Monograph 2011

Buffalo Genetic Resources of India

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A unique germplasm of Western India

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PREFACE

Buffaloes in the Indian sub-continent are an integral part of traditional agriculture and hold the greatest promise and potential for food production. They were first domesticated by the ancient Indus valley people around 2500 to 5000 B.C. Of the total 158 million buffalo population in the world, India alone accounts for about 59.5% of them. Indian buffaloes contribute 48 million tonnes of milk, which is about 55.6% of total milk produced in the country. Being an important dairy animal in India, there are 10 well defined buffalo breeds, of which Murrah, Nili-Ravi, Mehsana and Jaffarabadi are notable ones having good potential for milk production. Apart from these, there are about 15 or more, lesser known buffalo populations, some of which have superior genetic potential for high milk production, ability to thrive under harsh environmental conditions and resistance to tropical diseases. In addition to their ability to survive under low or zero input system, these buffalo populations play a significant role in the livelihood of many traditional livestock rearing communities of rural India.

Banni, a non-descript buffalo mainly found in the Kachchh district of Gujarat state in Western India was evolved over centuries by "Maldharis", the traditional livestock keepers of the region. The "Banni" region is one of the finest pasture lands of South Asia with different varieties of grasses for livestock grazing. Banni buffaloes are a significant source of income and play an important in the livelihood of Maldhari community. There is a need for conservation and genetic improvement of this breed in order to exploit its genetic potential for high milk production. No systematic characterization and documentation of Banni buffaloes have been done in the past except for few isolated reporting on these buffaloes. To rationalize the breeding strategy and to design appropriate conservation program, it is necessary to characterize and evaluate Banni buffalo based on physical/phenotypic and genetic characteristics. Further, genetic structure of Banni buffaloes vis-à-vis buffalo breeds of the region needs to be established in order to understand the genetic relationship/differentiation among them. Some efforts in this direction have been carried out and highlighted in this monograph.

This bulletin is compilation of information on production and reproduction performance of Banni buffaloes along with its morphological characteristics and genetic diversity. The authors wish to thank Dr. B.K. Joshi, Director, NBAGR for taking initiatives in compiling and updating the information available for this important buffalo breed. The authors hope and trust that the bulletin will be useful to the policy makers, researchers and students in getting glimpses of this important buffalo breed.

Authors

Introduction

Water buffalo (Bubalus bubalis) is the mainstay of Indian dairy industry with a contribution of about 54% of the total milk production in the country. Buffaloes are valuable not only as milk producers, but have multiple roles in rural livelihood system, where it forms a part of cultural structure of the society apart from employment generation and nutritional security. In some areas, buffalo keeping is a way of life for certain social groups, particularly amongst tribal people (Todas of Nilgiris in Tamil Nadu) and pastoralists/semi pastoralists (Maldharis of Banni area in Gujarat). India possesses wide variety of buffalo genetic resources comprising 10 well recognized breeds and many lesser known populations which are equally important to buffalo husbandry in India.

Gujarat state is blessed with some of the best germplasm of buffalo in the world and the breeds like Jaffarabadi, Surti and Mehsana have been known for their high productivity, heat tolerance and resistance to tropical diseases. Apart from these breeds, Banni buffalo, a unique pool of germplasm found in the Kachchh region of the state is known for its typical and locally adapted extensive production system and being one of the main sources of livelihood for the "Maldharis" (traditional livestock keepers). The Banni area of Kachchh district of Gujarat state is one of the finest pasture lands in Asia with about 30 varieties of grasses and is well known for its livestock wealth. The Banni buffalo, which was evolved by the "Maldharis" community in this region, has good adaptability to harsh climatic conditions, drought resistance and survival on scanty fodder and shrubs. They have good genetic potential for milk production and form a main source of livelihood for Maldharis. Also, Banni buffaloes are gaining popularity among the farmers and private dairy owners in North Gujarat and Mumbai (Maharashtra) due to their high milk production potential, fairly good lactation length, hardy nature and regular breeding.

Habitat and Distribution

Banni buffaloes are distributed throughout the Kachchh district of Gujarat and in some parts of Banaskantha and Patan districts of North Gujarat (Figure 1). These buffaloes are centered between Hajipir to Khavada areas of Kachchh district. Typical Banni animals are seen in Bhirandara, Hodka, Luna, Mithadi, Udama, Dhorda, Goravali, Kaduli, Rabviry and Kakar villages of Banni region (Bhuj circle) and in Anjar, Bhachua, Nakhatrana and Lakhpat circles of Kachchh district.

Figure 1. Breeding tract of Banni buffaloes in Kachchh district of Gujarat state in Western India.

Location and Demography of Banni Region

Kachchh is the second largest district in India covering an area of 45,612 square kilometres and situated in the north western part of Gujarat and has a 352 km coast line on the Arabian sea. Pakistan lies to its north. Kachchh is a land of deserts, dry salty alluvial, mudflats and extensive grassland. Broadly, Kachchh can be divided in four distinct regions.

a. The deserts of the Great Rann, to the north

b. The grassland of Banni

c. Main land, consisting of plains, hills and dry river beds and

d. Coastal line along the Arabian sea in the south with mangrove creeks to the west.

The predominant population of Banni region is Muslims constituting about 90% followed by Hindus called Meghwal with about 10% (Figure 2).

These people have been traditionally keeping livestock especially Banni buffaloes in this region. The Meghwal (Hindu) community on the other hand has traditionally been assigned the task of producing leather and wood crafts. The other major castes keeping livestock in Kachchh districts are Ahir, Rabary / Desai, Gadhavi and Soda-Rajputs.

Figure 2. A Maldhari with his Banni buffalo

Banni Grasslands

Gujarat takes pride from "Banni", the Asia's largest stretch of grassland. The Banni region is one of the finest pasture lands supporting the traditional livestock system (Figure 3). The Banni region consists of 45 villages, mostly inhabited by Maldharis whose main occupation is rearing livestock. They possess large numbers of Banni buffaloes of true breed characteristics, good milk production potential and strong body conformation/characteristics. Since the time of princely state of Maharao of Kachchh, the Maldharis were allowed to utilize the land for grazing their livestock, without occupancy right for the land. Moreover, Banni grassland is preserved/ protected as grazing area under land revenue code and cultivation of crop is not permitted.

Banni derives its name from the vernacular "baneli" which means reclaimed by the operation of natural forces. The area has been described as probably a bank or bar of soil brought down by the North flowing Kachchh rivers and sandwiched between the greater Rann and most major towns of Kachchh. It stretches almost parallel to the coastline of Kachchh about 105 km long and from 16 to 26 km broad. The area is a flat pasture land within the greater Rann and situated in the Northern region of the Bhuj taluks, between north latitude of 23o 19' and 23o 52' and East longitude 0f 68o 56' and 70o 32'. Banni grassland has never been comprehensively surveyed and different agencies have given different measurements for the total area. Various estimates over three decades suggested that Banni is spread over 1312 sq. km. to 3487 sq. km. If managed properly the Banni grassland has the potential to provide fodder for the entire state. Banni area was declared a protected forest in 1955 and its administration is being handled by the state revenue department.

