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Dietary overlap between cattle and chital in the Queensland dry tropics

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Abstract. Chital deer (*Axis axis*) are an ungulate species introduced to northern Queensland, Australia, in an environment where land is managed for large scale cattle production. Rainfall and pasture growth are markedly seasonal and cattle experience a nutritional shortfall each year before monsoon rain. The presence of chital is perceived by land managers to reduce dry-season grass availability and this study sought to estimate the potential effect of free-living chital on regional cattle production. Diet overlap was greatest during the wet season when both ungulates principally consumed grass, and least during the dry season when chital diet comprised only ~50% grass. Using local estimates for energy values of wet and dry season grass, and the maintenance energy requirements of chital and cattle, we estimated the relative dry-matter seasonal grass intakes of both ungulates. The grass consumed annually by 100 chital could support an additional 25 cattle during the wet season and an additional 14 cattle during the dry season.

Keywords: *Axis axis*, cattle, Chital deer, co-grazing, diet, dry matter digestibility, dry tropics, forage, grazing, grazing equivalents, introduced species, rangelands, seasonal, ungulates.

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Introduction

Since European colonisation there have been 15 ungulate introductions to Australia that have resulted in free-living populations (Bomford and Hart 2002), including six species of deer all of which have the potential to increase their current abundance and distribution (Davis *et al.* 2016). The impacts of naturalisation of non-native ungulate species are varied according to context but include reduced abundance of native wildlife (Dolman and Wäber 2008), degradation of ecological communities (Husheer *et al.* 2003), disease transmission (Bengis *et al.* 2002), and dietary overlap with domestic livestock (Hansen and Reid 1975).

Chital deer (*Axis axis*) maintain a distribution close to their point of release in 1886 in the Burdekin dry tropics north of Charters Towers in Queensland. Since original release, the local population has maximally spread some 100 km and reached an estimated population of 32 000 animals with densities varying widely across the range from negligible to $>170/km^2$ (Brennan and Pople 2016). Other large herbivores reliant on the same forage resources include three principal species of macropod, eastern grey kangaroo (*Macropus giganteus*), red kangaroo (*Osphranter rufus*) and common wallaroo (*O. robustus*) present at a combined average density of $4.4/km^2$ in 2014 (https://www.qld.gov.au/__data/assets/pdf_file/0027/67725/quota-submission2018.pdf, accessed 16 October 2020), and cattle (*Bos indicus*), present at $\sim5–25/km^2$ (McIvor 2012). Landholder attitudes to wild deer in the Burdekin district have changed since 1990, concurrent with a perceived increase in their population size. Current attitudes of landholders to chital are predominantly (although not uniformly) negative, with the belief that they compete with cattle for grazing resources (Brennan and Pople 2016).

Predominant land use in the Burdekin dry tropics is extensive beef cattle production, average property sizes being ~30 000 ha carrying an average herd of ~3400 cattle (McIvor 2012). The primary limitation to beef production in northern Queensland and indeed northern Australia is nutrition, in terms of both seasonal availability and quality (McCown 1981). In the dry tropics rainfall is concentrated over summer months resulting in an annual nutritional shortfall for both cattle (McLean *et al.* 1983) and chital (Watter *et al.* 2019*a*) before the onset of the wet season. Dry season pastures are principally deficient in energy and protein (Mlay *et al.* 2006), although cattle in northern Queensland also show responses to supplementation of minerals including phosphorus (Ternouth 1990), sodium and sulfur (Hunter *et al.* 1979). Nutritional deficiencies affect cattle by reducing growth rates and reproductive output. Although supplementary feeding of cattle in the dry season is intended to overcome specific nutritional shortfalls, most particularly nitrogen, the success of feeding regimes is reliant on there being adequate standing dry grass to provide a source of energy as carbohydrate. It is common to feed nitrogen in the form of urea in a substrate of either molasses or salt (Holroyd *et al.* 1977) with the principal benefit to cattle being the stimulation of rumen microbial protein production (McLennan *et al.* 1981) and increased intake and digestibility of poor quality roughage (Iwuanyanwu *et al.* 1990). To conserve grass through an extended dry season, cattle stocking rates must be managed in concert with other herbivores competing for the same resources.

Both macropods and cattle are considered primarily grazers, but chital are known to alter their diet seasonally and exploit a range of non-grass forages including forbs, shrubs and trees both in India (Dave 2008), and the north Queensland dry tropics (Watter *et al.* 2020). The change from wet season grazer to dry season mixed feeder (Dinerstein 1979) means that the level of dietary overlap between chital and cattle varies throughout the year. During the wet season when pasture biomass, particularly grass, is abundant, the commercial impact of chital grazing agricultural land is negligible. However, during the dry season when seasonal rainfall, plant growth and pasture biomass are predictably low, the grass consumed by chital throughout the year is a cost to cattle production. This study estimates the relative seasonal intakes of grass by cattle and chital and thus the herbivory cost of chital co-grazing pastures with cattle.

