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Qualitative Characters of Indigenous Sheep in Central Brazil: Putting Phenotype into Perspective

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Abstract: For centuries, indigenous sheep have been bred in extensive low-input systems in Midwestern Brazil. The hypothesis of this study was the assumption that phenotypic evaluation of indigenous livestock may drive the establishment of breed standards and official breed recognition, and, therefore, promote more local business opportunities. On the basis of more integrative and participatory theoretical background to applying any decision based on phenotype, we designed this research to determine the most typical and unusual phenotypes of Pantaneiro sheep. Pantaneiro ewes (281 ewes from five conservation units in five counties) were evaluated, bearing in mind both conservation and development. Descriptive statistics were used to classify ewes into typical, intermediate, and unusual phenotypes. Chi-squared tests for association were performed to test if morphological variation in the different sampling sites occurred randomly ($p > 0.05$) or not ($p < 0.05$). Some results suggest some sort of diversifying selection pressure, i.e., distinct preferences among keepers. We observed considerable morphologic variation among ewes, but it was straightforward to determine the predominant phenotypes. The study evokes integrative agrobiodiversity by putting phenotypical characterization of indigenous livestock into perspective. Discussions coming from this study may support innovative governance and participative decision-making, allied with strategies that value the socioeconomic, biocultural, and adaptive aspects of indigenous livestock in tropical regions and developing countries. This is a challenge for government, rare-breed keepers, value-chain actors, and civil society.

Keywords: locally adapted; local breed; breed standard; *Ovis aries*; conservation genetics

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1. Introduction

1.1. General Background

Worldwide, there has been a trend towards the extinction of indigenous breeds, likely due to the establishment of new commodity-driven agricultural frontiers associated with land-use change and agricultural intensification, which compete with traditional farming systems [1–3].

In South America, most of the livestock originate from early colonisation in the 15th century. Several reports have described how Portuguese and Spanish ships managed to transport farm animals from the Iberian Peninsula and Africa into South American countries. Over centuries, livestock adapted to the tropical conditions of extensive grasslands, becoming recognised as locally adapted or indigenous [4–7].

In Brazil, imports of several sheep breeds in the last few decades marked indiscriminate cross-breeding, which reduced the numbers of indigenous sheep in farmlands [6]. As a consequence, in 1983, the Brazilian Agricultural Research Corporation (Embrapa, Brazil) included conservation strategies of animal genetic resources among its priorities [5,8,9].

Typically, Pantaneira sheep, named after the Pantanal ecosystem (a biodiversity hotspot in Midwestern Brazil), are kept in low-input grazing systems [10]. Currently, the sheep breeders' association in Brazil lacks an official description of Pantaneiro sheep [11]. There is great uncertainty about the number (head) of Pantaneiro sheep in the country. At present, literature about Pantaneiro sheep suggests that the majority of herds are managed in public or private research corporations and universities. This has presented some opportunities for protecting indigenous genetic resources and has enabled on-farm conservation programs that can connect the different conservation units [12,13]. Still, it is unusual for farmers to invest much in local sheep farming in Brazil. Many farmers spend their time in other economic sectors in addition to managing other rural activities [14].

In fact, there is considerable heterogeneity in productive characteristics among sheep farms in Brazil, especially regarding the physical area, production system, flock size, coexistence with other activities, and management [14]. Even in the most developed regions, the challenges are mostly technical (control over many aspects, reduced technical efficiency, and low technology adoption by most farmers), which must be overcome to allow for economic viability [14].

There is no doubt that several research outcomes have contributed to describing the performance of carcass and milk from Pantaneiro sheep [13,15,16]. This might put conservation strategies closer to market opportunities and prospects for regional development. However, despite many efforts made by Brazilian research institutions and scholars to preserve Pantaneiro sheep, formal business experiences with indigenous sheep are scarce [10,17].

Rather than formal business, it seems that Pantaneiro sheep are more associated with factors such as traditions, hobbies, and food security for some small farmers and employees in rural areas. The current situation reveals a disconnection between the historical importance of indigenous livestock, their local adaptation [4,18], and formal business opportunities (i.e., alternative food systems in the meat and dairy sector, rural tourism, culture, and contemporary art).

The lack of recognition for indigenous sheep and breed standards is a gap that may be discouraging business initiatives and limiting market strategies (i.e., certification, prepackaging, and labelling). It limits scientific contributions from conservation genetics and other fields of research [19] and potential advances in sustainable management of herds assisted by conservation programs. These programs usually operate by managing genetic diversity (i.e., controlling inbreeding and introgression, monitoring associative patterns between phenotype and genotype, and preserving the adaptability (fitness) of local breeds [12,17,20,21].

Moreover, the lack of literature materials discussing the possibility of using Brazilian native sheep breeds (strategically) is notable [10].

1.2. Objectives of the Manuscript

The research was designed in order to determine the most typical, intermediate, and unusual phenotypes of Pantaneiro sheep in the Midwestern Region of Brazil. The study also aimed to discuss the results of phenotypic variability in the perspective of practical implications, such as participative rare breed management and future breeding strategies.