Figure 3. Banni grassland ecosystem

Rainfall and Temperature

Kachchh is a rainfall deficient area, its average being 325 mm. Banni situated in the western most edge, rainfall due to South West monsoon is lesser, sporadic and uncertain as compared to the Eastern parts and costal area of Kachchh. The temperature reaches up to 50o C in the hottest months (May to June) and minimum temperature recorded is about 5oC in winter season (December to January).

Soil Type

The soil of Banni area is highly calcareous, saline and loam sandy with poor water holding capacity, low permeability and being prone to erosion. The nature of soil has limited the agricultural farming to a great extent in this area and grasses grow naturally in rainy season.

Figure 4. Soil in Banni region unsuitable for crop cultivation

Rain Water Harvesting in Banni

Ground water exists at a shallow depth in Banni, but soil salinity and intrusion of sea water make the water salty and unusable. Since there is no source of fresh water, it has always been a necessity for the villagers to harvest and conserve rain water for their animals and domestic use. Maldharis of Banni area have developed a "well in pond" system for conservation and utilization of rain water, called "virda" (Figure 5, 6). Maldharis construct virdas at the bottom of the dried pond to harvest the rain water. Virda is normally constructed to a depth of about three to five meters. The sides of the pit are lined with tree branches (Prosopis juliflora) up to a height of about 1.75 to 2.00 meter from the bottom. A square frame made of woods / tree branches are fixed on the top and grasses are inserted between the wooden branches to control soil erosion and prevent soil particles from entering the well. The unlined upper portions of the wells are made into a sloping circular platform. Maldharis of the village, collaborate in the digging, constructions and renewal of virdas. They dig many virdas at a distance of two to three meters from each others (Figure 7). The number of virdas costructed depends on the requirements of water in the village and all the virdas are connected to common buffalo troughs made of clay. These water troughs are protected from trampling by buffaloes through erection of thorny branches of Prosopis juliflora tree. The duration for which a virda can be used varies from 20 days to four months depending on the intensity of water exploitation and water holding capacity/size of the pond. In a year with normal rainfall, water remains in the large ponds for three to four months and during a good rainfall year up to six months. When water dries up in the ponds, Maldharis start digging out the virdas for getting drinking water. The percolated rain water in the virda remains relatively sweet for 20 to 45 days, but it gets progressively salty. Then villagers remove silt from the next virda a few meters away to access the fresh water. This is repeated until the next rainy season.

Figure 5. Rain water harvesting in Banni region

Figure 6. Typical "virda" for harvesting rain water

Figure 7. Several "virdas" at a place to get drinking water

Population Status

The total buffalo population in the state of Gujarat is about 8.7 millions (Table 1) in 2007 with an increase of about 21.9% in the last five years. Among the 8.7 million buffaloes in the state 38.41% belongs to Mehsana breed, 17.74% Surti, 15.96% Jaffarabadi and 5.98% Banni (Figure 8). About 22% of the total buffalo population in the state is of non-descript type.

Table 1. Breed-wise buffalo population statistics in Gujarat state

Sr. no.	Breed / Population	Population	Percent
1.	Mehsana	33,70,215	38.72
2.	Surti	15,56,856	17.89
3.	Jaffarabadi	14,00,004	16.09
4.	Banni	5,25,015	6.03
5.	Non-descript	18,51,479	21.27
	Total	**8703569**	**100.00**

Source : Anonymous (2007), 18th Livestock Census - 2007, Directorate of Animal Husbandry and Dairying, Gandhinagar, Gujarat

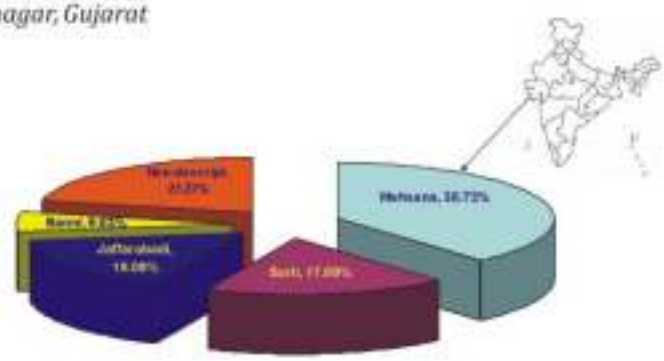


Figure 8. Percent distribution of different buffalo breeds in Gujarat state

The total population of Banni buffalo is reported to be 5.25 lakhs in the state (Anonymous, 2007). The Kachchh district has the maximum population (1,68,93870) followed by Sabarkantna (78,622), Surendranagar (55,588) and Banaskantna (35,142) districts (Table 2). Among the cattle population in the region, only a negligible 0.013% are estimated to be crossbreds with the farmers rearing zebu cattle, mostly for draught purposes. It is clear that farmers in this region prefer buffaloes as their main milk animals.

Table 2. District wise population of Banni Buffalo in Gujarat state

S. No.	Districts	Population	S. No.	Districts	Population
1	Kachchh	1,68,938	13	Anand	21,911
2	Banaskantna	35,142	14	Kheda	39,710
3	Patan	12,261	15	Panchmahal	8,436
4	Mehsana	8,449	16	Dahod	2,507
5	Sabarkantha	78,622	17	Vadodara	14,281
6	Gandhinagar	18,661	18	Narmada	1,214
7	Ahmedabad	4,168	19	Bharuch	4,311
8	Surendranagar	55,588	20	Surat	11,234
9	Rajkot	17,585	21	Navsari	1,523
10	Porbandar	606	22	Valsad	3,696
11	Junagadh	7,890	23	Tapi	6,386
12	Bhavnagar	1,896		**Total**	**5,25,015**

Note: Zero population of Banni Buffalo in Amreli, Jamnagar and Dang, districts.
Source: Anonymous (2007), 18th Livestock Census - 2007, Directorate of Animal Husbandry and Dairying, Gandhinagar, Gujarat

Banni Buffalo Production System

Banni buffaloes are mostly maintained by Maldharis whose livelihood is totally dependent on buffalo rearing for sale of milk, milk products and animals. The Maldharis of Banni are landless, uneducated and mostly without any regular employment of permanent nature. In each village, herds of buffaloes are maintained by a group of villagers under an exclusive traditional production system. Two types of production systems are followed for rearing Banni buffaloes in the breeding tract.

Traditional extensive production system

In lower Banni region (Western Banni) i. e. Nakhatrana and Hajipir area, one time milking (morning alone) is done in 24 hrs as this area is distantly located from the nearby city of Bhuj and only limited facilities are available for transportation of milk. This marketing practice influences the management system of these animals (Figure 9).

