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Article

Food competition between the White-tailed deer and three exotic herbivorous species in Northeast *Tamaulipas*, Mexico

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Abstract:

In the present study the results of the assessment of food availability and interspecific competition of four species of game interest (whitetail deer, Sika deer, red deer and Eland antelope) are shown on a ranch in the northeast of Tamaulipas. The local vegetation was described, among which the dune, the association of halophytes, the spiny scrub and the high scrub subinerme; 22 families, 41 genera and 46 species were identified. The results indicate that white-tailed deer have a 42.9 % preference for shrubs, 36.5 % for herbaceous species, 18.5 % for grasses and 2.1 % for trees; Sika deer, 69.6 % for grasses, 17.2 % for shrubs, 13.1 % for herbaceous and 0.15 % for trees; Red deer 46.7 % for grasses, 43.9 % for herbaceous and 9.4 % for shrubs; finally, the antelope, 37.2 % for herbs and 32.8 % for grasses, 28.9 % for shrubs and 0.08 % for trees. It was detected that spring was the most critical season in competition, as there was a strong food similarity with the three species of exotic herbivores (49 % with Sika deer, 54 % red deer and 47 % with the antelope), followed by Winter season when verified with red deer (43 %) and antelope (55 %); a similarity of diets with a single species was identified for summer and fall (45 % for Sika deer and 43 % for Eland antelope).

Key words: *Cervus elaphus* Linnaeus, 175, *Cervus nippon* Temminck, 1836, diet determination, histology of plants, *Odocoileus virginianus* Zimmermann, 1780, *Taurotragus oryx* Pallas, 1776.

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Introduction

Five species of deer have been recorded in Mexico: Mule or Bura deer (*Odocoileus hemionus* Rafinesque, 1817); White-Tailed Deer (*Odocoileus virginianus* Zimmermann, 1780); *Temazate* deer (*Mazama americana* Erxleben, 1777); *Corzuela* of *Yucatán* deer (*M. pandora* Merriam, 1901) and the Little Goat or Mountain Deer (*M. temama* Kerr, 1792). The White-tailed Deer is the most widely geographically and ecologically distributed (from which 35 subspecies live in the American continent and 14 in Mexico, the latter displayed throughout the whole territory), while the Bura deer is restricted to the north and northwest of the country and the *Temazate* deer to the humid tropical regions (Halls, 1984).

However, in spite of finding this diversity of species in the country, many owners of hunting ranches have introduced exotic species to different habitats, which has caused some problems; one of them is "competition for exploitation", which is defined as "the competition for food between species, even if they were never in direct physical contact, the mere presence of the other species with similar feeding habits, will decrease the quantity of food of the other "(Smith and Julander, 1953; Amstrong and Harmel, 1981; Soberón, 1982; Mellink, 1989).

There are few studies on the subject of competition between species of native *versus* exotic ungulates in Mexico; The precedent is the work of Gallina (1981 and 1993), which describes the competition between White-tailed Deer and cattle in the *La Michilía* Biosphere Reserve, *Durango*; her results indicate that deer consume 135 species of plants and cattle only 36.

Based on the above, the aim of the actual work was to analyze the diets of four species of ungulates, and the similarity that these have in an area located to the northeast (near the *Laguna Madre*) of the state of *Tamaulipas*. The species of interesest were the White-tailed Deer (*Odocoileus virginianus*), the Red Deer (*Cervus elaphus* Linnaeus, 1758), the Sika Deer (*Cervus nippon*, Temminck, 1836) and the Eland Antelope (*Taurotragus oryx* Pallas, 1776).

Materials and Methods

Study area

Field work was carried out at the UMA (Unit for the Conservation, Management and Sustainable Use of Wildlife) called *Rancho Los Ébanos* (registered by Semarnat as DFYFS-CR-EXT-0272-TAMPS), located in *Matamoros* municipality, State of *Tamaulipas*, 60 km south of the city of *Matamoros* and north of the *Laguna Madre* (Figure 1); Its geographical reference coordinates are 25°20 'and 25°25' N and 97°40 'and 97°44' W.