'Grazing equivalents' are commonly used in Australian agriculture to estimate the cost of wild herbivores to domestic livestock production. Australian 'dry sheep equivalents' refer to the energy required to maintain a 45 kg Merino wether, which on an energy basis equates to ~2.1× for a 45 kg fallow deer (*Dama dama*; Tuckwell 2003), or 0.4× for eastern grey kangaroos (Dawson and Munn 2007). However, the extent of competition between grazing animals will depend on whether food is limiting and vary according to the degree of dietary overlap between forage species consumed within and between seasons (Dawson and Munn 2007). Where food is abundant and herbivores can display preference for types of food (Watter *et al.* 2020), there may be little dietary overlap. However, during the dry season when food availability is restricted, competition between grazers would be expected to increase.

By applying known energy requirements for cattle and chital, the estimated metabolisable energy (ME) contents of tropical grasses, and the relative intake of grass by both species we determined a grazing equivalent based on grass consumed. This measure is meaningful to cattle producers who may view increasing chital numbers in terms of a reduction in the carrying capacity of their grazing land for cattle.

Materials and methods

Study area and climate

The study site, 'Spyglass' is a 38 200 ha Queensland government owned cattle property located ~110 km north of Charters Towers (20°06.0S, 146°16.0E) in northern Queensland, Australia. The district experiences seasonal rainfall with 79% of the average (598 mm) falling in the five months from November (https://www.longpaddock.qld.gov.au, accessed 16 October 2020). Average maximum temperatures in summer are 34°C (December) and minimum averages in winter 11°C (July). The environment is an open savanna comprised of vegetation dominated by trees, narrow-leaved ironbark (*Eucalyptus crebra*) and yellowjacket (*Eucalyptus similis*) and a mixture of native (*Dactyloctenium radulans*) and introduced (*Cenchrus ciliaris*) grasses. In years of average rainfall Spyglass supports a herd of ~4000 adult cattle.

Model for comparing grazing impact of cattle and chital

The 'energy' model used for comparing chital and cattle makes two necessary assumptions. First, that food intakes of both cattle and chital are at maintenance levels for energy year-round rather than increased levels required for both growth and reproduction. The second assumption is that both animals utilise the same environment (i.e. spatial grazing overlap). The data by which the two species are compared are the differences in seasonal intake of grass and the differences in efficiency of grass utilisation while considering the wet and dry season differences in the ME of available grass. The unit of comparison is the relative seasonal dry matter (DM) consumption of grass by chital and cattle which results in average sized chital and cattle maintaining bodyweight.

Estimation of grass intake by cattle and chital

The diet composition of cattle and chital was estimated during one dry season (October 2015) and during the following wet season (March 2016). These sample times were chosen to represent periods of minimal and maximal pasture biomass resulting from differences in seasonal rainfall. The method of estimating grass intake differed between herbivores due to the commercial value of cattle and the availability of chital samples as part of a larger ecological study (Watter *et al.* 2019*a*). Grass-to-non-grass ratios of the cattle diet were estimated using faecal near infrared reflectance spectroscopy (fNIRS). This technique differentiates between non-digested tropical grass (C_4 species) and non-grass (C_3 species) in faecal matter which has been shown to correspond to $C_4:C_3$ ratios in the diet (Coates and Dixon 2007). Estimations of grass intake of chital were made by macroscopic examination of rumen contents of chital (Watter *et al.* 2020) shot at the same location and during the same seasons. Sample collection from chital and cattle occurred during the same 5-day periods to minimise variation in diet due to variation in available vegetation.

Cattle faecal samples were collected, individually bagged and frozen for transport to the laboratory. There they were thawed, oven-dried at 60°C for 8 hours, ground using a centrifugal mill (Foss Cyclotec 1093, Hillerød, Denmark) to 1 mm, re-dried overnight at 60°C and scanned using a Foss 6500 near-infrared spectrometer (Foss A/S, Hillerød, Denmark). These data were analysed using the prediction equation (Coates and Dixon 2008) derived from cattle fed diets containing tropical (C_4) grasses and (C_3) non-grasses which predominate in the tropics.