Figure 9. Milking of Banni buffaloes by women folk in the breeding tract.

Figure 10. Loose housing of Banni buffaloes

Figure 11. Open house of Banni buffaloes

Figure 12. Calf shelter under trees

The animals go to the forests for grazing in the evening, stay inside the forests overnight and come back to the owner's door early in the morning. Most of the times, the owners do not accompany the animals, and the buffaloes follow the routine on their own. The animals stay loose in the village nearby owner's house and no special housing and supplementary feeding is provided (Figures 10, 11). In greater Banni (Eastern Banni) i. e. Khavda and Bhirandiyara area demand of milk is more as compared to lower Banni. This area has better transport facilities to the main towns and hence two time milking (morning and evening) is practiced. Maldharies in Eastern Banni follow better management practices and provide concentrates to the animals at the time of milking. The concentrates are given according to the productivity of the animals. Also, concentrates are provided to the pregnant animals from the fifth month onwards even after drying. The surplus milk in these areas are converted into khoa, which is later sold for sweet preparation (Figure 13).

Figure 13. Preparation of traditional milk product "Khoa" in the breeding tract

Semi-intensive Production System

The adjoining area of Banni viz. Anjar, Mundra and Bhachau taluks of Kachchh, where crop production is prominent, semi-intensive production system is followed. Farmers from these areas and private dairy owners of Ahmedabad, Surat, Bombay, send their dry animals to Banni on contract grazing at the rate of Rs. 100 to 150, per buffalo/month. These animals are sent back to their owners at about fifth month of pregnancy.

Calf Management

Special attention is given for rearing and management of calves in the Banni region. During the first week, colostrum and ad libdum milk are provided to calves. Maldharis keep the calves of lactating animals in temporary enclosures in open area or under the trees (Figure 12). The boundaries are made through thorny bushes / babul wood supports, weaved up to 3-4 fits height. The calves are kept loose within in the enclosures. Calves are allowed to suckle two times daily, both in the morning and evening. After completion of lactation, the young calves maintained under extensive production system follow the adult animals for overnight grazing.

Feeding Practices and feed resources

Historically, Banni is said to be one of the finest grasslands of Asia. The salinity varies widely in Banni and accordingly grass species and vegetation exist in varying proportions. The important grass species preferred by the Maldharis in Banni area include Dicanthium annulatum (Jinjvo / marvel grass), Cenchrus ciliaris (Dhaman / anjan), Sporobollus fertilis (Khevali / Gharola), Eleusine compressa (Ganthelo / Khevan), Sporobolus helvolus (Okrich), Desmoslenchia bipinnata (Dabh / dabhado / barbha), etc. Mostly, the buffaloes in Banni area sustain themselves by grazing in Banni grasslands. However, in some places like upper Banni, Maldharis offer supplementary feeding to lactating and pregnant animals using home made concentrates (Figures 14, 15).

Figure 14. Feeding of concentrates

Figure 15. Concentrate feeding at the time of milking

Selection and Breeding Practices

The concentrates are made by mixing either 25% cotton seed cake and 75% wheat Bran or 35% groundnut cake and 65% wheat bran. The former mixture is given at the rate of 3 to 4 kg per animal while the later is given at the rate of 4 to 5 kg per animal. During the lean season especially in summer, Maldharis provide dry fodder / grasses supplied by the state government through Banni Development Scheme. Most of the Maldharis in Banni maintain one breeding bull for every 20 to 25 buffaloes in the herd. They have adopted traditional methods for selection of males to improve the genetic potential of Banni buffaloes within the harsh constraints of their environment. Maldharis have a phenomenal capacity to keep track of the animal's ancestry going back three to four generations. For selection of breeding male, a

comprehensive traditional approach is adopted rather than emphasizing only on higher milk production. Typically, they ensure a combination of true breed characteristics, good body conformation and milk production. Normally, health and strength, horn pattern, pedigree information on milk production and disease, behavioral aspects, good herd instinct, ability to be part of a large herd, etc are considered while selecting the bulls for breeding.

Artificial insemination is not followed in Banni area because Maldharis consider Banni buffalo as a distinct category. The extensive production system also limits the artificial insemination services. Maldharis do not allow mating between sire and daughters in order to avoid inbreeding. Breeding males from one village are exchanged with other villages after three / four years regularly. The breeding practices adopted in Banni revealed that Maldharis are well aware of the importance of breeding bull for improvement of genetic potential of buffaloes. Moreover male calves are raised with more attention, proper feeding and management. The demand for Banni buffalo bulls is more and farmers get better remuneration from bulls rather than from heifers.

Disease Prevalence and Mortality

The major health problems reported by the Maldharis in Banni buffaloes are parasitic infestation / diarrhea, respiratory disorders, mastitis, lameness due to injuries during grazing, abortions and foot and mouth disease. Animal health care facilities are very limited in Banni area. Vaccination against Foot and Mouth disease is more common than against Haemorrhagic septicemia. The overall mortality rates in adult buffaloes and calves are reported to be about 1.8 and 4.0 percent respectively.

Migration Pattern in Banni

The southwest monsoon rainfall is erratic and uncertain in Banni and and often making the sustainability of Banni buffalo rearing at stake. The frequent spell of droughts in the region has transformed the livestock genetic resources particularly Banni buffaloes to adapt to adverse conditions under extensive production system. The animals lose body weight during summer season and regain their weight once again the greens become abundant after a favorable rainy season. Some Maldharis start migrating during mid march or in April and the duration and distance of migration, totally depend on intensity of previous year rainfall and feed resources available in the surrounding area / Banni grassland. The migration usually take place within the district and mainly from Banni area to Nakhatrana, Mandvi, Bhuj and Mundra talojas, where, irrigation facilities is available. The Maldharis migrate along with their limited family members with cloths and utensils, etc. The families in groups from the village migrate with their dry animals. The lactating buffaloes and calves in the village are managed by the remaining family members. The migration distance is around 100 to 250 km area within the district.

Physical Characteristics

Banni buffalo is medium to large in body size with compact body and typical coiled horns often with double coiling. The head of Banni buffalo is wide with slight depression in the middle and no slope towards base of the horns. Face is comparatively elongated and straight with a wide muzzle (Figure 16, 17).

Figure 16. Face of Banni buffalo

Figure 17. Typical double coiling of horns in Banni buffaloes.

Eyes are prominent, black and bright. The body is generally covered with hair. The neck of Banni buffaloes is medium and thin without skin folds over the region. The dewlap is almost absent in both the sexes. The chest is slightly deep and the barrel is long with well sprung ribs. The hind quarter is wide, heavy and well developed. The back is wide at hip joint and the overall body is wedge shaped. The legs are medium in length with broad bones and hooves are black, small in size and firmly attached, which might be the effect of adaptation to grazing under extensive production system.

