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Population Studies of Deer (*Odocoileus virginianus*, *Mazama americana*) in Southern Yucatán, Mexico

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Estimate the population density of deer in the municipality of Tzucacab, Yucatán in the periods of 2003-2004, 2007-2008 and 2008-2009, determine the use of the habitat by these populations and the sustainability of the deer harvest from the estimated population densities.
Study Design: A descriptive and vertical free-living deer population study was carried out in southern Yucatan, Mexico over a three-year period.
Methodology: The map of the municipality of Tuzcacab was zoned in quadrants of 36 km^2, completing a total of 36 quadrants; Unrestricted random sampling was applied to select seven quadrants in the period from 2003 to 2004 and 18 in each annual period between 2007 and 2009. Population samplings were carried out by applying three population estimation methods: direct sighting in a linear transect of 5 km in length, count of tracks in transect except period 2003-2004 and faecal pellets group count in plots. The evaluation of the use of habitat was carried out using

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the Bonferroni intervals, from the data of faecal pellets count. The evaluation of the deer harvest was carried out using the sustainable harvest model.
Results: The population densities were different in each method, the density by the excreta count was 4.63 ± 2.49 deer / km^2 in 2003-2004, 0.294 ± 0.198 deer / km^2 in 2007-2008, and in the year 2008-2009 was 0.419 ± 0.0000085 deer / km^2. Habitat use in 2007-08 and 2008-2009 was higher in the tropical forest, lower in agriculture and similar to that expected in secondary succession forest (acahual). The values of sustainable harvest, taking as a value the density per count of excreta in the plot because it showed the highest statistical precision, in the period 2003-04 it is sustainable, but in the period from 2007 to 2009 it is not sustainable.
Conclusion: The population densities of deer (*O. virginianus* and *M. americana*) in Tuzcacab by means of the excreta count method, have decreased significantly. The habitat use preference is the tropical forest. The deer harvest in the period from 2007 to 2009 is not sustainable.

Keywords: White-tailed deer; Odocoileus vriginianus; temazate deer; Mazama americana; population density; habitat use; harvest.

1. INTRODUCTION

There are four species of deer in Mexico: *Mazama americana, Mazama pandora, Odocoileus virginianus* and *Odocoileus hemionus*, all of them have been used for meat consumption and as hunting trophies, especially *O. virginianus* [1,2].

To make the legal use of these species, it is necessary to estimate the density or abundance of populations of free animals, this activity represents the support of population studies, because from these results it is possible to make basic decisions about management of these, either for conservation or exploitation purposes, according to the General Law of Wildlife in Mexico [3].

Studies of population changes of deer and other species of economic and social importance in Mexico throughout annual periods are necessary, because they identify population trends and with this information decisions are made on sustainable extractive use [4].

The population studies of deer in Mexico have been diverse [5,6,7], but it is little to characterize the population dynamics over several annual periods [8]. Some studies of population dynamics of deer have been carried out from simulation of population models in several countries [9,10], these studies are important when there is scarce data; however, they must be complemented with studies *in situ* to confirm the validity of the results generated by these models.

Population studies of deer in Yucatán are limited; Deer population estimates have been made with different methods, the most used are by direct sighting in linear transect, tracks count, and faecal pellets group count in plots [11,12]. The results vary, from 0.6 to 5.4 deer / km^2 [12,13]; In Yucatan there are no population studies of deer over several years, therefore the population trend is not known.

The objectives of this research were to estimate the population density of deer, evaluate the habitat preference and the sustainability of the deer harvest during the annual periods of 2003-2004, 2007-2008 and 2008-2009 in the municipality of Tzucacab, Yucatán, Mexico.

2. MATERIALS AND METHODS

2.1 Study Site

The study was carried out in the municipality of Tzucacab in the south of the state of Yucatán, located between the coordinates 19°38 "and 20° 09" of north latitude and 88°59 "and 89°14" of west longitude, it limits the north with The municipalities of Tixméhuac and Chacsinkín, to the south with the State of Quintana Roo, to the east with Peto and to the west with Tekax, with a surface area of 1,289 km^2 [14]. The native vegetation in the municipality has a high level of fragmentation. The climate of the study area is Aw1 (i ') g, warm subhumid with an annual mean temperature of 25.6°C, with continuous rains in summer and intermittent in winter with total annual rainfall of 1204.9 mm^3 [15].

