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Population and Demography of Asian Wild Buffalo (*Bubalus Arnee* Kerr, 1792) at Koshi Tappu Wildlife Reserve, Nepal

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Abstract
Asian wild buffalo (*Bubalus arnee,* Kerr, 1792) is a globally endangered and the protected species in Nepal. Population size and demographic structure of this species was studied in the Koshi Tappu Wildlife Reserve (KTWR). Most suitable swampy habitats in KTWR maintain pure breed of Asian wild buffalo. The population census of this species was carried out during March to April, 2016 using direct count method. The total population was 433 including 180 adult female, 114 adult male, 26 sub-adult male, 20 sub-adult female, 27 two-year calves, and 66 one-year calves. Male to female ratio was 0.63, and calf to cow ratio was 0.37. Population's exponential growth (ri) was highest (0.097) in year 2010 and it was negative in 2009. However, the population is still not considered viable and secure in this habitat due to floods in the Koshi River, risk of disease transmission from domestic buffaloes, genetic degradation due to feral buffaloes and cattle, tough competition for food and space. However the total population size (433) and effective population size (294) is convincing for its sustenance and percentage rate of loss of variation (0.17) in 2016 indicated optimistic trend for viable population. Reintroduction of species into Chitwan National Park of central Nepal has been successfully taken up during January-February of 2017 as a part of species conservation, and planned to establish an effective population size in the new habitat.

Keywords: asian buffalo, effective population, koshi tappu wildlife reserve, protected species, reintroduction

INTRODUCTION

The Asian wild buffalo (*Bubalus arnee* Kerr, 1792) belongs to the family-Bovidae which includes four genera (IUCN, 2013; IUCN-SSC, 2010) namely *Bubalus* (Asian buffalo), *Syncerus* (African buffalo), *Bos* (Gaur and Cattle), and Bison (American and European Bison). These four genera encompass twelve non-interbreeding species. The historical distribution of the Asian wild buffalo ranged across south and south-east Asia, from Mesopotamia to Indo-China (Mason, 1974; Cockrill, 1974). Asian wild buffaloes remained confined in three large disconnected areas viz, (1) northern India, including Nepal, Bhutan and Bangladesh; (2) Peninsular India; and (3) scattered areas in Indo-China (Choudhury, 1994, 2010) in early period of twentieth century. Asian wild water buffaloes were also reported to occur in Chitwan National Park (CNP), Nepal until early 1960s (Spillett & Tamang, 1966; Seidensticker, 1975). They were exterminated from the area as a result of diseases transmitted by cattle, and buffaloes barring 20 to 30 individuals in the flood plain along the Koshi River in the eastern part of the country (Spillett & Tamang, 1966).

Asian wild buffalo maintains stable home range but exhibits seasonal movement within different habitat areas. They are social animal and live in a herd of varying sizes. Generally each herd includes one or two adult males with 30-40 females with calves. Largest group size of the wild buffaloes counted to be 90-100 animals with an alpha male. Bachelor males are also evident in the area. Asian wild buffaloes are morphologically robust with strong musculature; bulls are even larger and stronger.

In Koshi Tappu Wildlife Reserve (KTWR), a prime habitat of Asian wild buffalo, periodic census of this species began since 1976. Koshi Tappu is prone to anthropogenic and natural threats such as habitat invasion by feral and domestic buffaloes, cattle, annual floods. Similarly, cross breeding with feral and domestic buffaloes increases the chances of genetic erosion. The data collected during these censuses has taken in to account to understand the trend of population growth, effective population size, and rate of loss of genetic variation to evaluate the probability of sustenance of this endangered species and to conceive future conservation plans. Therefore, this study contributes to long-term conservation and management of this species and its habitat through assessment of population size, demographic structure and, and growth trend of the species over a period (1976-2016). This can be possible through the process of sustainable development mechanism.