The area has a surface area of 3 250 ha, where two subareas were selected, one measuring 200 ha (*La Guerreña)* and the other 800 ha (*Los Ébanos*).

Figure 1. Location of *Rancho Los Ébanos*, *Matamoros, Tamaulipas*.

Extreme climate prevails in the study area, with -7 °C in winter and 40 °C in summer (Gobierno del Estado de Tamaulipas, 1999). *Mezquitales* (*Prosopis* spp.) is the most important vegetation combined with halophytic grasslands (*Spartina spartinae* (Trin.) Merr., *Monanthochloe littoralis* Engelm. and *Distichlis spicata* (L.) Greene), thorny shrubland (*Acacia* spp., *Karwinskia humboldtiana* (Schult.) Zucc. and *Helietta parvifolia* (A. Gray) Benth., etc.) (Leopold, 1952; García and Jurado, 2008; Molina *et al*., 2013).

Wildlife in the area is made up by the 150 bird species, in addition to medium mammals such as the White-Tailed Deer(*Odocoileus virginianus),* skunk (*Conepatus leuconotus* Lichtenstein, 1832*)*, *armadillo* (*Dasypus novemcinctus* Linnaeus, 1758), wildcat (*Lynx rufus* Schreber, 1777*)*, *coyote* (*Canis latrans* Say, 1823) and hare (*Lepus californicus* Gray, 1837*)*, among others (Garza, 2000). Also, there are other introduced exotic species with hunting endings (Semarnat authorization number: DFYFS-CR-EXT-0272-TAMPS).

Description of habitat

In order to know the habitat, the Canfield line (Canfield, 1941) was used, with samples of 15 m long, randomly distributed in the two areas where the study was carried out; grasses, herbs and weeds were measured at the ground with a ruler, while shrubs and trees were measured by the interception of the crown with the line.

Biomass production

For the calculation of biomass production, the Adelaide Method (or Hand Reference Unit) was used. It consists of choosing a branch that is called a reference unit, so that it is representative in form and foliar density of the species of interest; this selective unit is taken from the boundaries of the work area. With it, a rotation

around the tree or shrub is made taking into account the number of hand units that would contain each one of the sampled individuals (Chávez, 2000).

The dimensions of the plots that were used in the research were 0.5 x 2 m for the low stratum, 5 x 5 m for the middle stratum and 5 x 10 m for the high stratum (Chávez, 2000).

Subsequently, the samples used as reference units were dried in a laminar flow oven at a temperature of 65 °C in a period of 24 to 48 hours, and drying up to 72 hours depending on the amount of moisture contained. Once the constant weight of the sample was obtained, the amount of dry matter available per sampled area was calculated.

It is important to mention that total biomass production will never be consumed in its entirety since there are parts of the plant that are not preferred by herbivores such as lignified stems and / or presence of thorns, characteristic of local vegetation, and for practical reasons the total production of biomass is divided among four, since a quarter is actually used for consumption by animals (González, 2004).

Botanical composition of the diet

The determination of the botanical composition of the diet of the species was carried out in two phases:

a) The first consisted of a botanical collection of the plant species present in the area during the four seasons of the year, in order to identify the plant species collected, and later to make a reference catalog in which the main cellular structures of plants were identified by using the Microhistological Technique; photographs were taken for later comparison with what was found in the feces (Sparks and Malechek, 1968; Peña and Habib, 1980).

b) In the second phase, feces were collected from the species of interest during the four seasons of the year, preferably fresh and fully identified in the areas near the sampling plots.

Once these two phases were completed, the plant cell structures in the feces were compared with the reference catalog of plants in the study area. In order to do so, the histology of plants technique, in which plant tissues (stomas, trichomes, glands, cell walls, vascular ducts, etc.) are identified and contrasted with those found in the feces (Sparks and Malechek, 1968; Peña and Habib, 1980).