The native vegetation or tropical forest in the study area are the medium sub-deciduous forest (MSDF) and the low sub-evergreen forest (LSGF) in different degrees of succession (acahual), due to the high fragmentation in the sampling areas, patches of secondary vegetation

are found in acahual and agricultural crops [16]. Fig. 1 shows the State of Yucatán in the Mexican Republic and the municipality of Tzucacab.

2.2 Installation of Sampling Sites

From geographic maps obtained from the National Institute of Statistics, Geography and Informatics [17] at a scale of 1: 300,000, the municipality of Tzucacab was divided into quadrants of 36 km^2 (6 x 6 km). In the period from November 2003 to June 2004, seven transects were installed. In the periods from October 2007 to June 2008 and from October 2008 to June 2009, 18 transects were established in each period. In all periods, monthly transects of 5 km in length were established in each selected quadrant. A table of random numbers was used to select the quadrants. A linear transect was opened, with the support of a compass and tape measure, the geographical positions with GPS were also recorded at different points along each transect. Coordinate records were made in degrees and minutes with WGS 84 datum.

In Fig. 2 the location of the total quadrants is shown, the ones shaded in yellow are those that were randomly selected to place transects and plots installed in the municipality of Tzucacab.

In each transect, square plots of 100 m^2 of surface were established, alternated to the left and right, placed 20 meters perpendicularly. The longitudinal distance between plots was 100 meters, in the period 2003-04 350 plots were installed, and in the periods 2007-08 to 2008-09 900 plots were placed in the 18 transects. Each plot was cleaned of old fecal groups, to record only those that were found in an inspection 30 days later. Once the plots were installed, they were associated with three types of vegetation, according to the dominant species in the site where the plot was installed: tropical forest, agricultural and acahual, defining the forest as the type of vegetation that presents characteristic strata of MSDF or LSGF; acahual, as the vegetation in different stages of secondary succession; agricultural, as the vegetation that was substituted for livestock use and agricultural cultivation.

2.3 Population Estimation Methods

The population estimation was carried out by three methods: sighting of deer, counting of tracks and counting of faecal groups or excreta in the plot along the transects were carried out in the period from 2007 to 2009. In the period 2003-04, only sighting and counting of excreta were carried out. The sighting records were made from 7:00 to 11:00 am, at an average speed of 1.25 km / hour. The animal sighting method was applied in a linear transect, recording the angle of sighting and radial distance, to estimate the perpendicular distance. The data obtained from the direct counting of animals were processed with the model used by [18], using the Fourier Series to estimate the population density with its 95% confidence intervals.