MATERIALS AND METHODS

Study Area: Koshi Tappu Wildlife Reserve (KTWR) covers a geographical area of 175 km^2 lying between 26°33'-26°45'N and 86°54'-87°04'E on the floodplain of the Sapta Koshi River near the Indo-Nepal border in the low land of south-eastern part of Nepal. The wildlife reserve was established in 1976 to preserve habitats of the last remains of Asian wild buffalo population in Nepal (Figure 1). The Reserve experiences mainly sub-tropical monsoonal climate with annual rainfall between 1300 mm to 2051 mm (Sah, 1997); 80-85% of rainfall occurs during mid-June to late September. The daily maximum temperature of KTWR ranges between 23^0C to 34^0C, and minimum between 16^0C to 29^0C. The temperature rises from pre-monsoon (April) and lasts until May, and lowers during October to January. The reserve is mostly flat with gentle elevation (75-100 m amsl) which forms a roughly rectangular shape within an average length of about 16.3 km and width of 9.3 km. It is drained by the Sapta Koshi River, a major tributary of the Ganges, and the Trijuga River which joins the Sapta Koshi in the western border of the KTWR. Surrounding 173 km^2 area of this reserve was declared as the buffer zone in 2004.

Flora and Fauna of KTWR: The vegetation of the reserve mostly composed of tall grasses such as *Saccharum spontaneum*, *Imperata cylindrica*, *Dryopteris cochleata*, *Cyanodon dactylon*. Small patches of *Acacia catechu-Dalbergia sissoo* forest, and deciduous mixed riverine forest also serves as important habitat for other wildlife (Sah, 1997). Among the other wildlife species in KTWR recorded are spotted deer (*Axis axis*), barking deer (*Munitacus muntajak*), hog deer (*Hyelaphus porcinus*), wild boar (*Sus scrofa*), blue bull (*Boselaphus tragocamelus*). A newly migrated small herd of Asian wild elephant (*Elephas maximus*) also share this habitat since almost last five years. The Koshi River is also home to almost 80 species of fish, endangered species such as Gharial crocodile (*Gavialis gangeticus*), and Gangetic Dolphin (*Platanista gangetica*). Around 485 species of birds have been recorded so far in and around the Wildlife Reserve.

Census Techniques: Wild buffaloes are primarily restricted in their occurrence to floodplain grass lands, savannah and riverine mixed forest; and rarely venture away from water sources (Dinerstein, 1991; 2003). To study the population of wild buffalo, entire area of the reserve was divided into different blocks and used sweeping and detail count method (Kandel et al., 2014) in order to avoid likelihood of missing out any of the animals. Chances of sighting wild buffaloes over all the habitat types at KTWR were fair. For carrying out the census, entire area of KTWR was broadly divided into two segments: east and west from the main course of Sapta Koshi River; each segment was further divided into two separate blocks, north and south blocks. The division of blocks in KTWR for the census work was as follows:

a. Eastern Blocks: East to Sapta Koshi River:

South-East Block: Haripur-Kusaha area

North-East Block: Madhuwan-Prakashpur side including Sri Lanka Tappu

b. Western Blocks: West to Sapta Koshi River:

South-West Block: Badgama-Jagatpur area-south from Pathari Range Post

North-West Block: Kamalpur-Bhagalpur area north from Pathari Range Post

The animals were closely observed during the census in order to distinguish and clear identification of the age and sex of the animals. Four wheel drives, elephant ride and also on-foot tracking were used during census to maximize animal sightings. Elephants were especially used in habitats predominated by tall grasses and swamps to improve detection in dense vegetation. In each block, team members were assigned at a visible distance of about 50-100 meters. Experienced field technicians were involved for the census work. GPS units, binoculars of 7x35 magnification, and digital camera were used to locate and identify each herd and solitary males. Direct observation was used to count and observe each individuals. Field census was conducted in two sessions: 0700-1100 hours in the morning, and again 1500 hours until visibility permitted. Phenotypic characteristics were applied to distinguish wild buffaloes with feral backcross and domestic buffaloes following Cockrill (1974), and Heinen (2002) methods. The criteria used by Dahmer (1978), Heinen (2002), and Heinen & Kandel (2006) were also applied to distinguish wild stocks from feral ones.