Similarity of the diets

In order to compare the similarity between the diets, the Kulcynski index (Legendre and Legendre, 1983) was used; this index makes a contrasts of the numerical similaritys and differences, which is very common in Population Ecology to know the overlapping of diets of wild animals (Hennig and Hausdorf, 2006).

Statistical testing

Pearson's correlation coefficient was used to determine the relationship between the data obtained in the diet of the species, which, being dimensionless and robust in the presence of outliers, provides a dimensionless association measure (Rudolf and Williams, 1993).

Because the Pearson's correlation coefficient used generates values of this type, a discriminant analysis was made in which the following criteria were taken (Table 1).

Table 1. Values that were used for the discriminant analysis.

Pearson's Correlation Values	Correlation of the diet
0.00-0.25	Low
0.26-0.50	Mean
0.51-0.75	High
0.76-1.00	Very high

Results and Discussion

Habitat description

A total of 22 plant families, 41 genera and 46 species and four main types of vegetation in the study area were identified:

1) Dune vegetation, which is limited to a strip of sand in the surroundings of *Laguna Madre*.

2) Halophytic associations, which have been found within the margins of some intermittent lagoons in the area, neighboring the halophytic grassland.

3) Thorny scrub, made up by species smaller than 2 m tall.

4) Tall shrubland with a mix of thorny and not-thorny plants, with deciduous species from 3 to 4 m high.

Number (2), the halophytic association, had the broadest cover, with species such as *Suaeda fruticosa* Forssk. ex J.F.Gmel., *Borrichia frutescens* (L.) DC., *Prosopis reptans* Benth., *Monanthochloe littoralis;* followed by (3) the thorny scrub, with *Celtis pallida* Torr., *Prosopis glandulosa* Torr., *P. juliflora* (Sw.) DC. *Acacia rigidula*

Benth., *A. farnesiana* (L.) Willd., *Malvastrum americanum* (L.) Torr., *Zanthoxylum fagara* (L.) Sarg. and *Karwinskia humboldtiana* and last, (1) the dune vegetation, with the presence of *Batis maritima* L.

Biomass production by season

Biomass production according to the season resulted as described:

a) Spring: the biomass production was 856 kg ha^{-1}, distributed as follows: 10 % belongs to the highest stratum and the species with the best contribution were *Celtis pallida*, *Prosopis glandulosa* and *Forestieria angustifolia;* 49 % to the middle stratum, the most important species being *Paspalum lividum* Trin. ex Schltdl., *Prosopis glandulosa* and *Borrichia frutescens* and the resting 41 % of the total biomass production came from the low stratum, made up by herbs and grasses, and the most reporting species were *Solanum nigrum* L., *Salvia* sp. and *Lantana camara*

b) Summer: total production was 1 600 kg ha^{-1}, coming 10 % from the highest stratum and made up by *Celtis pallida*, *Prosopis glandulosa* and *Forestiera angustifolia* Torr.; 28 % from the medium stratum, with *Paspalum lividum*., *Borrichia frutescens* and *Citharexylum berlandieri* B. L. Rob. and the resting 62 % came from the low stratum, made up by being *Lantana camara, Salvia* sp*. and Chloris virgata* Sw. the most important species.

c) Fall: In this season, total production was 1 500 kg ha^{-1}, 9 % which came from the high stratum and made up by *Celtis pallida*, *Forestieria angustifolia* and *Zanthoxylum fagara* (L.) Sarg.; 47 % from the medium stratum, with *Paspalum lividum*, *Salicornia virginica* L*.* and *Forestieria angustifolia* and 43 % to the low stratum, made up by *Monanthochloe littoralis*, *Chloris virgata* and *Aristida purpurea* Nutt.

d) Winter: The production was 2 050 kg ha^{-1}, 9 % of which concentrates in the highest stratum, with *Forestiera angustifolia*, *Celtis pallida* and *Zanthoxylum fagara*;

68 % comes from the medium stratum and the most representative species were *Paspalum lividum*, *Sporobolus asper* (P. Beauv.) Kunth and *Salicornia virginica;* 23 % comes from the low stratum where *Aristida purpurea, Monanthochloe littoralis* and *Chloris virgata* are outstanding.