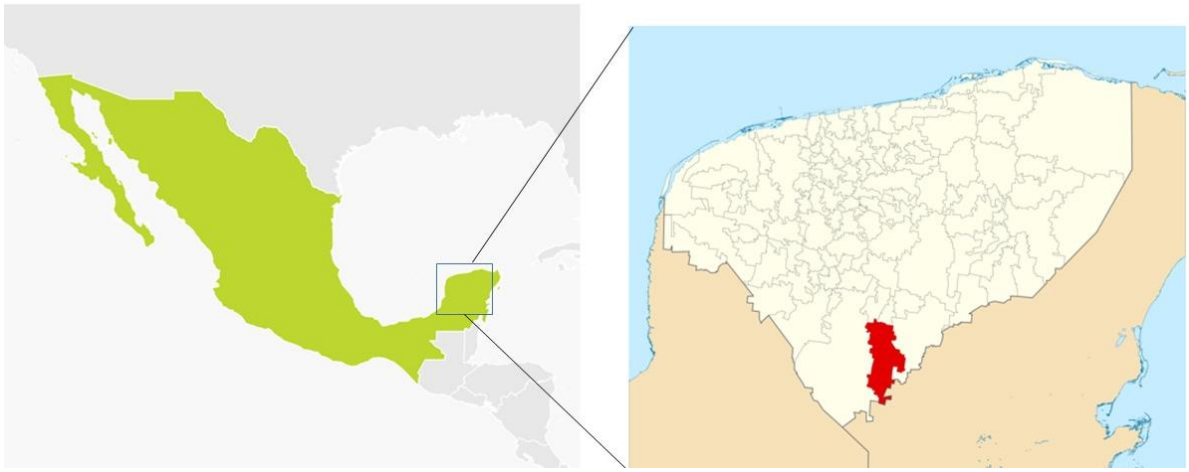

Fig. 1. Map of Mexico and the Municipality of Tzucacab in the state of Yucatan marked in red
https://es.wikipedia.org/wiki/Municipality_de_Tzucacab#/media/Archivo:Mexico_Yucatan_Tzucacab_location_map.svg. https://www.tomtom.com/es_es/drive/maps-services/shop/travel-map/mexico/

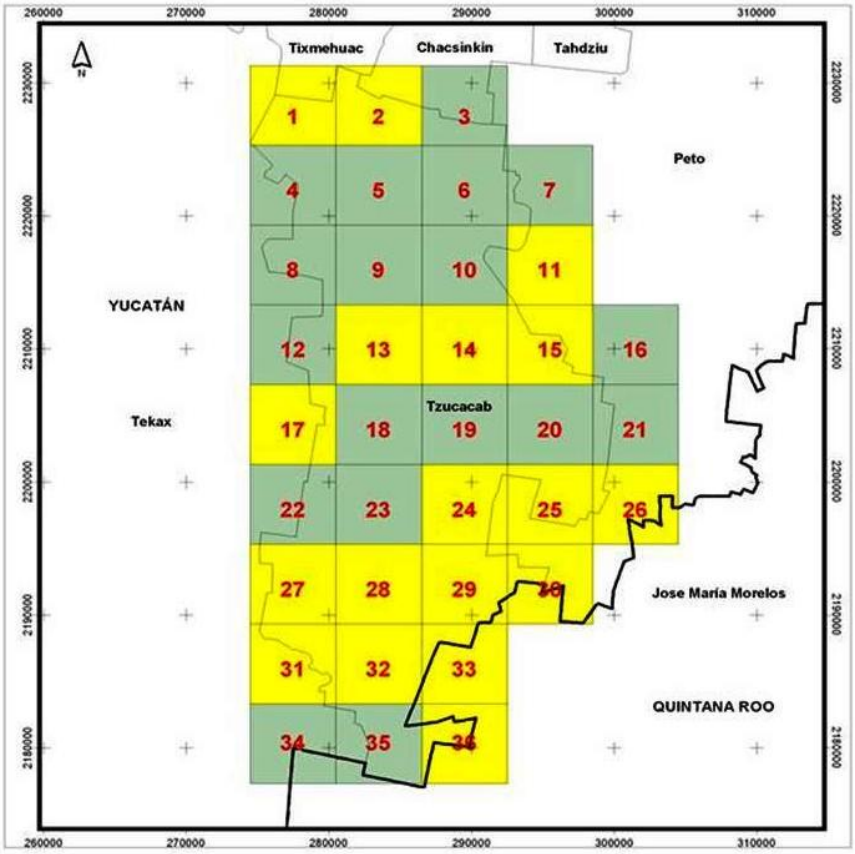

Fig. 2. Map of the municipality of Tzucacab zoned by quadrants of 6 x 6 km, scale of 1: 300000. The quadrants in yellow were those selected at random for the deer population sampling. Field study 2003-2004, 2007-2008, 2008-2009

Once each transect was established, the old tracks present in it were cleaned, to later record recent tracks. The estimation of the population density by counting the deer tracks was carried out by the formula reported by [19].

The estimation of the population density by fecal groups was carried out by the method of Eberhardt and Van Etten mentioned by [19].

The distribution pattern of the deer populations used was the Morisita standardized dispersion index, using the Chi-square as a statistic significance test, by means of the Ecological Methodology software, version 6.1.4 [20].

