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Source: Zoological Science, 28(4):264-267. 2011.
Published By: Zoological Society of Japan
DOI: http://dx.doi.org/10.2108/zsj.28.264
URL: http://www.bioone.org/doi/full/10.2108/zsj.28.264

ZOOLOGICAL SCIENCE **28**: 264–267 (2011)

Diet Composition and Quality in Indian Bison (*Bos gaurus*) Based on Fecal Analysis

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Diet composition and quality of the Indian Bison (*Bos gaurus*) was estimated by fecal analysis. The results, together with studies in other parts of India, indicate that gaurs are primarily intermediate or adaptable mixed feeders. Fecal composition varied seasonally, with high proportion of grasses, forbs, and woody plant leaves, particularly *Cynodon dactylon, Cyperus rotundus* in monsoon and post monsoon, and *Strobilanthes callosus*, *Strobilanthes ixiocephalus*, *Grewia tiliaefolia* and *Syzygium cumini* in winter and summer. Gaur selected herbs, shrubs, and grasses, and avoided eating woody plants for most of the year. Seasonal changes in the chemical composition of the feces were related to changes in phenology. The levels of crude protein, within certain limitations, and lignin in the feces were probably the most reliable indicators of diet quality. The ratio of crude protein:lignin was highest in monsoon and winter, corresponding early growing and fruiting seasons respectively. The usefulness of feces in estimating the composition and quality of the diet of an intermediate feeder is assessed.

Key words: Indian Bison, *Bos gaurus*, diet quality, fecal analysis, crude protein, lignin

INTRODUCTION

Body size is a major determinant of ruminant energy requirements . The body length of gaur is usually 250–360 cms, with withers height of 170–220 cms. Males may weigh between 1000–1500 kg, and females between 700–1000 kg. Ungulates, such as the gaur, have higher energy requirement/ unit body weight than other species. This can only be met by selecting higher quality forage, which tends to be more dispersed in the habitat than the lower quality forage selected by smaller ruminants (Bell, 1970; Jarman, 1974).

The digestive system of ruminants may be classified into three main types: (1) concentrate feeders, or browsers, which mainly feed on the foliage of trees, shrubs, or forbs, (2) bulk and roughage feeders, or grazers, which feed predominantly on grasses, and (3) intermediate, or adaptable mixed feeders, which either browse or graze depending on what is locally available (Hofman, 1973). The digestive strategies of browsers and grazers are different. Browse contains indigestible material in the cell wall, mainly lignin and structural carbohydrates (such as hemicelluloses and probably cellulose that are bound to it). Little benefit is gained from retaining browse in the rumen for lengthy periods because lignin is absolutely not digestible. Browsers, therefore, maximize the extraction of the digestive cell contents by having a short period of digestion in order to process as much matter as possible. In contrast, grazers have longer retention times to facilitate fermentation of the cellulose in the cell wall (Van Soest 1980, 1982).

Most bovids are either concentrate feeders or mixed feeders. The aim of the present study is to determine the feeding habits using the botanical and chemical contents of feces as indices of diet composition and quality.

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doi:10.2108/zsj.28.264

MATERIALS AND METHODS

Study area

Indian Bison or gaur (*Bos gaurus*), a vulnerable species (IUCN, 2007), was studied in Bhagvan Mahaveer Wildlife Sanctuary and Mollem National Park (BMWLS and MNP) between July 2004 and June 2008. Bhagvan Mahaveer Wildlife Sanctuary and Mollem National Park situated in the south-western ghats of Goa encompasses an area of 240 sq.km ascending to an altitude of over 800 m and lying between latitude 15°14′09.82″–15°22′51.57N and longitude 74°09′47.79″–74°20′02.92″E. The forest cover of this area has been classified as tropical evergreen, semi-evergreen, moist deciduous, and south Indian subtropical hill savannah woodlands (Champion and Seth, 1968). Gaur is the state animal of Goa and inhabits the sanctuary in an approximate population of 250–300 individuals (Pers. Comm. Forest Dept., Goa).

