Males have large, semi-circular horns that in large specimens form three-fourths of a circle. Most urial have horns that point inwards, towards the back of their necks (heteronym horns). Some males, however, may have homonym or sickle-shaped horns, which are deeply corrugated. Class 1 males feature a broad, dark line on the neck and a dark lateral stripe. Their horns are around 40cm long. Class 2 males have redder pelage and a white scrotum, show the initiation of a saddle, and their grey forelegs (more prominent in class 1) turn white. Their horns are up to 60cm in length, Class 3 males have a clear saddle and ruff, and their horns are semi-circular. Class 4 males have large horns forming three-fourths of a circle.

Females don't have the saddle patch or bib, and are much lighter in colour. As with the argali their horns are much smaller and thinner and emerge with a larger gap at their base than those of the males. Their horns curve outwards in a more or less parallel manner. Sub-adult females are like adult females, but are lighter and smaller.

Class 1-2 Male

Class 3-4 Male

Yearlings are slightly smaller and greyer than adult females and a thin black line initiates the ruff on the neck. The horns are roughly similar in size to females. **Kids** are rather grey, small and have no horns.

HABITAT

Urial prefer large (primary and sometimes secondary) river valleys and alpine steppes. They favor gently rolling hills and avoid steep slopes. Open and arid lands serve as their habitat. Generally, urial are found at much lower elevations than argali. They avoid dense forest cover (Menon 2003; Valdez 2008).

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APPENDIX 1: DOUBLE-OBSERVER CHECKLIST

Important points to consider when conducting Double-observer surveys:

1. Double-observer method is based on the principles of **mark-recapture theory**
2. This involves **two observers** searching for and counting animals simultaneously, while ensuring they **don't cue each other on the animals' location**
3. Keep the **three main assumptions** in mind while surveying:
   i) Ungulate groups can be individually identified
   ii) Each observer has visual coverage of the entire survey area
   iii) Observations by observer 1 and observer 2 are independent of each other
4. Ideal survey team is generally between **6-8 people**

Planning your survey:

1. Delimit **study area** with **landscape features and geographical barriers** in mind
2. Divide the study area into **blocks (c.20-30km^2)** keeping in mind the **three assumptions**
3. **Identify the survey routes** i.e. "transect", to follow in each block

Conducting your survey:

1. **Blocks** are generally **delimited prior to field surveys** but can be **modified** using in-field experience and local inputs
2. **Two observers** surveying the **same block** should walk the transect such that they have the **same visual coverage** of the block
3. The two observer should **never communicate their observations** or cue each other
4. During survey **collect data on**:
   i) GPS location of observer during sighting

ii) Species observed

iii) Age and sex category of individuals in the observed herd

iv) Behavior and location of the herds

v) Unusual features of individuals in a herd

5. **Walk transects slowly** and scan the mountains every 100-200m
6. **Recaptures** of groups of animals needs to be **reconciled** between two observers at the end of the survey and the data needs to be recorded daily.

APPENDIX 2 FIELD DATA SHEETS

KIBBER(i.e. Study Area): OBSERVER 1*

Date : 20/06/2018

Start time: 08:45, End time: 13:10 Effort(Km): 13.2

Block	Group size	Obs name	Lat	Long	Time	C 1	C 2	C 3	C 4	AF	SF	Y	K	UC	Species	Notes
Farrah	31	Kamal		078.21	09:53	2	2	2	4	7	5	6	-	3	Blue Sheep	Below the peak
Farrah	7	Kamal		078.34	12:14	-	-	-	-	4	-	3	-	-	Ibex	Seated near cave

KIBBER: OBSERVER 2

Date: 20/06/2018

Start time: 09:15, End time: 13:25 Effort(Km): 13.2

Block	Group size	Obs name	Lat	Long	Time	C 1	C 2	C 3	C 4	AF	SF	Y	K	UC	Species	Notes
Farrah	31	Rinchen		078.24	11:02	2	2	2	4	9	5	7	-	-	Blue Sheep	On top of peak

KIBBER: OBSERVER 1

Date : 20/06/2018

Start time: 09:00, End time: 13:00

Effort (Km): 10.2

Site	Group size	Obs name	Lat	Long	Time	C 1	C 2	C 3	C 4	AF	SF	Y	K	UC	Species	Notes
Thinum	23	Munib	32.18	078.01	09:03	8	4	4	7	-	-	-	-	-	Blue Sheep	On ridge top
Thinum	4	Munib	32.34	078.10	09:24	-	-	-	-	4	-	-	-	-	Blue Sheep	1 female broken horn
Thinum	13	Munib	33.00	078.23	10:43	-	-	-	-	8	-	3	-	2	Blue Sheep	-
Thinum	5	Munib	33.20	078.24	12:03	-	-	-	5	-	-	-	-	-	Ibex	Near stream

KIBBER: OBSERVER 2

Date: 20/06/2018

Start time: 09:30, End time: 14:45 Effort (Km): 10.2

Site	Group size	Obs name	Lat	Long	Time	C 1	C 2	C 3	C 4	AF	SF	Y	K	UC	Species	Notes
Thinum	23	Dhamal	32.18	078.01	09:52	8	4	4	7	-	-	-	-	-	Blue Sheep	ridge top
Thinum	4	Dhamal	32.29	078.02	10:14	-	-	-	-	3	-	-	-	1	Blue Sheep	1 female broken horn
Thinum	15	Dhamal	33.52	078.23	13:12	-	-	-	-	10	-	-	5	-	Ibex	-

Master DOS Field Data Sheet

					Observer 1									Observer 2									
Block	Date	G. Size	Ob 1**	Ob 2**					AF	SF	Y	K	UC ***					AF	SF	Y	K	UC	
Thinum	20/06/ 2018	23	1	1	8	4	4	7	0	0	0	0	0	8	4	4	7	0	0	0	0	0	Blue Sheep
Thinum	20/06/ 2018	4	1	1	-	-	-	-	4	-	-	-	-	-	-	-	-	3	-	-	-	1	Blue sheep
Thinum	20/06/ 2018	13	1	0	-	-	-	-	8	-	3	-	2	-	-	-	-	-	-	-	-	-	Blue Sheep
Thinum	20/06/ 2018	5	1	0	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Ibex
Thinum	20/06/ 2018	15	0	1	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	5	-	Ibex
Farrah	20/06/ 2018	31	1	1	2	2	2	4	7	5	6	-	3	2	2	2	4	9	5	7	-	-	Blue Sheep
Farrah	20/06/ 2018	7	1	0	-	-	-	-	4	-	3	-	-	-	-	-	-	-	-	-	-	-	Ibex