A matrix was prepared with the data collected during the installation of transects in each of the quadrants to carry out the analysis of habitat use. In this matrix, the transect number, type of habitat, number of tracks and faecal pellets in the plot were related. Subsequently, the relative areas for each type of habitat were estimated, based on the hectares estimated by [21]. The different types of habitats were tropical forest, acahual and agricultural, which corresponds to a total surface of 760.3481 km^2. The model to determine the statistical differences regarding habitat preferences was with the Bonferroni intervals [22]. The geographic coordinates of deer tracks and excreta were recorded in order to locate them on the map with the quadrants selected for sampling.

The significance of the population densities of deer between the periods 2003-04, 2007-08 and 2008-09, were determined through the 95% confidence intervals, which are obtained from the estimates of the standard errors of the population densities [23].

2.4 Estimation of Sustainable Harvest

The sustainability evaluation of the deer hunt was carried out by the sustainable harvest model (SH), based on the number of animals hunted in Tzucacab, which was published in the first report made by [24], which is 180 per year, the amount of surface area in Tzucacab as available habitat for wildlife (agricultural areas,

acahuales and tropical forest) 760.3481 Km^2 [21], the population densities of the years 2003-04, 2007-08 and 2008-09. The SH of [25] was applied, the proportion of females in the total population is 50%. , the reproductive productivity of 1.5 (1.5 fetus / female and 1 calving / year / female) [26]. The SH for deer is based on life expectancy, which is long, therefore the proportion of SH should not exceed 20% or 0.20 [27].

3. RESULTS AND DISCUSSION

The sightings of deer in the period 2003-04 were 15 deer: 10 temazate (*Mazama americana*) and five white-tailed (*Odocoileus virginianus*). In 2007-08, 13 deer, two temazate and 11 white-tailed were observed. In 2008-09, six deer were recorded, two temazate and four white-tailed. Fig. 3 shows the estimates of population density with this method.

Fig. 4 shows the population estimates by means of the transect track count in the two study periods. The number of deer tracks was scarce, for that reason also their density is low. The presence of fecal groups or deer excreta was also scarce in the 900 plots installed between 2007 and 2009; However, in the period 2003-04, the excreta count was higher despite having fewer plots, therefore the density is higher. Fig. 5 shows the estimates of deer density in Tzucacab by counting faecal groups in plots.

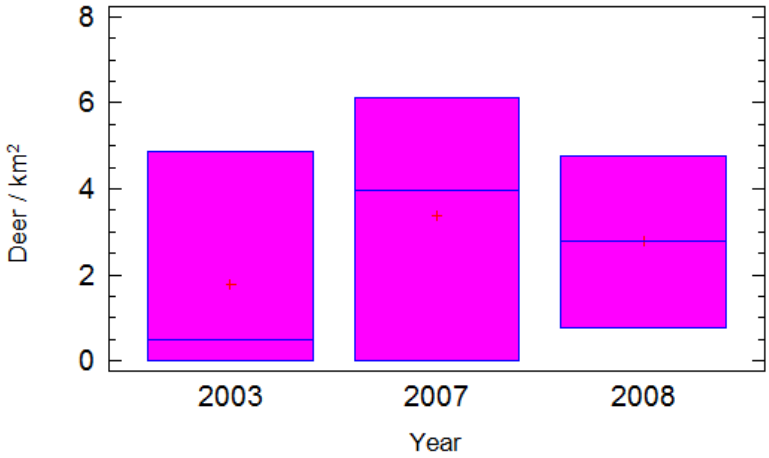

Fig. 3. Confidence Intervals at 95% of deer density through sightings in linear transect, in three sampling periods, in Tzucacab, Yucatán