METHODS FOR POPULATION STUDIES

Age and Sex identification: The criteria for identification of the wild breeds of wild buffalo, their age and sex was used as described by Dahmer (1978), Heinen (2002) and Heinen & Kandel (2006). Major criteria considered during census were skin and pelage color, change pattern in coloration in male and female individuals, horn size and shape, herding behavior, etc. The age of animals was determined as follows:

- Young calves/Infants (<1 year): buff in color.
- Juvenile Calf (1-2 years): darken buff color in the first year that gradually turns lighter in color in the second year.
- Young Adult/Adult (>3 years): the coat color changes to dark to very dark with noticeable whitish markings in different parts of the body. There are one or two white chevron marks on the underside of the neck. They have white hocks, white tail tips, and fine white markings around the eyes and along the sides of the nose and mouth.

- White markings are more apparent in adult age which gradually fades out with age. Young females are smaller and the pelage retains the light coloration. Adult males are dark black, except for whitish markings as described above at prime breeding age (>4 years). Adult females have longer upwardly extended horns than males, but males have much thicker horns. Number of young calf <1 year of age and number of females in a population were considered for calculating calf to cow ratio. It is an index of growing population.

Population growth rate: Population growth rate of wild buffalo population in KTWR was calculated from exponential growth rate formula as adopted from Dahmer (1978), Heinen (1993a), Heinen (2002), Heinen & Kandel (2006). Demographic structure and calves to cows ratio was calculated from the same data sets:

Exponential growth rate, $r_i = \frac{\ln(Nj/Nk)}{t}$

Where, ri = Growth rate calculated for that time interval
Nj = Population size at the end of interval
Nk = Population size at the beginning of the interval
t = Number of years in the interval

Effective Population: Effective population size of Asian wild buffaloes in KTWR is calculated from original population data as described by Stiling (2002).
Effective population size (Ne)
= 4(NmxNf)/(Nm+Nf)
Where, Ne = Effective population size,
Nf = No. of female individuals,
Nm = No. of male individuals

Rate of loss of genetic variations: If an individual fails to mate to an individual possesses a rare gene, the genetic information encoded in that gene may not pass on to the next generation that would result in loss of genetic variation from the population (Berger, 1990). This normally happens in the small and fragmented populations. The percentage ratio of population loss per generation (Stiling, 2002) is calculated using the following formula:

Percentage ratio of loss of genetic variation (per generation) = (1/2N)*100
Where, N is the number of individuals in the population (population size)

RESULTS AND DISCUSSION

Population Status and Demography: The last home of the Asian Wild Buffalo *(Bubalus arnee)* in Nepal is Koshi Tappu, the riverine flood plains of the Sapta Koshi River in the Eastern Tarai. The range of the Wild Buffalo in Nepal was once much more extensive all over the Tarai region. Finding shelter in the riverine forests and forage in the flood plains even while the monsoon water subsides was an ideal habitat available for wild buffaloes in KTWR. Now, the range of the wild buffalo has been much restricted by the construction of the Koshi barrage along the Indo-Nepal border (Kandel et al., 2014), and they are confined to the strips of Koshi Tappu due to the settlements developed around the reserve area after the KTWR established. Similarly, other reasons are yearly unpredictable shifting of main course of the Koshi river, and also internal migrant (Chalise, 2016). The local domesticated buffaloes also mixed up with the wild breeds as like feral buffaloes but the study was precisely focused on the pure herds of wild population using precise identification criteria.