Estimation of grazing equivalents of cattle and chital

The variation in the value of food plants to grazing animals is principally due to differences in the DE of foods and secondarily due to animal differences in converting DE to ME. Energy available to animals from food is ME, and can be estimated by applying a coefficient (which is species specific) to the measured DE of a food. This coefficient is empirically derived, and is a measure of the efficiency with which animals convert DE to ME (Dryden 2011). Although the conversion is influenced by the quality of forage which animals receive, this was not a factor in our study which compared different ruminants accessing the same forage. For cattle, the conversion factor of 0.82 is reliable in the absence of predictions of energy loss through urine and methane (Tedeschi *et al.* 2017). It ranges in deer species from 0.83 to 0.88 (Dryden 2011). With no conversion factor available for chital, we used 0.85, which has been determined for rusa deer (*Cervus timorensis*) (Dryden 2011), which is a similar-sized Asiatic cervid. Higher conversion factors in cervids suggest that deer convert DE to ME more efficiently than cattle. Metabolisable energy of food is converted to net energy (NE) available to the animal, and predicted by the equation (for maintenance), $ME_m = NE_m/k_m$, where k_m is the efficiency of conversion of ME to NE, ($k_m = 0.02$ M/D + 0.5), and M/D is the ME content of the food, (MJ/kg DM) (Dryden 2011).

The nutritive value of tropical grasses in the Charters Towers region varies principally according to the stage of growth with actively growing plants in the wet season having higher dry matter digestibilities (DMD) and ME values than senescent dry season plants (McIvor 1981). Only minor differences in DMD were attributed to either species or differences between leaf and stem from three grass species reported. Mean wet season DMD was ~65%, reducing to ~40% in the dry season (McIvor 1981), corresponding to ME values of 9.0 MJ ME/kg DM and 4.8 MJ ME/kg DM, (ME = 0.17 DMD% – 2.0) (Moran 2005).

The average net energy requirement for maintenance of non-lactating adult deer and cattle is 0.39 MJ/kg$^{0.75}$/day (Dryden 2011) and 0.322 MJ/kg$^{0.75}$/day (Lofgreen and Garrett 1968) respectively. Comparisons between grass consumption of chital and cattle were made on the basis of the proportion of grass in the diet, the seasonal ME content of the grass and the animals' net daily requirement for energy.

Results

Diet composition

Chital diet analysis by macroscopic examination of rumen contents showed a significantly greater utilisation of grass as a proportion of dry matter intake during the wet season (mean = 95%, $n = 20$), compared with the dry season (mean 54%, $n = 18$), (Watter *et al.* 2020). The non-grass component of chital diet comprised 38 dicotyledons identified at least to genus, and these were consumed to a greater extent during the dry season (Watter 2020). By contrast the grass intake of cattle showed less seasonal variation and there was no significant difference ($P > 0.05$, $t = 1.54$) between the wet (mean = 91%, $n = 22$) and dry season (mean = 88%, $n = 20$) (Fig. 1).

Estimate of chital grazing equivalent to cattle

The average weight of 163 adult chital carcasses including gut fill was 55.2 kg from 73 males (mean = 69.2 kg, se = 1.56) and 90 females (43.8 kg, se = 0.75). The average net energy requirement for maintenance of non-lactating adult deer is 0.39 MJ/kg$^{0.75}$/day irrespective of species (Dryden 2011). Hence the average daily net energy requirement would be 7.9 MJ.

The net energy requirement for maintenance of cattle is 0.322 MJ/kg$^{0.75}$/day (Lofgreen and Garrett 1968). A non-pregnant and non-lactating cow weighing 450 kg would require 31.5 MJ NE/day. Thus, the total NE required to maintain a 450 kg cow is four times the NE required for an average weight chital deer.

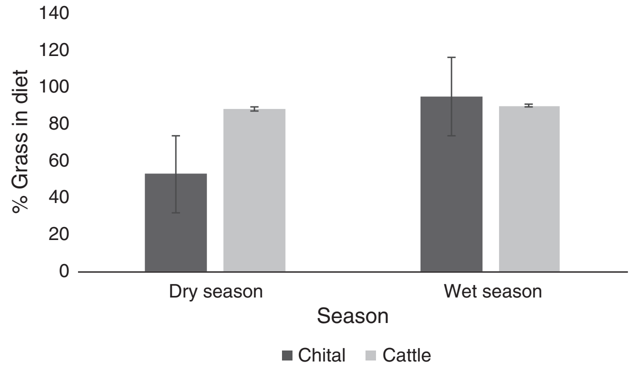

Fig. 1. Percentage (± s.e.) of grass in the diet of chital and cattle during wet and dry seasons.

The comparison of chital diet to cattle diet is restricted hereafter to the grass component as this is the predominant portion of cattle diet. The greatest dietary overlap between chital and cattle occurred during the wet season when both species predominantly ate grass. Using a wet season ME value for grass of 9.0 MJ/kg DM and dry season value of 4.8 MJ/kg DM (McIvor 1981), the daily grass consumption by cattle and chital can be calculated (Table 1), and so the grazing equivalent estimated.