The skin is soft, thin and generally black in colour but few animals are also observed possessing copper colour. In some animals white patches are also observed on forehead, lower legs and switch of tail. The udder of Banni buffaloes is well developed, round in shape and squarely placed. The hind and fore quarters are uniformly well developed. Typically, the whole udder of Banni buffalo looks like four equal divisions with teats well attached to each quarter. Majority of animals have conical teats with round and pointed tips. The breeding bull, she-buffalo and a herd of Banni buffalo breed are presented in figures 18, 19 and 20 respectively.

Morphological Traits

The overall least squares means along with their standard error for various morphological traits are presented in Table 3.

The mean values for most of the morphological traits in Banni buffalo are found to be higher than that of Mehsana buffaloes (Pundir et al., 2000) whereas they are fairly similar to that of reported for Murrah buffaloes (Nivsarkar et al., 2000).

Figure 18. Male Banni buffalo

Figure 19. Banni she-buffalo

Figure 20. Banni buffalo herd

Table 3. Mean + S.E and range of different morphological traits in Banni buffalo.

Trait	Mean + S.E (cm)	Range (cm)
Body length	153.7 + 0.4	147–157
Heart Girth	205.5 + 0.6	195–211
Height at withers	136.7 + 0.2	132-139
Face length	53.7 + 0.2	52–54
Ear length	29.3 + 0.1	28–30
Height at hip bone	127.8 + 0.3	125–129
Height at pin bone	120.3 + 0.3	117–121
Height at elbow joint	70.9 + 0.2	68–72
Distance between hip bone	55.4 + 0.3	53–57
Distance between pin bone	27.9 + 0.1	27–28
Tail length	88.4 + 0.5	87–91
Tail switch length	64.2 + 0.4	62–66
Width of forehead	26.6 + 0.1	26–29

Production Performance

The overall least squares means + S.E for various production and reproduction traits of Banni buffaloes as recorded based on the interview of farmers are presented in Table 4. The mean age at first calving observed for Banni buffaloes (39.7 + 0.4 months) is found to be lesser than that of reported for Murrah [43.9 + 0.2 months (Dhara, 1994) to 53.9 + 0.7 months (Kumar, 2000)] and Mehsana buffaloes (42.8 + 0.4 months, Pundir et al., 2000).

Table 4. Mean + S.E and range of different performance traits in Banni buffalo.

Trait	N	Mean + S.E	Range
Age at first calving (Months)	337	39.7 + 0.4	38 - 41.5
Service Period (Days)	350	66.4 + 1.3	59 - 71
Calving interval (Months)	349	12.2 + 0.7	12 - 12
Services per conception	375	1.0 + 0.1	-
Lactation length (Days)	348	293.3 + 1.5	282 - 298
Dry period (Days)	347	71.8 + 1.4	69 - 74
Peak milk yield (Litres)	397	15.7 + 0.1	12 - 17

Similarly reproductive traits like service period and calving interval are found to be lesser than that of Murrah (Sadana et al., 2006) and Mehsana buffaloes (Pundir et al., 2000). The mean peak milk yield in Banni buffalo is estimated to be 15.7 + 0.1 litres.

Socio-Economics of Banni Region

Banni area contributes a great deal to the economy of the district by producing large quantities of milk, ghee and khoa. The Banni Maldharis are predominantly pastoralists and landless labourers who keep large herds of buffaloes. These Banni buffaloes are an exception to the general rule of water buffaloes which are found in regions where shade and water are abundant. This buffalo is perhaps the only one in the world adapted to arid conditions and very low / limited water availability. Today the sources of livelihood in Banni area are as given below:

i. Sale of animals particularly Banni buffalo.
ii. Sale of milk and milk product (Khoa)
iii. From handicraft and embroidery work
iv. Through contract grazing at the rate of Rs. 100 to 150 per buffalo / month

Genetic Characterization of Banni Buffaloes using Microsatellite Markers

Genetic diversity measures

Different measures of genetic variation like observed number of alleles, effective number of alleles, observed and expected heterozygosity and polymorphism information content (PIC) with respect to Banni buffaloes are presented in Tables 5 and 6. The frequency of alleles at different microsatellite loci are presented in figure 22. A high degree of allelic polymorphism was found to exist in Banni buffalo population with 21 of the 24 microsatellite loci analyzed exhibiting 4 and more number of alleles. A total of 127 alleles was observed with a mean of 5.29 across 24 microsatellite loci ranging from 2 (ILSTS 045 and ILSTS 073) to 10 (ILSTS 058). The observed heterozygosity was found to be moderate with a mean of 0.441 and a range of 0.022 (ILSTS 045) to 0.809 (ILSTS 066) across different microsatellite loci. The overall mean polymorphism information content was found to be 0.525 with 15 of the 24 microsatellite loci having values more than 0.5, 8 having values between 0.25 and 0.50 and only one microsatellite locus (ILSTS 019) having PIC value less than 0.25 (Figure 21).

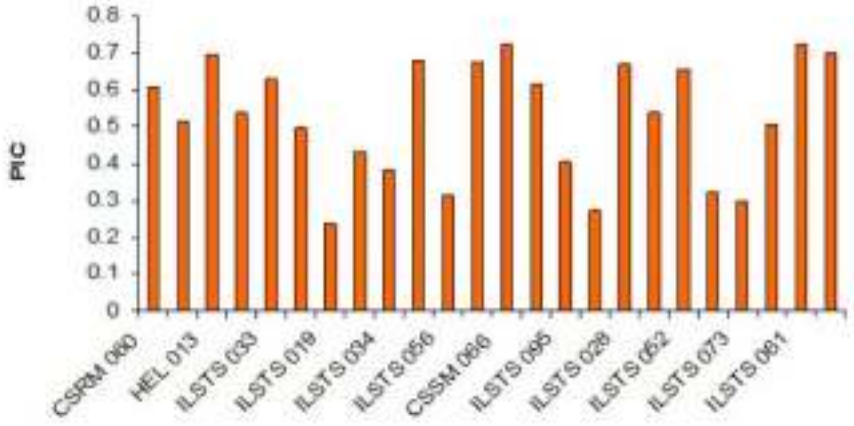


Figure 21. Polymorphism information content observed at different microsatellite loci in Banni buffalo

Figure 22. (a-f) Frequency of alleles observed at different microsatellite loci in Banni buffalo