The first census of Asian wild buffalo at KTWR was done in the year 1976 and counted 76 animals in total, out of which there were 12 adult male, 18 adult female, 22 juvenile and 11 infants (Dahmer, 1978), and the population of this species found to increase right from the first census (Table 1). Two subsequent census of wild buffaloes were done in 1987 and in 1988 (Heinen, 1993b) and recorded 91 and 93 individuals respectively. The census program of Asian wild buffaloes at KTWR after 2000 was undertaken in every 2-5 years. The increasing population trend over the years suggests an exponential growth rate except in 2010 census; in that total animal counted were 215. In the year 2008 devastating flood in the Koshi River took heavy toll of animals of all age groups. The population size in the year 2011 and onwards indicated increase in population (table 1).

Table 1: Demographic structure of Asian wild buffalo over census years

Years of Census	Adult Male	Adults Female	Sub-Adult Male	Young Female	Juvenile (2-yr)	Infant (1-yr)	Total	Calves/Cow ratios	M/F ratio
1976	12	18	NA	NA	22	11	63	0.611	0.67
1987	32	29	NA	NA	14	16	91	0.552	1.10
1988	37	33	NA	NA	8	15	93	0.455	1.12
2000	56	53	NA	NA	17	19	145	0.358	1.06
2004	54	63	NA	NA	24	18	159	0.286	0.86
2009	55	119	NA	NA	22	23	219	0.193	0.46
2010	57	108	NA	NA	24	26	215	0.241	0.53
2011	66	117	NA	NA	15	39	237	0.333	0.56
2014	47	125	64	44	32	38	350	0.304	0.38
2016	114	180	26	20	27	66	433	0.367	0.63

Sex ratio and calves to cows ratio: The latest census conducted during March-April 2016 indicated the increase up to 433 individuals; where male and female ratio was 0.63 and calf to cow ratio was 0.36 (Table 1). Whereas in censuses in 2014 and 1988, male to female ratio was lowest, 0.38 and highest was 1.12 in respective census years. Male to female ratio focuses on fecundity rate of the wild buffalo population at KTWR, females needs to be more to convert the population more viable. This needs to have long term study on change of male - female ratio. Higher the number of female more would be fecundity rate of the population which could be analyzed and predicted by evaluating sex ratio at different census episodes. High fecundity rate affect the calves to cow ratio; higher is the ratio more is the viability of population. Calves: cow ratio was highest in 1976 (0.61) which was gradually declined thereafter but the lowest was 0.19 in 2009 (Table 1, Fig. 2) because flood in 2008 affected population badly. The consequence of flood has led to severe effect on the number of calves and young animals. Impact of flood was seen on growth of the population. Overall trend of wild buffalo population growth over time is depicted in Table 2. Such down fall of population sizes are highly prone to natural disasters such as flood, diseases, hunting, etc.

Table 2: Exponential growth rate (ri) of Asian wild buffalo at Koshi Tappu Wildlife Reserve over the years

Years of Census	Total Population	Growth interval in Consecutive Years of Census	Exponential growth rate (ri)	Growth interval between first to each census	Exponential growth rate (ri)
1976	63	1976 to 1987 (r1)	0.033		
1987	91	1987 to 1988 (r2)	0.022	1976 to 1987 (r1)	0.033
1988	93	1988 to 2000 (r3)	0.037	1976 to 1988 (r2)	0.032
2000	145	2000 to 2004 (r4)	0.023	1976 to 2000 (r3)	0.035
2004	159	2004 to 2009 (r5)	0.064	1976 to 2004 (r4)	0.033
2009	219	2009 to 2010 (r6)	-0.018	1976 to 2009 (r5)	0.038
2010	215	2010 to 2011 (r7)	0.097	1976 to 2010 (r6)	0.036
2011	237	2011 to 2014 (r8)	0.018	1976 to 2011 (r7)	0.038
2014	350	2014 to 2016 (r10)	0.106	1976 to 2014 (r8)	0.045
2016	433	1976 to 2016 (r tot)	0.048	1976 to 2016 (r10)	0.048

During census conducted in 2016 in the area, only males group, single to many male band group of various sizes were noticed. The composition of male band group and number of event/occasion noticed during the field work are presented in the table 3.