Figure 2 shows a comparison of the four seasons analyzed.

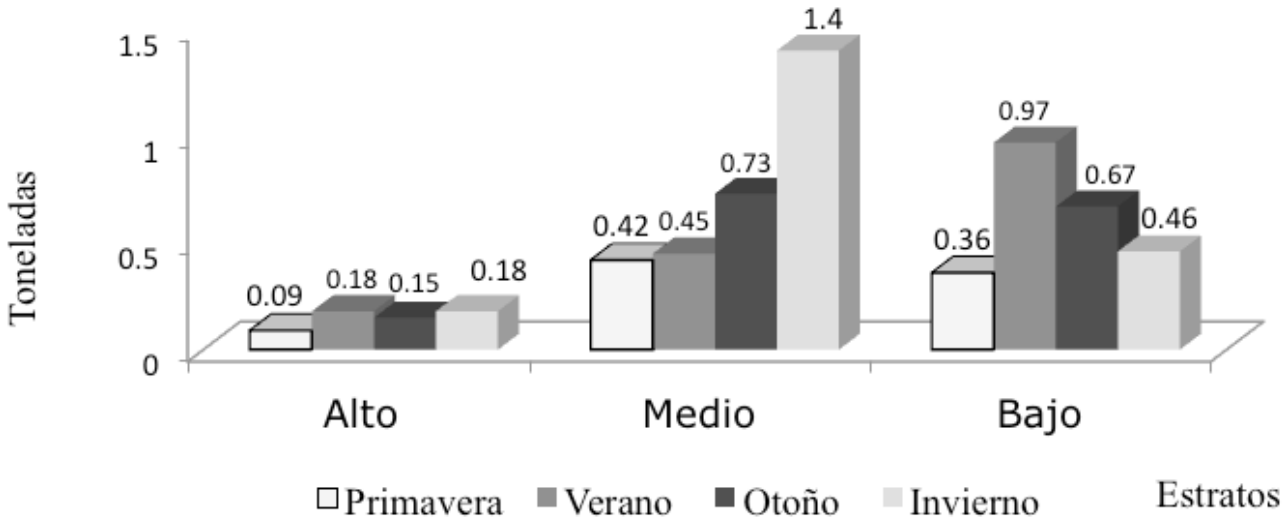

Figure 2. Comparison of biomass production between the seasons.

Diet of the species madeup

White-Tailed Deer (VCB). For spring it was recorded that the VCB consumes 20 species, of which it prefers *Solanum nigrum* (19.8 %) *Salvia* sp. (19.3 %) and *Lantana camara* (18.2 %). In the summer, 17 species with a preference for *Leucophyllum frutescens* (Berland.) I.M.Johnst., *Solanum nigrum* and *Acacia berlandieri* Benth. (29.6 %, 26.6 % and 14.9 %, respectively) were identified. For fall its diet consisted of 16 species, among which were *Acacia berlandieri* (35.9 %), *Solanum nigrum* (13.8 %) and *Lantana camara* (12.8 %). The winter season

included 22 species, with a higher preference for *Acacia berlandieri* (26.6 %), *Solanum nigrum* (25.8 %) followed by *Malvastrum americanum* (5.2 %) and *Foriestieria angustifolia* (5.2 %).