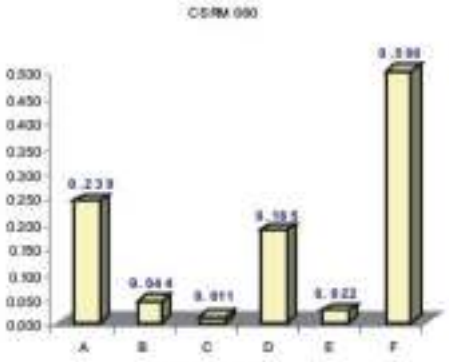
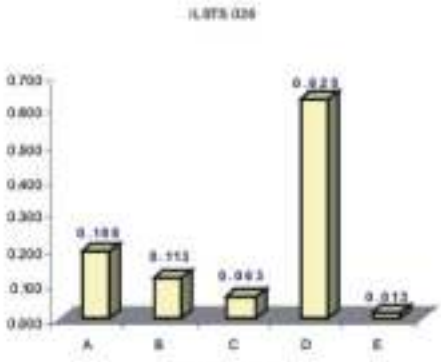


Figure a



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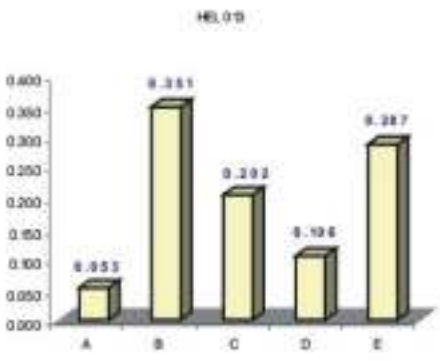

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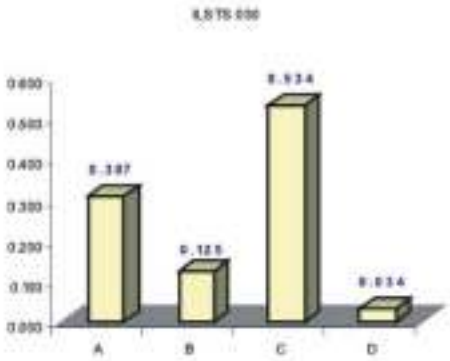

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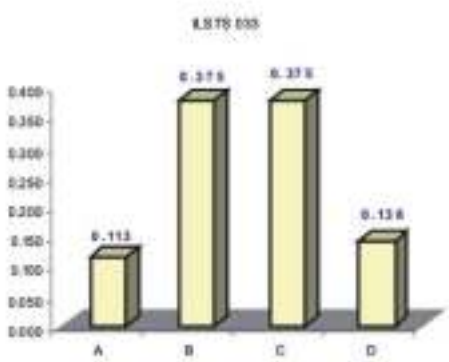

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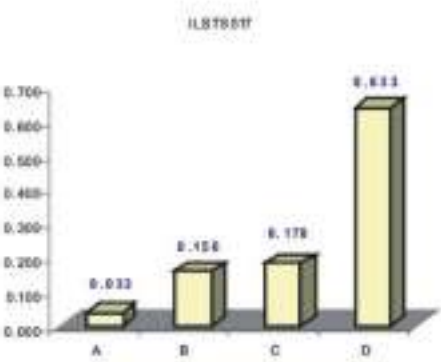
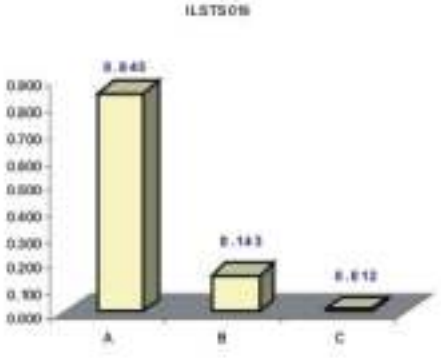


Figure f

Figure 22. (g-l) Frequency of alleles observed at different microsatellite loci in Banni buffalo



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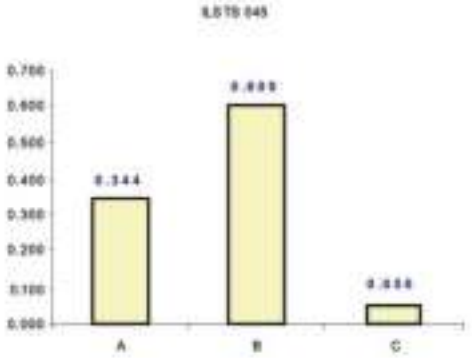

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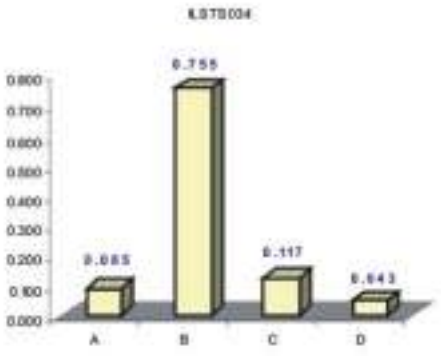

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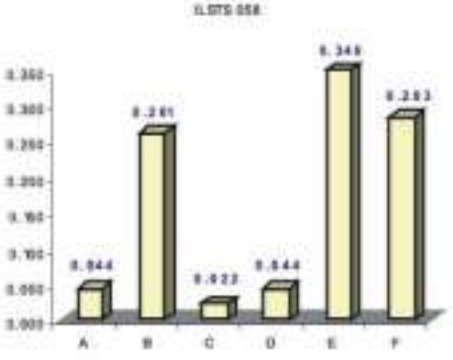

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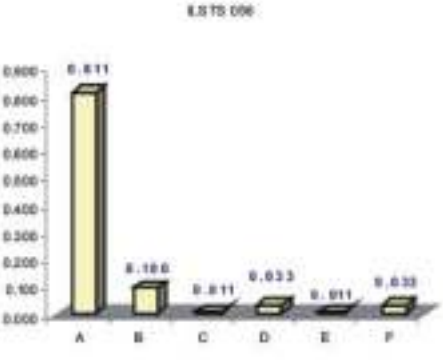

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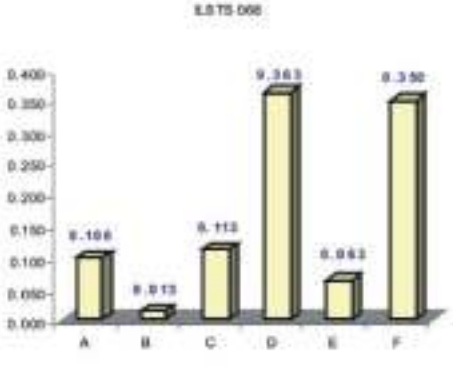
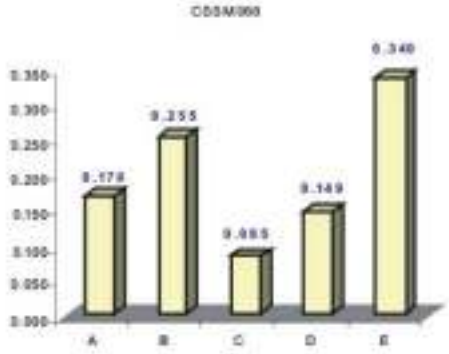


Figure l

Figure 22. (m-r) Frequency of alleles observed at different microsatellite loci in Banni Buffalo