The motivation of this paper lies in the fact that phenotypic evaluation of indigenous sheep may lead to multi-stakeholder decisions (value chain actors), opening the door for opportunities from business to science. Against this background, the hypothesis of this study was the assumption that phenotypic evaluation of indigenous livestock may facilitate and drive the establishment of breed standards and official breed recognition, and, in turn, more local business opportunities for smallholders.

2. Materials and Methods

2.1. Sampling

A total of 281 ewes were evaluated near five towns in Mato Grosso do Sul, Brazil (Campo Grande, Corumbá, Dourados and Terenos) (Figure 1).

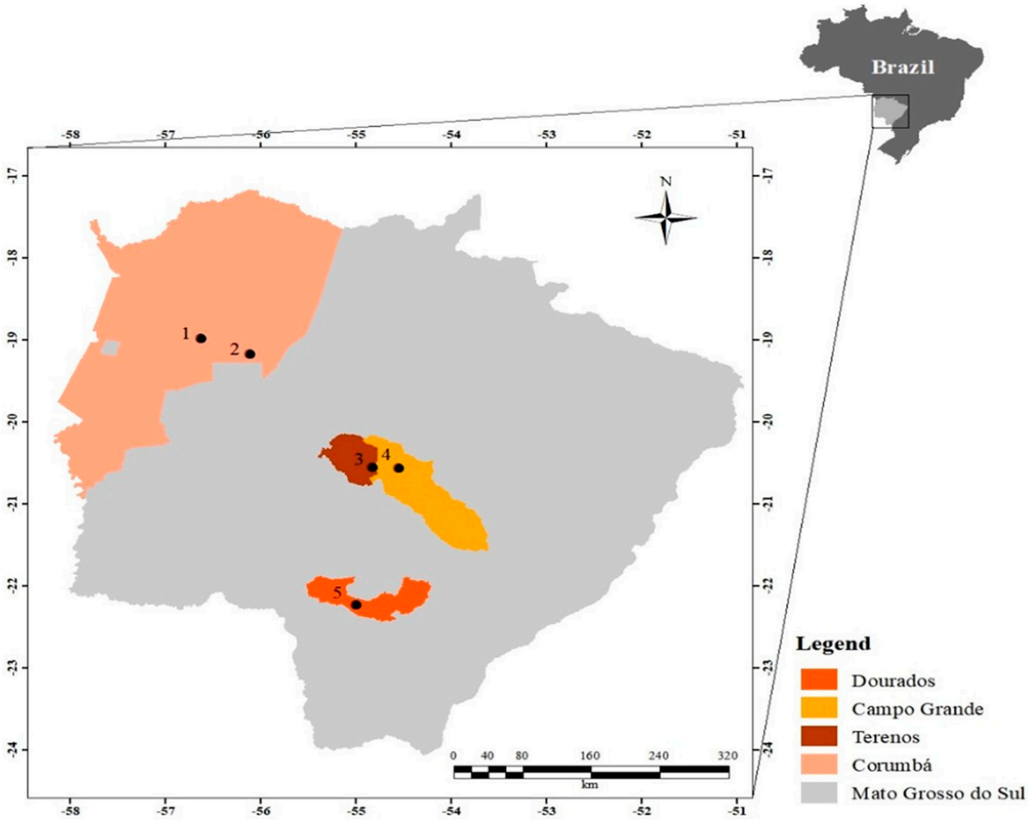

Figure 1. Distribution of the animals evaluated in sampling sites: Nhumirim Farm, Embrapa Pantanal (1); Havaí Farm (2); Model Farm, Embrapa Gado de Corte (3); Uniderp/Anhanguera Experimental Farm (4); Universidade Federal da Grande Dourados Experimental Farm (5).

The sampling criteria are shown in Table 1.

Table 1. Sampling criteria adopted in the study.

Subject Matter	Criteria
Convenience sample (legitimacy of herds assessed)	At least three researchers analyzed all sampling sites. Networking and consensus achieved with the Support Program for the Emerging Centers, sponsored by the Foundation for the Development of Education, Science and Technology of the State of Mato Grosso do Sul (PRONEM/FUNDECT).

Table 1. *Cont.*

Subject Matter	Criteria
Sample collection	Sheep kept in Midwestern Brazil, in surrounding areas or in the Pantanal biome; ewes at least 36 months old (estimated by verifying the change of the third pair of incisive teeth [22]); ewes presenting ear tags or tattoos.
Validation of field worksheets and candidate morphologic variables (prior to evaluation of ewes)	Speech Content Analysis [23,24] from experts (at least two researchers).
Photographs of each ewe	Front, side, and back of the body and head, including legs, skin, and hair colour (at least five pictures per ewe).
Photographs taken by a standardised method.	Approximately 3 m from the sheep (Nikon camera, model Coolpix P530); there was no occurrence of experts refusing the legitimacy of ewes evaluated (no phenotype was discarded from the data set after field trials).
Ear tagging of ewes lacking identification	Restricted to ewes considered legitimate Pantaneiro specimens (team consensus) during field trials (veterinarians, zootechnicians, biologists, and biotechnologists (during master's degree, PhD, or postdoctoral research) and herd manager.
Ruminal implant for all ewes evaluated (traceability)	Ceramic coated artefact containing a chip with a unique number, applied orally (30 g; diameter: 11 mm (3 g/cm^3).
Cross-checking the legitimacy of ewes on the basis of picture sharing and expert opinion	At least two researchers; validation by team consensus (veterinarians, zootechnicians, biologists, and biotechnologists (master's degree, PhD, or postdoctoral fellow) and herd manager).