Sika Deer (VS). In the spring, the consumption of 15 species was identified, with a preference for *Chloris virgata* (30.6 %), *Aristida purpurea* (19.6 %) and *Pappophorum bicolor* E. Fourn. (18.2 %). In the summer its diet consisted of 17 *species, among the most preferred were Monanthochloe littoralis* (23.6 %)*, Acacia berlandieri* (19.9 %) *and Aristida purpurea* (18.2 %). For the fall, the diet consisted of 15 species, among the most important of which were *Monanthochloe littoralis* (31.1 %), *Chloris virgata* (15.7 %) and *Acacia berlandieri* (12.9 %). Finally, for winter, 13 species of plants were observed, with a higher preference for grasses such as *Spartina patens* (Aiton) Muhl (47.8 %), *Aristida purpurea* (17.7) and *Chloris virgata* (12.8 %).

Red Deer (CR). The species of plants consumed by the CR throughout the year were distributed as follows. in spring, 13 species were recorded in the diet, among which *Solanum nigrum* (40.6 %), *Spartina patens* (18.7 %) and Aristida purpurea (16.8 %) were the most consumed. In the summer, their diet included 12 species, of which *Solanum nigrum* (42.8 %), *Aristida purpurea* (17.9 %) and *Chloris virgata* (12.1 %) were preferred. In fall their diet consisted of 17 species, and the most important were *Solanum nigrum* (38.9 %), *Chloris virgata* (20.2 %) and *Aristida purpurea* (18.6 %). In winter, 12 plant species were observed, with a higher preference for *Solanum nigrum* (47.0 %), *Aristida purpurea* (19.7) and *Chloris virgata* (18.2 %).

Eland Antelope (AE). The AE consumed for the spring season, 17 species, in particular *Leucophyllum frutescens* (Berland) I. M. Johnston (20.6 %), *Acacia berlandieri* Benth. (11.7 %) and *Spartina patens* (11.3 %). For the summer, their diet consisted of 16 species, with *Aristida purpurea* (23.2 %), *Chloris virgata* (20.1 %) and *Solanum nigrum* (14.2 %) being preferred. During fall, it consumed 17 species as well, the most important of which were *Aristida purpurea* (17.0 %),

Leucophyllum frutescens (16.4 %) and *Chloris virgata* (15.4 %). In the winter, 16 species were identified, with a higher intake of *Solanum nigrum* (39.2 %), *Malvastrum americanum* (L.) Torr. (28.2 %) and *Leucophyllum frutescens* (11.4 %).

Figure 3 shows the consumption by stratum and season of each of the species under study.

The previous values were lower than (22 species) the results obtained by Gallina (1981, 1993) in the *La Michilía* Biosphere Reserve, *Durango*, who reported a consumption of 135 plant species; in addition, they differ from those of Villarreal (2000) in a *Nuevo León* estate where the Tamaulipan thorny scrubland prevailed, where he points out the presence of 51 species in the diet of the White-Tailed deer. All these works were carried out in areas with vegetation types different from those found in the study described here, in addition to which the species present are more numerous.

Diet composition for each species

Similarity between diets

In order to determine the similarity of diets, the assumption was made that the White-tailed deer is the most important species, as it is a local native, it is the most interesting to know if it states competition with other exotic species as well as among them. The data used for this analysis were taken from the histology of the plants compared with the material found in the feces (Table 2).

Table 2. Kulczynski Similarity Index Values between the White-tailed Deer and the three studied exotic species.

Season	Sika Deer(VS) %	Red Deer (CR) %	Eland Antelope (AE) %
Spring	49	54	47
Summer	36	39	42
Fall	45	33	34
Winter	20	43	55