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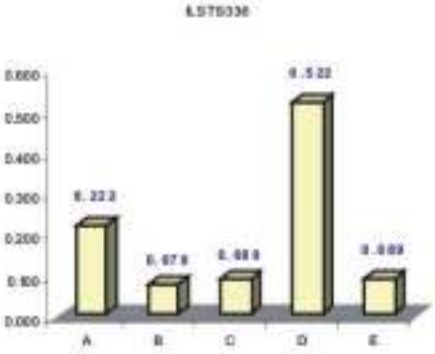

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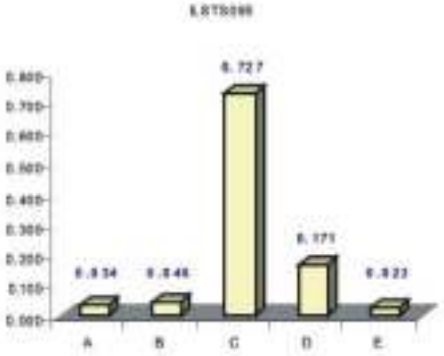

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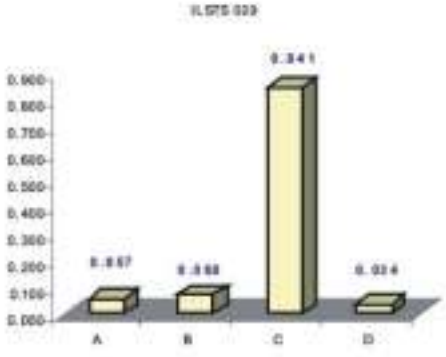

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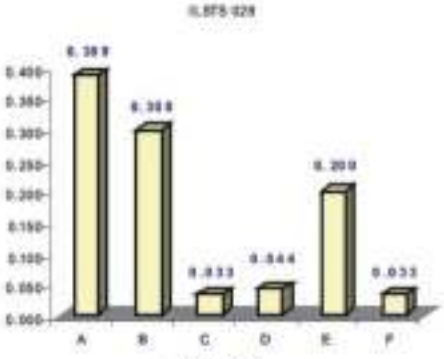

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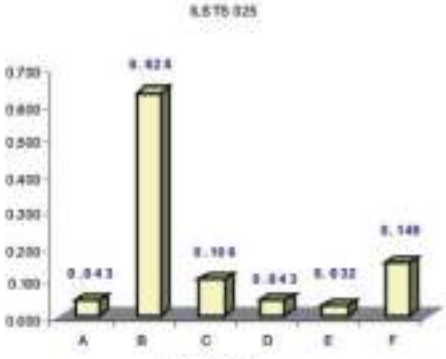
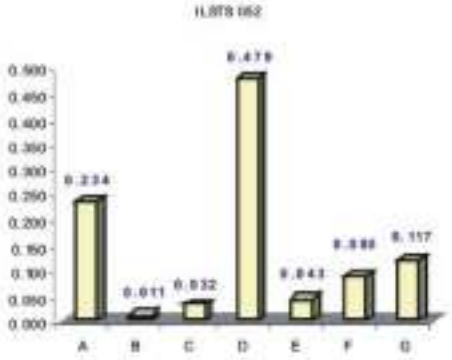


Figure r

Figure 22. (s-x) Frequency of alleles observed at different microsatellite loci in Banni buffalo



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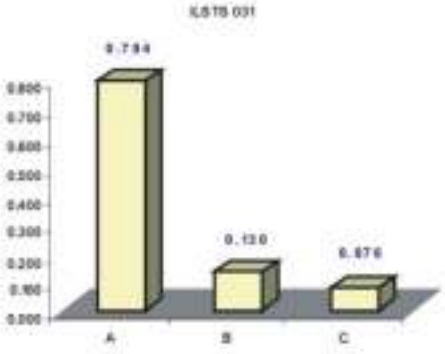

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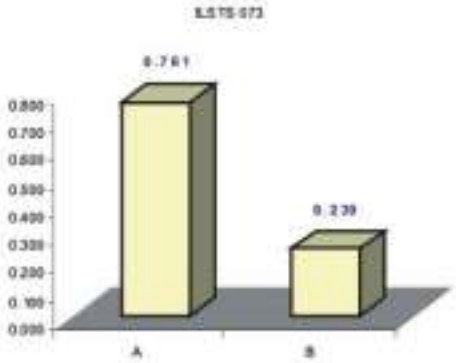

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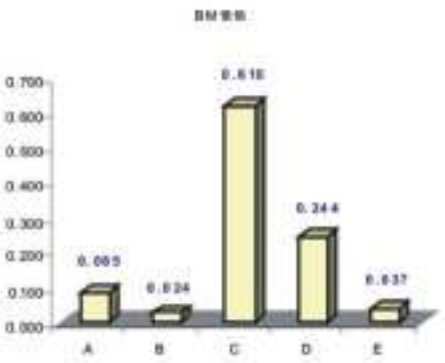

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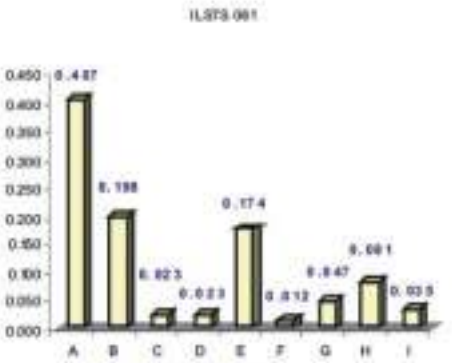

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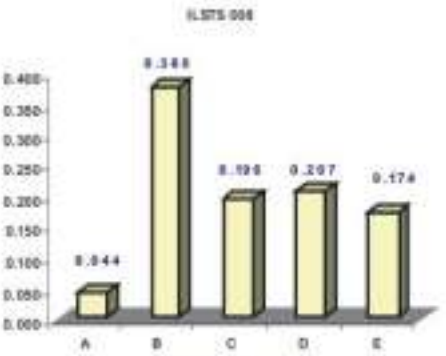


Figure x

According to Botstein et al., (1980), polymorphic markers were classified as highly informative which had a PIC value greater than 0.5, reasonably informative with PIC value ranging between 0.25 and 0.50 and relatively less informative if the PIC value was below 0.25. The allelic diversity and observed heterozygosity values are comparable to that of reported for Bhadawari and Tarai buffaloes (Arora et al., 2004), while they were relatively lower, compared to that reported for other buffalo breeds by Kumar et al., (2006) with a different set of microsatellite markers.