Composition of the diet

Diets were examined by identifying and quantifying fragments of plant epidermis egested in the feces. A reference collection of epidermal material from plants in the study area was prepared and used to aid identification. Fecal analysis was used because direct observation, ruminal analysis and fitsulative techniques were not possible. The area of plant epidermal fragments, as well as their frequency of occurrence, was considered in order to account for differential fragmentation of plant material (Hanson, 1970; Stewart, 1967).

Seventy dung samples were collected from droppings found between 2004 and 2008. Dung samples were handpicked from different sampling sites throughout the year. As there are no other large ungulates in the study area, the gaur dung could easily be identified as a large black pile of fecal matter. The pellets were dried in the sun, and stored in sealed polythene bags for subsequent laboratory analysis.

The commonly practiced alternative of reducing fragments to a uniform size, by grinding fecal material over a standard mesh screen was not employed, as this tends to make the fragments more difficult to identify.

Samples were boiled in about 2–3 ml of chloral hydrate solution directly for few minutes. If the chloral hydrate was too dark, the powder was allowed to settle, supernatant poured off and fresh quantity of chloral hydrate added and boiling repeated. After cooling distilled water was added and the material was boiled again. It was cooled, allowed to settle and supernatant poured off. This washing was repeated until the solution was clear.

Dehydration with alcohol following washing two or three times was done to remove all the water. It was passed through grades of alcohol:xylol mixtures (alcohol:xylol; 3:1, 1:1, 1:3) and finally in pure xylol. Mounting was done in DPX. (Satakopan, 1972).

The plant reference material, comprising about half of the total number of > 100 species identified in the study area, was prepared in the above manner. Epidermal fragments from the reference plants were photomicrographed to facilitate quick comparison with the fecal material.

Slides of fecal material were examined under binocular microscopes at a magnification of 100X. The first 20 fragments of leaf epidermis were identified for each slide making a total of 100 fragments/composite sample. The area of each fragment was measured with a graticule fitted in the eyepiece of the microscope. Fragments were counted in systematic transects across a slide along alternate rows to avoid duplication.

Availability and selection of food

The study of food selection was based on seasonal comparison between the composition of the feces and that of available vegetation, using Ivlev's (1961) index of selectivity:

$$\text{Selectivity} = U - A / U + A$$

Where U = percent use and A = percent availability. A positive index indicates selection for a particular food item, whereas a negative value indicates that it is avoided (Table 1). The standing crop of all vegetation within reach of gaur was used as a crude measure of forage availability. The vegetation was sampled in summer, winter, monsoon, and post monsoon, and classified into the following categories: leaves of woody plants (i.e trees and shrubs plus bamboo), grasses, forbs, and bark. A distinction was also made between ground vegetation, such as grasses and forbs, and aerial vegetation, such as woody plant leaves. Twenty-two sampling points were located along a single transect which passed through all of the vegetation zones in the study area. It was not possible to survey cliffs and other exposed rocky terrain. Vegetation samples were dried in an oven for 24 hrs and subsequently weighed.

Quality of the diet

It was not possible to examine the relationships between the levels of chemical indicators in the diet and in the feces of gaur, but studies of other wild ungulate species have shown that relationships do exist.

Dung samples were collected from between July 2004 and June 2008 and pooled into monthly composite samples as in the micro histological procedure for the analysis of crude protein. Duplicate samples were analysed sequentially. Usually there was only enough material for a single separate determination of crude protein.

Crude protein, measured as nitrogen 6.25, was determined by Kjeldahl procedure (AOAC, 1990). Cellulose and lignin contents were analyzed using the Van Soest (1975) detergent procedure, analysing neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL). For the ADL analysis, the samples were soaked in 12M Sulphuric acid for three hours and thoroughly washed with boiling distilled water. Lignin is very difficult to analyse accurately because it is insoluble and therefore cannot be determined directly by any specific procedure.