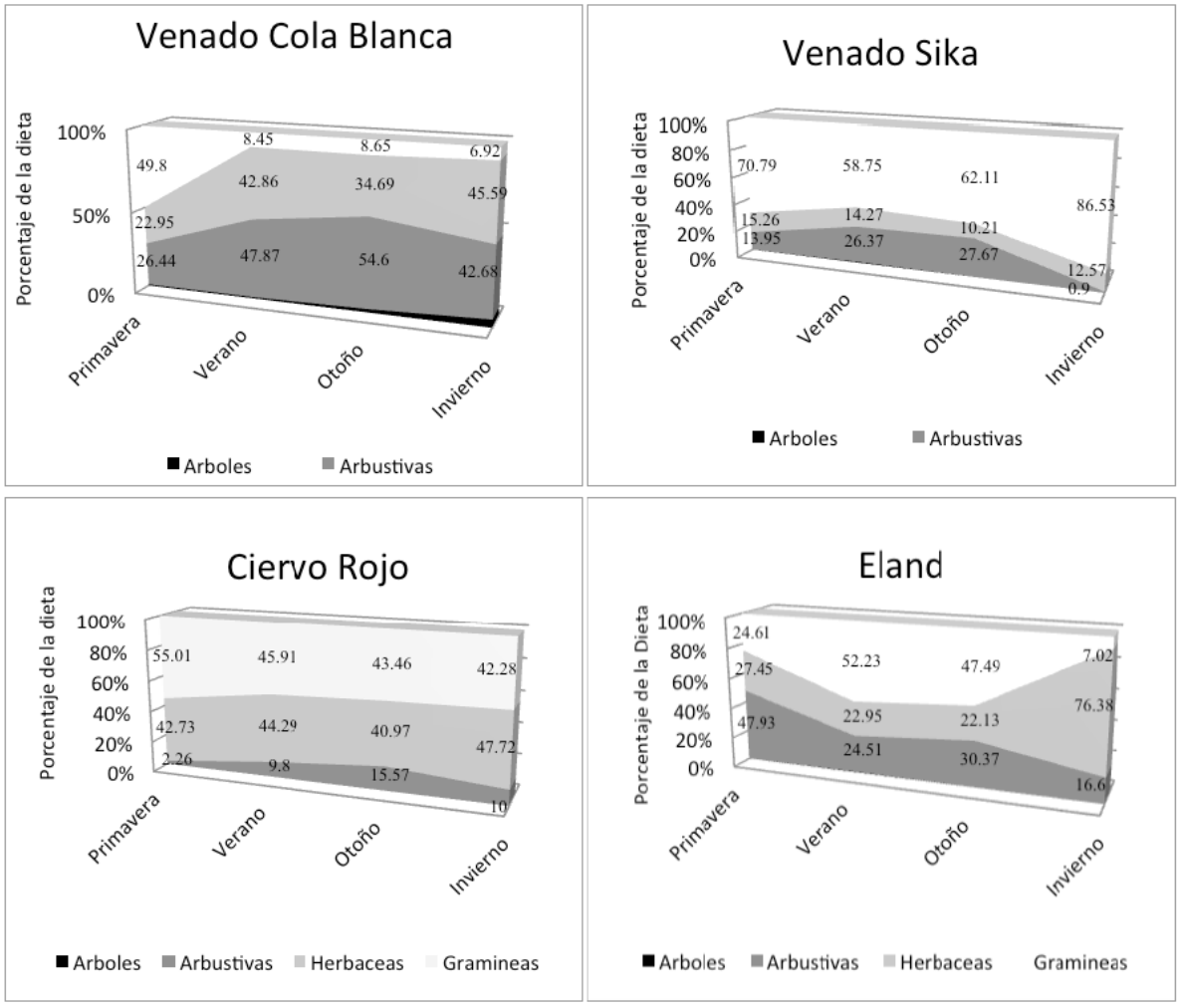

Figure 3. Diet composition of the four species under study by season and type of vegetation.

As it can be observed in Table 2, Spring has the greatest diet overlap and it can be considered the most crucial; it is outstanding that the White-tailed deer coincides in the selection of almost 50% of the species to feed upon with the other exotic animals (VS, CR and AE). For the summer, the VCB registered a greater competition with the AE (42%). For fall, VS was the only one that showed similarity to the VCB diet (45%), and for the winter, two species reached a high Kulczynski Similarity Index in the selection of species of the VCB diet, or CR and EA (43% and 55%, respectively).