Table 3: Composition of male band group observed during the field works at Koshi Tappu Wildlife Reserve

Age Group of Males	Sizes of Male band	No. of events
Adult Male	1	37
	2	9
	3	2
Sub-adult Male	2	2
	3	6
	4	2
	5	3
	6	3
	7	1
	9	1
	10	1

Male to female ratio in population at KTWR was also inconsistent. There was a rise in male to female ratio in 1987 which was gradually declined till 2009 and again gained but in zigzag manner. Gradual downfall of the calves to cows ratio till 2009 was also evident which gradually increases in a similar manner as male to female. There is strong correlation between male to female ratio and calves to cows ratio as is illustrated in Fig. 3. Flood had uniform impact on both male: female and cow: calves. There are some other factors in the area which had longer impact on male: female in spite of overall increase in population.

It is quite probable that some male individuals might be leaving herd and joining male band population. These individual could be sub ordinale males who are not getting chance to mate female of the group. Therefore size of male band in sub-adult category is large (Table 3). It reflects strong hierachy and pre-dominance of alpha male is very strong. Course of River Koshi is dynamic and almost every year affect the area of home range resulting to solitary or scattered males to leave the natal herd (Dahmer, 1978) after entering the age of sub-adulthood. Extensively large natal herd also gets splitted due to this behavior of river. Splitted herds occupy different territories other than natal herd- such as likely to split of south block of Haripur Island created small herds at south-west part from the Koshi River.

Population growth: Population size and its composition determine the growth rate. Current population size of the Asian wild buffalo at KTWR is highest in comparisons to previous censuses. The overall population growth (ri) over past 40-years (1976 to 2016) is 0.048. Growth rate between 1976 and 1987 was 0.033 and between 1988 and 2000 was 0.037. The population growth rate was highest during 2011 to 2014 (0.106). Negative growth (-0.018) was recorded in 2009 (Table 2 and Figure 4). Populations of wild buffalo bounced back after decimating impact of flood in 2008. The average rate of growth (0.048) during 1976 and 2016 shows an imperative trend towards the sustenance in future. However, growth rate at varies as population size changes. Number of calves at present in the population is an indication of potential status of population of wild buffalos in KTWR.

Effective population size: Effective population size is the number of adult males and females of a species in a given area or habitat. If individuals of a species mate only within a neighborhood, the effective population size may actually be smaller than the number of individuals in the population (Stiling, 2002) even though the population size is larger. Knowledge of effective population size is vital to know the phenomenon of the success of conservation of species and their interactions. Allendrof (1994) indicated in case of grizzlies that population as large as hundreds would likely to lose genetic variation because effective population sizes are only about 25 percent of actual size. Even fairly large isolated population becomes vulnerable to the harmful effects of loss of genetic variation. This situation truly applies to wild buffalo population of KTWR. Structure of effective population size of Asian wild buffalo in KTWR over different census years is represented in Figure 5, and percentage rate of loss of variation per generation as well as loss of variation of 10 generations is calculated as shown in Table 4.

The likelihood of an allele being represented in just one or a few individuals is higher in small than in large populations. Small and isolated populations face challenges in transferring of rare genes which lead to loss of variations. Such isolated populations will lose a percentage of their original variation over the time.

If population size goes less than 50 individuals, then excessive inbreeding need to be prevented to stop loss of genetic variation, calculated percentage loss of variation per generation and also 10 generations is presented in table 4. If population loss goes beyond the 500 individuals, it becomes critical size to prevent genetic drift (Simberloff, 1988). The Koshi Tappu population is increasing towards a fairly effective size, and likewise the reintroduced population shall gradually need to increase in future. Lacey (1987) showed that effects of genetic drift could be countered by the immigration of individuals in to a population. That situation is not applicable for this isolated population at KTWR.