RESULTS

Botanical composition of the feces

Gaurs were found to be primarily intermediate or adaptable mixed feeders with grasses, shrubs and herbs and forbs constituting the bulk of epidermal fragments. Grasses such as *Cynodon dactylon*, *Digitaria sp.* and *Cyperus rotundus* were predominantly eaten in monsoon, post monsoon, and winter, but tall grasses such as *Bambusa arundanacea* and *Dendrocalamus strictus* were eaten throughout the year.

Spermacoce sp. and *Vetiveria zizanoides* contents fluctuated similarly with high levels in feces in winter. Forbs were eaten year round, even in summer when few were available. The proportion of forbs in feces progressively increased from a minimum level of about 15% to 50% in winter.

Graminoids (grasses, sedges, and bamboo) usually accounted for > 60% of epidermal fragments. Levels of grasses and sedges tended to be highest in monsoon and post monsoon whereas those of bamboo were normally highest throughout the year. The compositions of woody plant leaves never exceeded 15% in monsoon and post monsoon, but were found to be highest (40%) in summer (Fig. 1).

Table 1. Comparison between the availability (%) of various categories of plants and the composition (%) of gaur feces in different seasons.

Season	Plant category	Composition (U)	Availability (A)	Selectivity U–A/U + A
Winter	Grasses and sedges	7	5	0.2
	Forbs	16	10	0.2
	Woody plant leaves	6	5	0.1
	Bamboo	2	0	1
Summer	Grasses and sedges	2	30	–0.9
	Forbs	15	13	0.8
	Woody plant leaves	30	20	0.2
	Bamboo	2	0	1
Monsoon	Grasses and sedges	23	5	0.6
	Forbs	25	30	–0.1
	Woody plant leaves	3	23	–0.8
	Bamboo	2	0	1
Post-monsoon	Grasses and sedges	35	5	0.8
	Forbs	18	7	0.4
	Woody plant leaves	3	23	–0.8
	Bamboo	2	0	1

Availability and selection of food:

Green vegetation was more abundant in monsoon, post monsoon, and winter than in summer, when green vegetation dries up nearly completely. Ground vegetation constituted between 75% and 100% of the standing crop within reach of gaur. The most abundant sources of potential forage in winter were

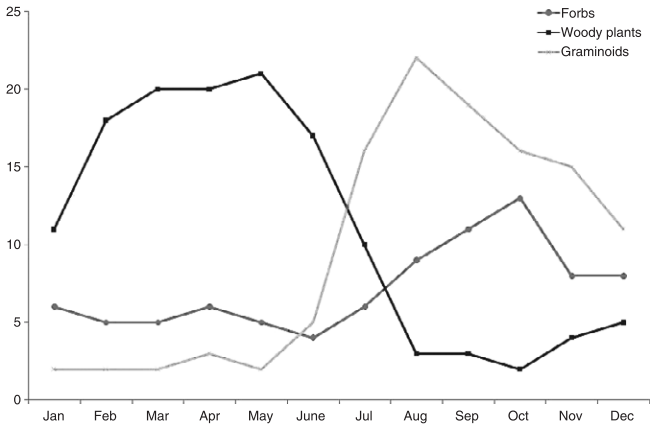

Fig. 1. Seasonal variation in plant epidermal fragments based on fecal analysis.

bamboo and *Strobilanthes* leaves, as supplies of fresh green grasses were limited. Seasonal comparison between the composition of the feces and that of the available vegetation indicates that leaves of woody trees were avoided throughout the year except in summer when green vegetation was scarce.

Three species of *Strobilathes* were available in the study area which comprised of more than 60% of ground vegetation in winter and summer. *Strobilanthes* species were the most preferred among the ground vegetation. *Dendrocalamus strictus* and *Bambusa arundinacea* were also available in abundance throughout the sampled plots and hence constituted the bulk of epidermal fragments in all season.