2.2. Preparation of Morphologic Evaluation

Prior to the morphologic evaluation, data from researchers, herd managers, and employees related to the conservation units were surveyed (Figure 1) using speech content analysis [23,24]. Because researchers were familiar with Pantaneiro sheep, this experience was used to check if any interesting feature could be added to the list of 11 morphologic variables. Roughly, content analysis allowed the team to register that the people that facilitated access to the conservation units referred to the Pantaneiro sheep as predominantly white-wooled sheep with ears that drop towards the face, not as long-eared as some typical sheep breeds from Africa.

Variables were grouped according to three aspects: (a) shape: cephalic profile (concave, convex, or plain), bevel (concave, convex or plain), muzzle (thin or thick); (b) disposition: horns (absent, rudimentary, normal), wool (belly, head, legs, and/or neck), spots (belly, head, ears, and/or legs), glasses (absent, bilateral, unilateral) (equivalent to a patch around the eye); (c) colour: hooves (white, mixed, black, or striped/brindle), wool colour (yellow, white, spotted, or black), skin colour (white, depigmented, dark, or spotted), hair colour (yellow, white, spotted, or black).

There was some alteration of people handling the sheep at different sampling sites, but the evaluation team was stable throughout all trials. The team operated with five key collaborators: one to handle the ewes, one to hold a black cardboard sheet and another to register the photographs, one to perform phenotypic evaluation, and one to fill in the field worksheets.

2.3. Statistics

First, researchers and field collaborators assessed the 11 morphological characteristics visually. Collected data were revised at the field level and in the office using images. Data were tabulated in Excel sheets to calculate descriptive statistics (f; %). Three classification criteria (established arbitrarily) enabled ewes to be grouped on the basis of occurrence: (1) typical: occurrence equal to or over 50% of the ewes; (2) intermediate: between 11% and 49%; (3) untypical: equal to or less than 10% of the ewes in the study (Figure 2, Table S1).

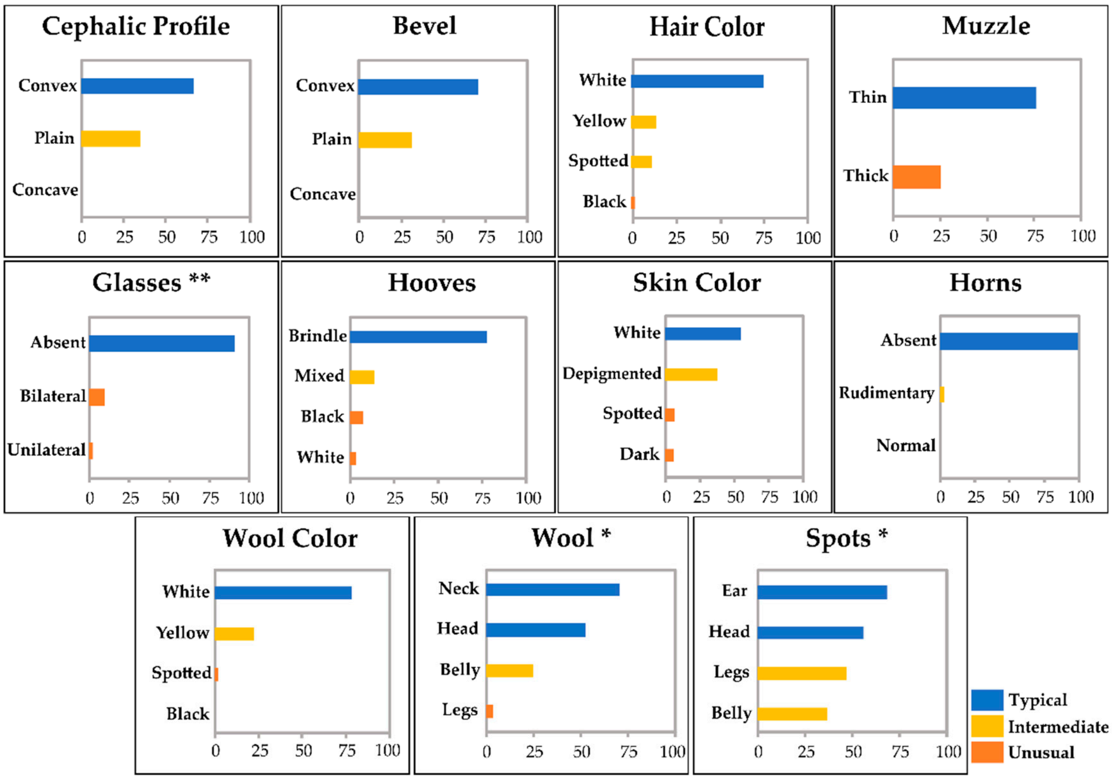

Figure 2. Frequencies of variables of morphological traits of Pantaneira ewes and the classification (typical (blue), intermediate (yellow), and unusual (orange)). * Summed percentages may extrapolate 100% because some ewes matched more than one category; ** patches around the eyes (pigmentation of hair).