The proportion of grass in cattle diets declined from 91 to 88%, between wet and dry seasons, indicating that at maintenance, respective DM grass intake would double (Table 1), a consequence of a concurrent decline in feed quality of the grass. Wet season consumption of grass by chital was 96% of the diet and reduced during the dry season to 53%.

Although NE requirements of chital and cattle would equate one cow to four chital annually, the degree of overlap between diets suggests that the relationship in terms of potential competition for food is differs between seasons. In terms of grazing offtake on the grass component of the pasture, a chital consumes ~25% of the amount of grass as a cow during the wet season and 15% during the dry season (450 kg cow, 55 kg chital, non-pregnant and non-lactating, maintenance ration). On a grass only basis, one cow consumes approximately the same as four chital during the wet season, and seven chital during the dry season.

Discussion

Comparison of the diet of chital and cattle indicates a different and variable reliance on grass. While cattle consumed grass at a constant proportion of around 90% of forage intake, the proportion of grass intake by chital varied significantly between seasons. Grass was the dominant available pasture plant type in both seasons, but senesced more than browse items in the dry season (Watter et al. 2020). Seasonal intake by cattle reflected plant availability, while chital intake reflected a preference for plants most actively growing. Cattle preferred grass in both seasons, taking both the actively growing and senescent form of the plant consistent with their morphological classification as 'grass and roughage' eaters (Hofmann 1989). Their proportionally large

Table 1. Dry weight of grass eaten per day by cattle ($n = 22$) and chital ($n = 20$) during wet and dry seasons based on maintenance metabolic rates of both cattle and chital

ME, metabolisable energy

	Grass in diet (%)	Net energy requirement (MJ/day)	ME content of grass (MJ/kg DM)	k_m	ME requirement (MJ/day)	ME from grass/day (MJ/day)	Grass per day (kg DM)
Cattle wet season	91	31.5	9.0	0.68	46.3	42.1	4.7
Chital wet season	96	7.9	9.0	0.68	11.6	11.1	1.2
Cattle dry season	88	31.5	4.8	0.6	52.5	46.5	9.7
Chital dry season	53	7.9	4.8	0.6	13.1	6.9	1.4

rumen increases their ability to utilise poor quality roughage (cellulose) by microbial digestion in a way concentrate selectors and intermediate feeders cannot. Using the same model, chital are classified as intermediate feeders predicted to optimise their diet through plant selection.

Chital affect the standing crop of grass proportionately less than cattle for two major reasons. Principally, the NE requirement of chital, which is a function of bodyweight, is considerably less than cattle and, in addition, chital grass intake declines in the dry season. The extent to which chital affect the grazing potential of cattle properties in the region depends on chital abundance which is not uniform; specific areas of high soil fertility (Watter *et al.* 2019*b*) close to water and homesteads (Forsyth *et al.* 2019) support high chital densities in a broad environment where densities are very low (Brennan and Pople 2016). Nevertheless, some landholders report more than 1000 resident chital on their properties which may have material effects on the productivity of the beef cattle enterprise. The economic impact of free ranging chital to a grazing enterprise in terms of forage depletion is likely to be somewhere between the two seasonal estimates for competition for grass. That is, for every 100 chital a property supports, it could potentially support another 25 individual cattle during the wet season and 14 during the dry season.

The calculation used to compare the grazing equivalent of chital deer and cattle offers a snapshot of grass eaten daily during the wet and dry seasons. Although feed is abundant during the wet season and chital do not pose a limitation to cattle production at that time, their presence during the wet season does reduce the available grass in the following dry season. Grass that chital eat during the wet is not available for cattle during the dry.

One limitation to the present study was that different methods were used to measure the grass intake of chital and cattle. Macroscopic examination of rumen contents has a bias which overestimates graminiods and underestimates forbs in the diet due to differential rates of digestion (McInnis *et al.* 1983). Estimation of the grass proportion of cattle diet by fNIRS has a variable bias according to the composition of non-grass species in the diet (Coates and Dixon 2008).

Overlap of diet and distribution between chital and cattle support landholder perceptions that chital represent a material source of competition for grazing resources where chital abundance is high. Limitations to pasture conservation from one wet season to the next arise due the difficulty in controlling non-domestic grazing animals. The degree to which this occurs is determined by chital density which influences decision making with respect to population control. Further study to assess the cost of chital control at varying animal densities may provide cost benefit scales to cattle producers intending to reduce chital populations by culling.

Conflicts of interest

The authors declare no conflicts of interest.

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