Quality of the diet

Monthly fluctuation in the levels of chemical constituents of the feces was reasonably consistent during the study period, particularly crude protein, and was compatible with changes in forage quality. The crude protein content of the feces was high during the monsoon and post monsoon and low in summer. Conversely faecal cellulose was low in monsoon and post monsoon and high in summer. The negative correlation of crude protein with cellulose content is significant ($r = –0.798$, $N = 24$, $P < 0.001$).

DISCUSSION

Using feces to estimate diet quality

Crude protein or nitrogen and lignin levels in the feces are probably the most reliable indices of diet quality although cell-soluble, hemicelluloses, and cellulose contents provide useful additional information, particularly regarding seasonal changes in chemical composition. Fecal nitrogen consists of three different sources, viz. undigested dietary nitrogen delivered from diet and microbial protein; metabolic fecal nitrogen, which comprises microbial cell wall from the rumen, and endogenous nitrogen (Mason, 1969; Van Soest, 1982). The level of bacterial nitrogen excretion is largely determined by the level of intake of fermentable energy, and therefore provides an indirect measure of crude protein intake, due to the relationship between digestible energy and crude protein content (Breden et al., 1963).

The relationship between cell-soluble matter in the feces and in the diet apparently has not been studied. The fecal cell contents do not include much soluble carbohydrate, lipid or protein originating from the diet because most of this is digested. The bulk of the cell-soluble fraction in the feces probably comprises endogenous material arising from bacterial and microbial cells, as well as from epithelial slough from the gut.

Table 2. The chemical composition (% dry matter) of monthly composite samples of gaur diet.

	CP	ADL	Cellulose
Summer	10	15	40
Monsoon	25	35	25
Post-monsoon	25	35	25
Winter	20	30	20

Diet composition

The chemical composition of gaur feces varied seasonally with changes in phenology. Seasonal variation with respect to plants eaten was well marked. The high level of protein and low level of lignin in monsoon probably reflect a diet of green shoots. The low levels of protein and lignin in summer are suggestive of a diet of fruits (Table 2). During summer the green grass and herbaceous resources dries up. As a result gaur may also browse on forbs and teak bark. In dry season, high fibrous diet increases the retention time of food in the gut (Owen-Smith, 1988) and also decreases the turnover rate of the rumen contents (Bell, 1971).

Studies conducted by Sathyanarayana and Murthy (1995) in Tamil Nadu revealed that gaur feed selectively in grass-dominated areas, and are primarily grass eaters. They also reported that animals prefer to feed on only the upper portion such as leaf blade, stem, seeds, and flowers of grass species. Further they added that gaur prefers fine and coarse grass to fresh grass. However in the present study, fine and fresh grass was preferred over coarse grass species and, during the dry season, gaurs browsed on tree species. Srivastava et al. (1996) based on their microhistological studies on gaur diet in Periyar Tiger Reserve, Kerala reported that 90% were grass species and 10% were herbs and shrubs.

Shukla and Khare (1998) with their studies in Pench wildlife reserve, central India reported that gaur grazed and browsed on a much wider variety of plants than any other ungulate species of India. It fed on green grass, young leaves and soft shoots during favourable forage conditions. They further reported that gaur hardly discriminated between low and high quality food during severe season. Domestic ungulates regarded primarily as grazers also browsed on several plant species during hot season.

On the basis of its feeding habits, we tentatively conclude that gaur is an intermediate or adaptable mixed feeder with the ability to adapt to poorer diets when high quality food is in short supply, such as in winter. Further studies can draw firmer conclusions.

ACKNOWLEDGMENTS

We wish to thank Prakash Salelkar and Amar Heblekar, Range Forest Officers in-charge of Mollem Range, and other staff for help-

ing us in field work. We also thank the Forest Department, Government of Goa for permitting us to carry out research on gaur.

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(Received May 13, 2010 / Accepted September 15, 2010)