Heterozygosity deficit and Hardy-Weinberg equilibrium

The mean FIS (0.223) across 24 microsatellite loci was significantly positive indicating considerable heterozygosity deficit within the population. Seven of the 24 microsatellite loci analyzed were found to be in Hardy-Weinberg equilibrium (Table 6). These results showed the possible existence of subdivisions within the population. Possible reasons could be selective breeding with fewer available bulls and relatedness of few samples analyzed as proper pedigree records are not available under field conditions. However, the major role of selective breeding in the heterozygosity deficit was not supported by the results of Ewens-Watterson neutrality test as all the microsatellite markers under the present study except ILSTS 008 were found to be neutral. The observed F-value for ILSTS 008 did not fall within the range of 95% confidence interval when the test was performed using 1000 simulated samples. Thus, the genetic analysis showed that Banni buffaloes have a reasonably moderate level of diversity as reflected by average heterozygosity estimates.

Table 5. Observed and effective number of alleles at various microsatellite loci in Banni buffalo

Locus	N	na*	ne*	Locus	N	na*	ne*
CSRM 060	40	5	2.421	ILSTS 036	46	6	4.109
ILSTS 026	43	4	2.038	ILSTS 095	40	8	2.381
HEL 013	45	7	4.880	ILSTS 029	45	4	1.842
ILSTS 030	39	5	2.862	ILSTS 028	44	6	4.084
ILSTS 033	43	6	3.180	ILSTS 025	43	6	4.280
ILSTS 017	41	4	3.054	ILSTS 052	41	7	4.316
ILSTS 019	46	3	1.221	ILSTS 031	35	4	1.899
ILSTS 045	32	2	1.932	ILSTS 073	44	2	1.882
ILSTS 034	43	4	2.188	BM 1818	36	5	2.952
ILSTS 058	41	10	5.679	ILSTS 061	38	7	2.944
ILSTS 056	44	6	3.103	ILSTS 008	39	5	3.935
ILSTS 068	45	5	3.266	Mean		5.292	3.076
CSSM 066	41	6	3.382				

na = observed number of alleles; ne = effective number of alleles

Table 6. Observed (Ho) and expected heterozygosity (He), heterozygosity deficit (FIS) and Hardy Weinberg equilibrium in two buffalo populations

Locus	Ho	He	FIS	HWE p-value
CSRM060	0.478	0.663	0.281	0.012
ILSTS026	0.538	0.597	-0.109	0.030
HEL013	0.717	0.747	0.032	0.038
ILSTS030	0.545	0.611	0.108	0.009
ILSTS033	0.600	0.696	0.139	0.192
ILSTS017	0.205	0.556	0.638	0.000
ILSTS019	0.310	0.268	-0.156	0.632
ILSTS045	0.022	0.524	0.958	0.000
ILSTS034	0.277	0.411	0.330	0.006
ILSTS058	0.435	0.735	0.411	0.000
ILSTS056	0.289	0.333	0.135	0.023
ILSTS068	0.575	0.728	0.213	0.007
CSSM066	0.809	0.769	-0.052	0.002
ILSTS036	0.600	0.663	0.097	0.012
ILSTS095	0.070	0.451	0.848	0.000
ILSTS029	0.205	0.190	0.051	1.000
ILSTS028	0.511	0.723	0.295	0.000
ILSTS025	0.660	0.574	-0.151	0.096
ILSTS052	0.617	0.700	0.119	0.026
ILSTS031	0.326	0.351	0.073	0.374
ILSTS073	0.386	0.368	-0.052	1.000
BM1818	0.366	0.566	0.357	0.000
ILSTS061	0.698	0.763	0.086	0.141
ILSTS008	0.348	0.750	0.539	0.000
Overall	0.441	0.572	0.223	-

Evaluation of Banni buffalo for mutation drift equilibrium

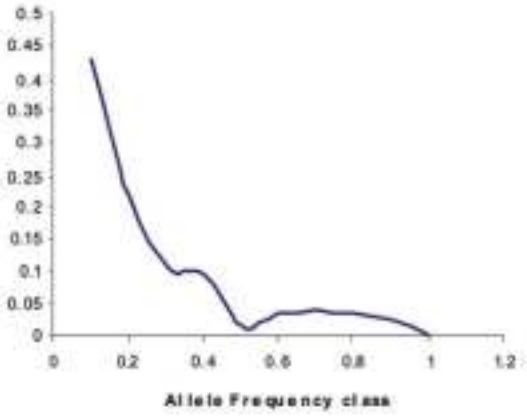
Populations that have experienced a recent genetic bottleneck exhibit a correlative and progressive reduction in allele number and heterozygosity, of which the former is faster in

nature (Nei, et al., 1975 and Denniston, 1978). The resultant transient heterozygosity excess at selectively neutral loci can be utilized to detect genetic bottleneck in naturally occurring populations (Cornuet and Luikart, 1996). The Banni buffalo population was evaluated for mutation drift equilibrium to detect the occurrence of genetic bottleneck in the recent past. Three different tests were performed to detect the microsatellite loci with significant transient heterozygosity excess under the assumption of three different mutation models viz. Infinite alleles model (IAM), Stepwise mutation model (SMM) and Two phase model (TPM) (Table).

Table 7. Different tests for mutation drift equilibrium in Banni buffalo

Test		IAM	SMM	TPM
Sign test	Expected no. of loci with He excess	14.32	14.72	14.84
	Observed no. of loci with He excess	15	13	7
	P-value	0.48	0.31	0.00
Standardized differences test	T2-value	1.18	-5.3	-1.3
	P-value	0.12	0.00	0.10
Wilcoxon sign rank test	P- value (one tail for He excess)	0.04	0.78	0.99

Figure 23. Mode shift analysis showing L-shaped distribution of allele frequencies in Banni buffaloes



Banni buffalo population, when evaluated under strict step-wise mutation model did not show significant heterozygosity excess across the microsatellite loci analyzed. However, when assumed under IAM, Wilcoxon sign rank test (which is statistically superior under conditions of small sample size and relatively lesser number of polymorphic loci) revealed significant heterozygosity excess indicating departure from mutation drift equilibrium (Table 7). It has to be mentioned that only few loci follow strict SMM and many loci can depart towards IAM during the course of natural process. Hence, a two phased model, which is intermediate to SMM and IAM may better fit the microsatellite data (Di Rienzo et al., 1994). However, Banni buffalo population did not show significant deviations from mutation drift equilibrium under this model. The qualitative graphical test to visualize the allele frequency spectra also showed normal L-shaped distribution without any mode shift indicating the absence of genetic bottleneck in Banni buffalo population (Figure 33).

Genetic structure of Banni vis-à-vis other buffalo breeds of the region

In order to resolve the genetic structure of Banni buffalo vis-à-vis other buffalo breeds of the region, a total of 230 animals representing five different breeds of buffaloes viz. Banni, Jaffarabadi, Surti, Mehsana and Murrah were analyzed. The pair-wise estimates of Nm (number of migrants per generation) revealed that the gene flow between Banni and other buffalo breeds of the region being lower than that of other breed pairs, thus indicating the geographic and reproductive isolation of Banni buffaloes. The global F-statistics revealed the genetic differentiation among different buffalo breeds was highly significant ($P<0.01$). The mean FST overall loci was 0.145, while the global heterozygosity deficit was found to be 0.216. Analysis of molecular variance further revealed the percent contribution of different components to the total variance. 14.33% of the total genetic variation was explained by between breed differences while the remaining 85.67% corresponding to differences within each breed.