Later, in an additional statistical analysis, chi-squared tests for association (χ^2) were performed in order to check if the different qualitative characters of ewes varied among herds at random (H_o) or not (H_a) ($p < 0.05$). This heterogeneity test was prepared so that the alternative hypothesis (H_a) could support arguments about the chance of some force (bias) acting as a source of diversifying selection among the conservation units. Because gene flow is likely to occur if conservation units and keepers start to network, the test was also set to pinpoint the outlier phenotypes and link this to the origin of sheep. Inferential statistics was used, bearing in mind that phenotypic variability is a starting point from which to discuss and decide about the near future of indigenous animal genetic resources.

A contingency table was prepared to facilitate the comparisons of the proportion of phenotypes (qualitative characters) among the five sampling sites assessed (Figure 3, Table S2). We performed data analysis using software Minitab, version 17, establishing 5% significance level.

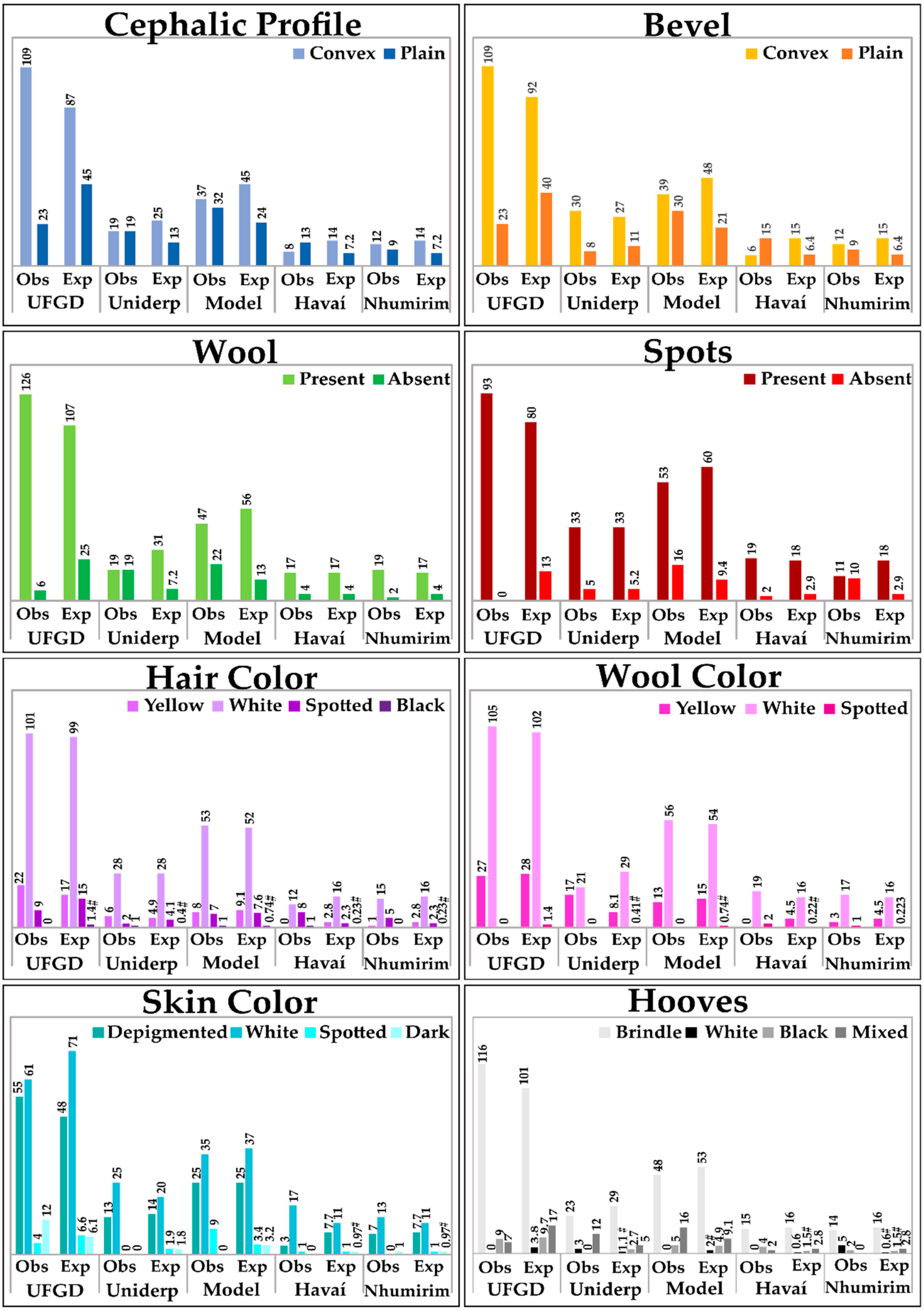

Figure 3. Observed and expected counts of variables of morphological characters in Pantaneira sheep that significantly differed among conservation units ($p < 0.05$); The validity of the p-value for the test is an issue because expected counts were very low.