Table 4: Rate of loss of genetic variation of Asian wild buffalo at Koshi Tappu Wildlife Reserve over the years

Year of Census	Population Size	Effective population size	% rate of loss of variation per generation	loss of variation of 10 generations
1976	63	30	1.67	16.7
1987	91	61	0.82	8.2
1988	93	70	0.71	7.1
2000	145	109	0.46	4.6
2004	159	117	0.43	4.3
2009	219	174	0.29	2.9
2010	215	165	0.30	3.0
2011	237	185	0.27	2.7
2014	350	172	0.29	2.9
2016	433	294	0.17	1.7

Policy Interventions and Management Implications

As the size of the wild buffalo population at KTWR is increasing every year, the population is likely to split into several groups; those splitted herds would likely to be intermixed with feral or backcrossed herds. So there is a danger of genetic erosion of putative wild stocks due to increased chances of cross breeding. Now it is urgently necessitate to ensure that abandoned or private feral/or backcrossed buffaloes are immediately relocated from the Wildlife Reserve so that the wild stocks would remain safeguarded. However, a few concerns regarding the long-term conservation and effective management of wild buffalo in KTWR must be evaluated and seriously be taken up immediately. On the other hand, as genetic variation is reduced by inbreeding, genetic drift or influence of neighborhoods of feral or domestic buffaloes, the effect of all these factors are likely to

increase in severity towards triggering declined population size.

Knowledge of the genetics and breeding behavior or breeding potentials of wild buffaloes is vital for safeguarding its population in the larger landscapes or land surfaces. So, a conservation biologist should know how genetic variation is decreased to help them maintain viable populations (Berger, 1990) such that the genetic conservation of the wild populations must be used in conjunction with preservation of the organism's habitat. The effects of inbreeding are more extreme in small populations (Stilling, 2002). The wild buffalo population at KTWR is still not considered viable and secure in this habitat due to various reasons such as floods in the Koshi River, risk of disease transmission from domestic buffaloes, genetic degradation due to feral buffaloes, tough competition for food and space. However the total population size (433) and effective population size (294) is convincing for its sustenance and percentage rate of loss of variation (0.17) in 2016 indicated optimistic trend for viable population. Reintroduction of species into the new habitat at Chitwan National Park of central Nepal has been successfully taken up during January-February of 2017 as a part of species conservation, and the Department of National Parks and Wildlife Conservation (DNPWC) has planned to establish an effective population size in future.

There are the factors of hindrances for having normal way of being intermixed between the populations of different herds or individual of wild buffaloes in KTWR due to the extreme interference by thousands of cattle and domestic buffaloes as well as feral buffaloes. Such issues shall need to be seriously handled by enforcing the National Parks and Wildlife Conservation (NPWLC) Act 1973 that would help to render the country a leader among developing countries in conservation practices (Lehmkuhl *et al.*, 1988; Yonzon & Hunter, 1991) for improving the management of protected area and offering wildlife protection (Heinen, 1993) for a long run.

CONCLUSIONS AND RECOMMENDATIONS

Immediate actions prescribed for the long-term management and survival of the Asian wild buffaloes at KTWR and create alternative viable population at new habitat in Chitwan National Park, Nepal are: Conduct official surveys of wild buffaloes and update very regularly; Monitor status, distribution and habitat conditions of wild buffaloes including other sympatric species every year; Intervene the habitat management uniformly over the Reserve for palatability and accessibility to grasslands and wetlands regularly; Take actions to stop grazing by domestic animals and to limit contacts with wild buffaloes; Restrict the domestic buffaloes to breed with wild bulls; Develop community animal health care facilities as was provided at Madhuban from 2005, and promote stall feeding; Carry out molecular study of wild, feral and domestic buffalo to characterize them, and also intensive studies on basic ecology including behavioral and other ecological aspects of the wild buffalo population at KTWR; Enhance the level of motivation and awareness amongst the local communities on significance of wild buffalo conservation in Nepal, and provide increasing support from the international community and donors for conservation, management and research; Further to translocate some more animals to create a viable and effective population size in to Chitwan National Park. It is only possible to have the strict conservation and effective management of the wildlife reserve and endangered species like wild buffaloes through the process of sustainable development mechanism.

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