The results obtained agree with those of Baccus *et al.* (1979) for White-tailed deer as it mentions a competition for food in the Kerr Wildlife Management Area in Texas, between VCB and VS in proportions up to 99 %. Amstrong and Harmel (1981) also report the decline in the White-tailed population (15 to 6 animals) compared to the Sika increase (from 16 to 36 animals) over a 5 year- period, and declare the competition as the main cause of this population behavior.

On the other hand, it was recognized a great similarity of selection of vegetation strata for their diet between VS and AE (97 %), CR and AE (76 %) and VS with CR (60 %). This coincides with Chávez (2000) who confirmed similarities between diets of the Axis deer (*Axis axis* Erxleben, 1777) and the European fallow deer (*Dama dama* Linnaeus, 1758) of up to 58.81%. This suggests that there is greater competition for resources between exotic and local species.

In order to corroborate the accuracy of the data obtained with the Kulczynski Index in the diet between species, a second test was performed with the Pearson Correlation Coefficient (Table 3).

Table 3. Values obtained with Pearson Correlation of the diets among the four species in the four seasons.

	VCB	**VS**	**CR**	**AE**
Spring				
VCB	1	0.93	0.76	0.53
VS		1	0.79	0.18
CR			1	0.08
AE				1
Summer				
VCB	1	-0.073	0.15	0.06
VS		1	0.62	0.97
CR			1	0.77
AE				1
Fall				
VCB	1	-0.05	0.10	0.24
VS		1	0.61	0.94
CR			1	0.76
AE				1
Winter				
VCB	1	-0.469	0.25	0.75
VS		1	0.60	-0.21
CR			1	0.65
AE				1

VCB = White-tailed deer; VS = Sika Deer; CR = Red Deer; AE = Eland Antelope.
The degree of significance in the correlation was taken
at 0.05 % (95 % confidence).

According to the above and returning to the values determined in the discriminant analysis, the spring season coincides with the data obtained by the Kulczynski Similarity Index, confirming a high degree of competition between native and exotic species, and correlations greater than 0.50 in all three cases.

For summer and fall, there is a low correlation between the four species, which may be explained by the fact that they are the seasons with the highest production of biomass and diversity of plant species in the area.

The mean values of Sika (0.47) and the Red Deer (0.25) were correlated with a high correlation with the antelope (0.75).

As in the Kulcynski Similarity Index, there is greater dietary competition among the three exotic herbivores, with high to very high values in the summer, fall and winter seasons, and a low correlation for spring from low to very high only for the food interaction between Sika and the Red Deer.

Conclusions

Spring is the most critical season in terms of competition for food resources for Whitetail Deer; (856 kg ha^{-1}), compared to summer, autumn and winter (with 1 600, 1 500 and 2 050 kg ha^{-1}, respectively). In the case of the other three exotic herbivores, summer, autumn and winter seasons are critical to the food they share with each other, so in the spring, management activities should be carried out.

There is more intense competition between the three species of exotic species, mainly grasses, during most of the year, and only the Eland Antelope and the Red

Deer compete with the White-tail Deer for shrubs and grasses at some time of the year.

The average stratum and low vegetation stratum of the study area are the most important, since they produce the highest amount of feed for the species of animals located in the place, approximately 90 % of the total annual biomass produced by the different types of vegetation.

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Conflict of interests

The authors declare no conflict of interests.

Contribution by author

César Augusto Olguín Hernández: field work and writing of the manuscript; Fernando Noel González Saldívar: responsible for the original Project, review and correction of the manuscript; César Martín Cantú Ayala: review of results, statistical analysis support and in writing of the manuscript; Luis Rocha Domínguez: support in plant identification and in discussion of the results; José Isidro Uvalle Sauceda: support in plant identification and in discussion of the results; José Guadalupe Marmolejo Monsivais: statistical analysis support and in the discussion of the results.