The dendrogram constructed based on pair-wise chord distance measures following UPGMA revealed the clustering of Mehsana and Murrah at a single node (Figure) followed by the joining of Surti with reasonable bootstrap values. The dendrogram further revealed the distinctness of Banni and Jaffarabadi from the rest of the three breeds analyzed.

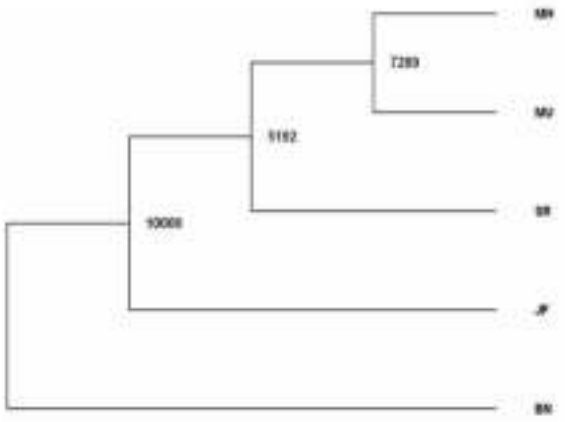


Figure 24. Dendrogram showing genetic relationships among five Indian buffalo breeds based on Cavalli-Sforza Chord distance (BN – Banni; MU – Murrah; MH –Mehsana; SR – Surti and JF – Jaffarabadi)

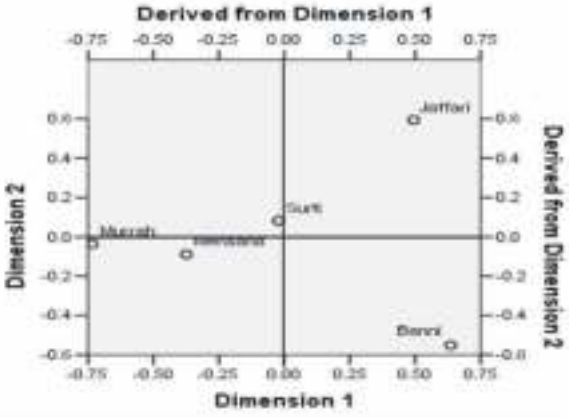


Figure 25. Multidimensional scaling plot of pairwise FST values between different buffalo breeds

Further to confirm the clustering pattern observed in the dendrogram, multidimensional scaling display of pairwise FST values revealed the close proximity of Mehsana, Surti and Murrah while Banni and Jaffarabadi were found to form distinct clusters each separately. Thus, Banni buffaloes were found to be genetically distinct from all the other buffalo breeds of the region.

Banni Buffalo Breeder's Association

Recently, the Maldhari herdsmen came together to form Banni breeders' association called as "Banni Pashu Uchherak Maldhari Sangathan" with a membership of around 650 animal breeders from the region (Figure 26). The main objective of the breeders association is to recognize the Banni buffalo as a distinct breed as well as to conserve and improve this germplasm scientifically supported by their traditional wisdom.

Figure 26. Logo of Banni breeders association

The association has started registering the buffaloes by giving tag numbers to individual animals and has released a directory of elite female Banni buffaloes with data on their milk yield. The association in collaboration with NGOs and other institutions organized Banni Pashu mela (Animal fair) and workshop on breed conservation and breeders' right protection.

Conservation Efforts

The department of animal husbandry, Government of Gujarat has initiated an in situ conservation project called "Conservation and improvement of Banni buffalo in Banni area of Kachchh" under the XI Five Year Plan in collaboration with Sardar Krushinagar Dantiwada Agricultural University (SDAU) and Sajheevan, an NGO. The objectives of the project includes evaluation of socio economic status of Maldharis in Banni, registration of elite females, collection and preservation of semen from bull calves of elite females for artificial insemination and to study the economics of milk production in Banni area. In this regard a Banni buffalo breeding farm has already been established in the breed tract with about 80 lactating buffaloes. Awareness program on the importance of conservation and improvement of Banni buffaloes in the form of "Banni Pashu Melas" are conducted at regular intervals with the participation of Maldharis, NGO's and scientists from Agricultural University, ICAR and Animal Husbandry department.

Constraints and Limitations

1. The major problem faced by the Maldharis is the spread of the invasive weed Israeli Babul, which significantly reduced pasture land (about 40%) and adversely affecting the growth of indigenous grasses in Banni grasslands. There is an urgent need to root out this plant from Banni which will automatically increase the availability of grasses for livestock grazing.
2. Inadequate milk marketing facilities due to lack of proper arrangements for procurement and transport of milk.
3. The trading pattern prevalent in Banni region is leading to erosion of superior buffalo germplasm. High yielding Banni buffaloes are regularly purchased and transported to Ahmedabad, Mubai, Pune, Surat and Hyderabad, where after completion of one or two lactations these elite animals are disposed by slaughter. This unidirectional migration and loss of valuable germplasm leads to genetic drain.
4. Lack of awareness among Maldharis with respect to health care of buffaloes leading to huge economic loss. Incidence of abortions, diarrhea and reproductive disorders are prevalent in Banni region and there is lack of support for government sponsored vaccination programs among Maldharis. Hence promotion of health care and extension services are very much needed in the Banni buffalo breeding tract.

Contact Agencies

1. National Bureau of Animal Genetic Resources, Karnal
2. Sardar Krushinagar Dantiwada Agricultural University, Gujarat
3. Department of Animal Husbandry, Government of Gujarat
4. Banni Pashu Uchherak Maldhari Sangathan
5. Sajheevan, a Non-Governmental Organization

Conclusions

- Banni buffalo, reared in the Kachchh region of western India by traditional Maldhari community is found to have better production potential under an extensive management system.
- These buffaloes are found to be genetically unique from other buffalo breeds of West India as revealed by microsatellite markers.
- The genetic diversity of Banni buffalo combined with their superior production potential make a strong case for the necessity of initiating systematic genetic improvement programs. Further studies need to be carried out in order to establish their genetic superiority by means of performance recording under field conditions.

- Measures need to be taken to revive the grasslands by rooting out the invasive Israeli Babul so that the livestock based sustainable Banni grassland ecosystem is protected.
- Promotion of health care and extension services in Banni region are very much needed to minimize the economic loss due to abortions, diarrhea and reproductive disorders in buffaloes
- The initiatives of the Banni Pashu Ucherak Maldhari Sangathan in creating awareness on conservation and genetic improvement of Banni buffaloes need to be strengthened further.

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