3. Results

The frequencies of morphological traits, showing the typical, intermediate, and the unusual phenotypes, are shown in Figure 2 and Table S1. In Figure S1, the qualitative features taken at the field level are made available.

Convex cephalic profile (65.8%), convex bevel (69.8%), and thin muzzles (75.4%) were typical phenotypes in Pantaneiro sheep. Some ewes had plain cephalic profiles (34.2%), plain bevel (30.2%), and thick muzzles (24.6%), and these were considered intermediate phenotypes. Horns were unusual in Pantaneiro sheep (98.2% were devoid of horns) and few (1.8%) presented rudimentary horns. Ewes presenting wool on the neck (70%) and wool on the head (52%) were typical. Some ewes presented wool on the belly (24%), and this had intermediate occurrence in the population assessed. Wool on the legs was unusual (3%). The hair colour of Pantaneiro ewes was typically white (74.6%). The yellow hair (13.2%) and spotted hair colour types (11.1%) had intermediate occurrence and black hair was unusual (1.1%). The colour of wool was typically white (77.6%). Some ewes presented yellow wool (21.3%) and it was unusual that sheep presented spotted wool (1.1%). There were no black-wooled sheep in the population assessed.

Regarding the pigmentation of the skin, white skin was typical (53.7%). Some ewes presented depigmented skin (36.7%), but it was unusual to observe ewes with spotted (5%) or dark skin (4.6%). The pigmentation of the hooves was typically striped or brindle (77%). Some sheep presented differently coloured hooves (mixed) (13.1%), and it was unusual to observe black hooves (7.1%) and white hooves (2.8%). Among all the ewes sampled, 75.3% had hair or wool spots on at least some region of the body. Some unusual ewes (10%) presented hair pigmentation near their eyes (in the form of "glasses").

Significant differences among the proportion of phenotypes among all conservation units (herds assessed) are shown in Figure 3 and Table S2. The observed and the expected counts of morphological characters that did not significantly differ among conservation units are shown in Figure 4 and Table S2.

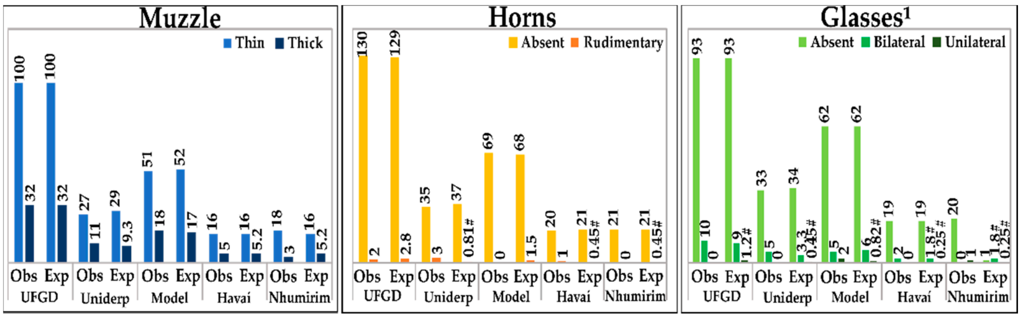

Figure 4. Observed and expected counts of variables of morphological characters in Pantaneira sheep that did not significantly differ among conservation units ($p < 0.05$); [1] Pigmentation of hair in the form of glasses; [#] The validity of the p-value for the test is an issue because expected counts were very low.

There was evidence of heterogeneity ($p > 0.05$) among herds in all qualitative characters, except for muzzle ($p = 0.792$), horns ($p = 0.063$), and eyeglasses ($p = 0.345$).

Among all conservation units, Havaí farm had the highest differences among the expected and the observed counts (Figure 3, Table S2), illustrated as percentage differences in Figure 5.

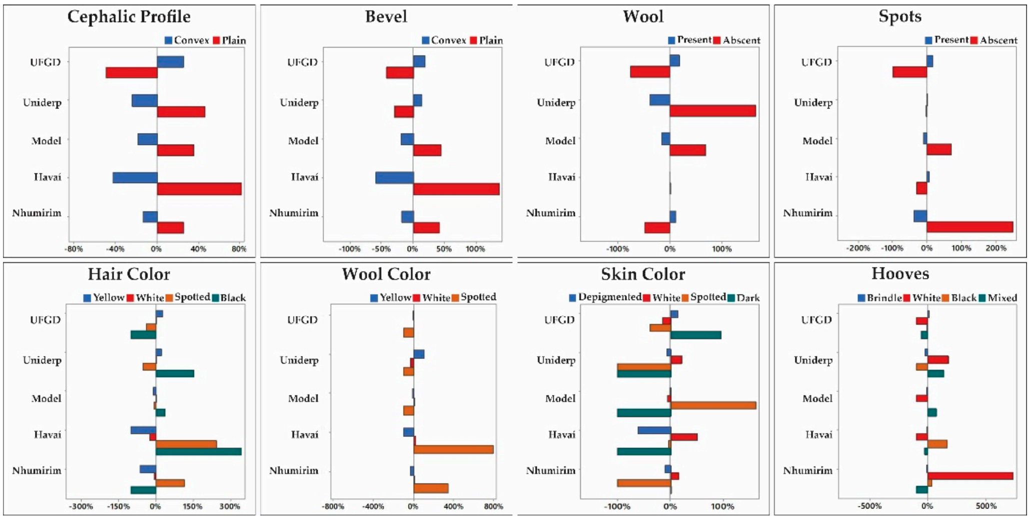

Figure 5. Percentage difference (between observed and expected counts) of morphological characters that significantly differed among conservation units (significance level of 5%). Positive: occurs more often than expected. Negative: occurs less frequently than expected. Counts are shown in Figure 3 and Table S2.

4. Discussion

4.1. Variability of the Morphological Characters

Variability among sheep is likely due to little intervention in the conservation units and lack of any breeding program (i.e., systematic selection criteria). The diversity assessed may reflect some historic events that have occurred since the introduction of livestock during the early colonisation of Brazil [25]. Alternatively, diversity may reflect indiscriminate cross-breeding [26,27] or occur at random. Studies relating phenotype to pedigree and genotype are still incipient in Pantaneiro sheep. Previous research has shown that Pantaneira sheep have alleles similar to those of southern flocked sheep and flocked sheep of Northeastern Brazil [27], sharing the same maternal origin as sheep of the Bergamácia, Dorper, and Ile de France breeds [28].

Different wool shades are important for the fibre industry [29], especially in relation to organic value chains. The differences in tone may be related to the melanocortin 1 receptor gene (MC1R) and/or to the genes involved in melanin synthesis/transport (ASIP, TYRP, and OCT), as suggested by the research into Brazilian Creole Sheep [30].

It seems that the colour of hooves may be a candidate variable to develop research relating to crossbreeding (hybridisation) based on a forensic approach or research on adaptability of sheep to the Pantanal ecosystem. Many modern sheep breeds present black or white hooves, which contrast with the case of Pantaneiro sheep.

High diversity is expected and can be quite typical of small flocks of indigenous livestock. Alternatively, differences among the proportions of phenotypes between conservation units may support the idea that there might be some force (bias), even if there are no official selection criteria put into practice. The absence of a breeding program may have preserved the most exotic types, but it might have triggered some other pressure or sources of variation. Because the sampling scheme at each conservation unit was random, there is evidence to support the existence of some bias. We are unaware of any reported data properly discussing and pinpointing sources of variation in the phenotype of Pantaneiro sheep, such as personal preferences among keepers (researchers, farmers, or other actors). This investigation is strategic in future research and may be a subject that increases networking and management of gene flow among conservation units. This debate should be encouraged among government institutions, indigenous-livestock keepers, supply-chain actors, academics, and civil society.

It is likely that the conservation unit at Havaí had the highest differences between the expected and the observed counts (Figure 3, Table S2) because it is the only conservation unit assessed that is private property. All the other conservation units are part of public research institutions or private or public universities. It is not straightforward to assign which units have been subject to more intense or very little interference by humans in the last few decades. Officially, there is lack of reported data about the adoption of some sort of breeding scheme [31], or characters that may have been under selection.

Some Pantaneiro keepers may have prioritised some particular phenotype over the years. Decisionmakers might have chosen some preferred ram (intact male) over the years. Perhaps people discard any black sheep in the progeny and maybe they allow sheep that present coloured patches on the body to be kept throughout the breeding seasons. Maybe some of the qualitative characters are unusual or typical in Pantaneiro ewes because of the environmental conditions or because some sort of breed culture took place at some time. Former research on livestock in the Pantanal biome suggests that local preferences among farmers may explain morphological variation among indigenous horses [32], as well as the fact that the presence of research institutions may explain greater distinctiveness among private farms that keep indigenous cattle [33]. Of main concern is that this may alter gene flow and inbreeding (homozygosity) and could relate to isolation by distance [34–36].

4.2. Putting Phenotype into Perspective

Phenotypic characterisation of sheep has been extensively reported, with emphasis on diversity [22,37,38]. Some studies have relied on morphologic characters as starting points to reveal the phylogeography of indigenous sheep, adaptability, and identification of distinct genepools in diverse agro-ecological regions using genomic data [39,40]. Typically, these may support decision-making and prospection of livestock, including the establishment of breed standards, registering breeds in herd books, and support for actors to structure breeding programs and use indigenous livestock to increase fitness and hardiness of pure breeds while protecting the founder populations.

It seems obvious to doubt if any ewe that has horns or wool on the legs should lead to their being recognised as a legitimate Pantaneiro specimen. Moreover, some may think these are inconvenient features for sheep in this frequently flooded region (Pantanal ecosystem). This is particularly interesting in adaptability traits of Pantaneiro sheep (including hooves and skin colour) that may be subject to selection [41]. On the basis of genomic studies, indicator traits for adaptability or resistance of sheep are likely breed-specific [42]. From an animal production viewpoint, there is interest in removing horns from certain breeds, which is related to a single genomic region on chromosome 10 that determines the presence and absence of horns in domestic breeds [43]. However, livestock judging depends on several abilities, such as integrating livestock industry knowledge and developing systematic oral communication [44,45]. Currently, this seems under-represented in the case of Pantaneiro sheep, similar to other livestock resources in the country [17].

There was no proper quantification of the occurrence of colour patches. However, different colours (brown and/or black) and different colour intensities were observed in the population assessed (Figure S1). Maybe the presence of small patches has never been a criterion by which to discard sheep in traditional extensive systems or in government and private conservation units. According to the Brazilian Association of Sheep Breeders [11], the abundance of colour patches should not be encouraged in some breeds. This sort of information is handy to support decisions, especially coming from referees that are entitled to register sheep in herd books.

It is probable that phenotypic characterisation will have little impact on local development if decoupled from agribusiness (i.e., food supply chain) [17,46]. Therefore, beyond basic science, it seems convenient to lower the distance between fields of research and adopt practical initiatives to protect and promote indigenous livestock. This may enhance the power to decide, both at the office and at the field level. Still, extension work in animal husbandry might not reflect all the research advances accumulated over time [47]. The situation calls for methods typically adopted in rural extension science, specifically participative, more democratic, and inclusive approaches [48–50]. This may put the indigenous Pantaneiro sheep into perspective, encouraging sustainable usage of animal genetic resources and supporting the production of traditional food, family farming, and local development [51].

From a value chain perspective, phenotypic heterogeneity can hinder the establishment of a straightforward breed identity (morphological homogeneity). There seem to be several paradigms and some impregnated culture referring to homogeneity in some food chains [52–56]. These may sometimes relate to the idea of common ancestry, consistency, and better quality of genetic resources used for human consumption. However, these features depend on the market niche and many other factors [57,58]. Therefore, defining morphological qualities of indigenous livestock may favour the establishment of a breed stamp, which, in turn, may add economic value to Pantaneiro sheep [59,60].

It is reported that worldwide sheep breeders of the past century have continued to improve on practices that began possibly 8000 years ago [61]. In current literature, there are some contributions to encourage a more integrative approach when referring to biodiversity of food and agriculture (agrobiodiversity) [62]. This seems to follow trends embracing farming systems' approach to research, agricultural innovation systems, and research-extension linkages [63,64]. It seems that management, policy, and practice should connect with socio-economic and biocultural values. Additionally, administrators and strategists should connect to biological and adaptive values and to values related to well-being, diet, nutrition, and health [17].

4.3. Practical Implications for Typical, Intermediate, and Rare Phenotypes

The results of the study shed light on some criteria by which to suspect, doubt, or even reject a phenotype (ewe) for not resembling a legitimate Pantaneiro breed standard.

The morphological characteristics considered typical within the population ($f \geq 50\%$) could be applied as parameters to facilitate the development of a breed identity or to prioritise some phenotypical aspect of Pantaneiro sheep. Therefore, recognition of Pantaneiro sheep as having no horns; no wool on the legs; white hair, skin, and wool; spots on the head and ears; convex cephalic profile and bevel; thin muzzle; wool on the neck and head, with brindle hooves seems to be a straightforward strategy towards breed identity and breed stamps.

For intermediate phenotypes (frequency greater than 11% and less than 49%), it could be up to the curator (judge or referee) to decide whether or not to prioritise them, as they reflect a considerable portion of the population assessed. However, promoting unusual phenotypes may hinder the establishment of a breed identity or measurements of genetic integrity [65].

It seems straightforward to suspect ewes with a concave cephalic profile and concave bevel, ewes with horns and black wool colour. Likewise, it is reasonable to doubt that ewes with wool on the legs, black hair colour, spotted wool colour, and with dark or spotted skin are legitimate Pantaneiro sheep. However, even if the share is slight, one must bear in mind that they are present in the governmental conservation units assessed and the experimental farms managed by universities (Figure 3 and Figure S1, Table S1). We believe that the phenotype of ewes that were considered to have intermediate occurrence (between 11 and 49% of ewes) are likely the most challenging when deciding whether to register, to discard, or create some alert mechanism on the basis of phenotype. It seems easier to decide on the guidelines that described the typical phenotypes of Pantaneiro ewes (i.e., brindled hooves, spots on the head, and spots on the ears).

4.4. Additional Thoughts and Guidelines

The level of perplexity about judging candidate ewes in register trials (herd books) may vary considerably when accounting for rare and typical qualitative characters. Referees entitled to register and sometimes perform pedigree analysis can be quite rigorous depending on the evaluated character.

Some keepers or ranchers may resist exploring rare features in breeding schemes. However, exclusion of rare phenotypes may contrast with the idea of maintaining maximum variability among indigenous animal resources [27], related to the concept of population viability in conservation programs [21]. Moreover, the conservation of agrobiodiversity is a preventive action [12,20,66]. Therefore, resisting actions that may reduce the effective population size, drive genetic drift, or cause genetic erosion [67,68] is a valuable attempt to maintain the adaptive qualities of indigenous livestock and to perform sustainable herd management. Discarding ewes with undesired characters is an issue in indigenous livestock because the herds are usually very small [4,12,66]. This implies dropping selection pressure (discarding phenotypes that do not properly match expectations).

Overall, rare breed management should avoid narrowing the founder population when developing a new herd book (breed) because diversity is a key element. In practice, this means being less rigorous. In terms of decision-making, at some time and level, choices may become arbitrary or partial [69,70], even in cases where lack of data is not an issue (i.e., associating phenotype with genotype). Understanding the decisions made by ranchers (indigenous livestock keepers) and government (research institutions and sometimes academics) may demand bridging population genetics and conservation genetics to behavioural science and other fields of research.

It seems that over the years, many rare-breed management programs have been in and between the concepts of conservation and development [71]. Moreover, population genetics and conservation genetics of indigenous livestock may be far more interdisciplinary and complex than imagined. In practice, some characters (phenotypes) may be accepted or rejected despite any scientific background, mainly because breeding of livestock was largely an art and selection of breeding animals is often a matter of personal preference [46,72]. This seems to be the case for Pantaneira sheep, i.e., observation of specimens presenting eye patches resembling sunglasses.

Notably, selection towards breeding based on preferences may confer benefits on the progeny or it may deplete the genetic variation underlying the selected traits, diminishing benefits to the offspring [41]. It is believed that the fitness of indigenous livestock in tropical regions is a result of natural selection (with little anthropogenic force) throughout many centuries of traditional farming (extensive low-input systems) [8,73]. Moreover, local adaptation and rare variants in molecular content configure the great potential of indigenous livestock for applied animal science [63]. These are typically key elements to justify and support in situ conservation of indigenous livestock [12,66,74,75].

4.5. Foreseeing Genomic Information

This study opens the door to the validation of heritability of morphologic characters in Pantaneiro sheep [41] and to how phenotype relates to genotype and associated SNPs. Because the results denote a step forward for describing the genetics related to morphologic characters, elucidation of the morphologic basis would likely help clarify how phenotypic variation will be maintained (with special attention to polygenic aspects) [41]. Overall, this may lead to applications in selective breeding and improvement of traits of economic importance [76]. Specifically, research should underpin causative gene variants to facilitate novel breeding strategies, such as marker-assisted or genomic selection [77], aiming to determine the effects of molecular content on phenotypic variability and yield. This relies on phenotypic data coupled with the discovery of genes within the scope of rare breeds [78].

The question is: Are these rare Pantaneiro phenotypes related to homo or heterozygosity or to some outlier group of genotypes? This needs clarification and usage of more data, such as genetic frequencies or specific genetic markers [79,80]. Currently, this impairs proper breed characterisation of Pantaneira sheep. Additionally, studies have stated that there is no conservation if there is no development coming from rare breed management [81]. These should serve as guidelines to apply any decision on the basis of phenotype or genotype.

5. Conclusions

The study revealed phenotypes that are unusual, intermediate, or typical to a particular indigenous sheep kept in governmental conservation units and private property in Midwestern Brazil.

It is challenging to decide whether to register, to discard, or to create some alert mechanism for the phenotypes with intermediate occurrence. On the other hand, it is straightforward to suspect that ewes with a concave cephalic profile and bevel as well as ewes with horns and black wool colour are legitimate Pantaneiro sheep. It is also reasonable to doubt that ewes with wool on the legs, black hair colour, spotted wool colour, and with dark or spotted skin are legitimate specimens of Pantaneiro sheep. Additionally, the recognition of sheep as having no horns, no wool on the legs, white hair, white skin and wool, spots on the head and ears, convex cephalic profile and bevel, thin muzzle, wool on the neck and head, and brindle hooves seems to be a straightforward strategy towards establishing breed identity and breed stamps.

The findings support decision-making for those interested in this particular topic, which overlaps with several other interests that range beyond registering livestock in herd books. The subject embraces food certification, market strategies, tradition, culture, and art.

Finally, the results may contribute to the development of participative strategies to sustainably manage, protect, and conserve indigenous sheep. These are present-day challenges that, if solved, may empower actors within and beyond the farm gate.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/d13110512/s1, Figure S1: Representation of some of the morphological variables evaluated in the study. 1: Convex cephalic profile; 2: plain cephalic profile; 3: convex bevel, 4: plain bevel; 5: thin muzzle; 6: thick muzzle; 7: absent horns (side view); 8: absent horns (bird's eye view); 9: wool on the head;, 10: wool on the neck; 11: wool on the belly; 12: wool on the legs; 13: white wool colour; 14: yellow wool colour; 15: spotted wool colour; 16: white hair colour; 17: yellow hair colour; 18: spotted hair colour; 19: black hair colour; 20: spots on the head; 21: spots on the ear; 22: spots on the belly; 23: spots on the legs; 24: eye glasses (patches around the eyes); 25: white hooves; 26: black hooves; 27: brindle hooves. Table S1: Absolute (fi) and relative frequencies (fri) of variables of morphological traits of Pantaneira ewes and the classification (typical (T), intermediate (I), and unusual (U)). Table S2: Observed and expected counts of Pantaneira sheep per farm.

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