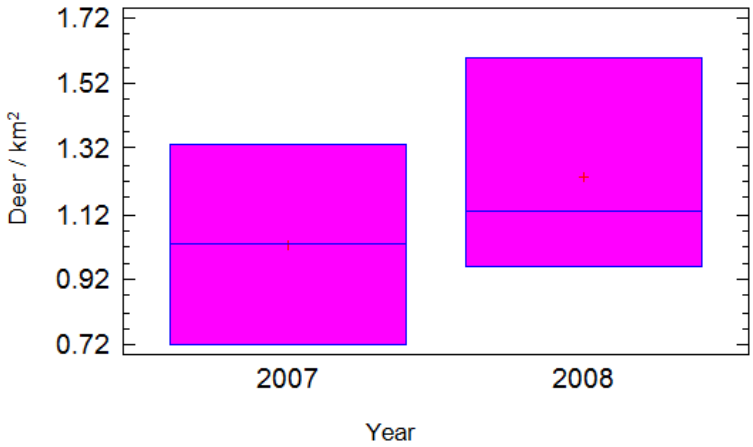

Fig. 4. Confidence Intervals at 95% of the density of deer through track record, in two sampling periods, in Tzucacab, Yucatán

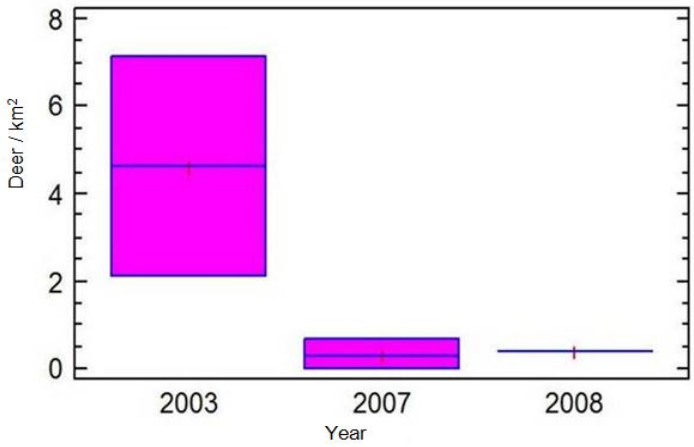

Fig. 5. Confidence Intervals at 95% of the density of deer by counting the excreta in the plot, in three sampling periods, in Tzucacab, Yucatán

Dispersion of the deer populations in Tzucacab by means of the Morisita index was by clusters, the value in each year is greater than 0.5. The Morisita dispersion index for deer is shown in Table 1, the spatial distribution is of the cluster type with a high significance value.

Tables 2 and 3 show the matrix of Bonferroni intervals, to evaluate the use and availability of each type of habitat by deer in the periods from 2007 to 2009. Deer make a greater use of the tropical forest than expected, while the agricultural habitat is less used than expected, and their use of secondary vegetation (acahual) is as expected. Fig. 6 shows the location of deer tracks, sightings in transects and faecal pellets in plots installed in the quadrants sampled in Tzucacab, in the periods from 2007 to 2009.

Table 1. Values of Morisita estimators and statistics to estimate the type of distribution that deer present in the municipality of Tzucacab, during the sampling period from October 2007 to June 2008 and from October 2008 to June 2009

Period	Morisita Standardized coefficient	Chi squared	Accepted hypothesis
2007-08	0.52	61.27 (P <0.001)	Cluster distribution
2008-09	0.62	83.71 (P <0.001)	Cluster distribution

Table 2. Matrix of use and availability of each habitat type, by deer in Tzucacab, Yucatán, during the period from October 2007 to June 2008

Habitat	Expected use ratio (Pe)	Observed usage ratio (Po)	Bonferroni interval
Tropical Forest	0.35	0.61	0.52 ≤ 0.61 ≤ 0.70 (Po> Pe) *
Acahual	0.22	0.30	0.21 ≤ 0.30 ≤ 0.38 (Po = Pe)
Agricultural	0.43	0.09	0.04 ≤ 0.09 ≤ 0.14 (Po <Pe)*

** Indicates a significant difference (P = 0.05)*

Table 3. Matrix of use and availability of each habitat type, by deer in Tzucacab, Yucatán, during the period from October 2008 to June 2009

Habitat	Expected use ratio (Pe)	Observed usage ratio (Po)	Bonferroni interval
Tropical Forest	0.65	0.77	0.68 ≤ 0.77 ≤ 0.85 (Po> Pe) *
Acahual	0.13	0.16	0.08 ≤ 0.16 ≤ 0.23 (Po = Pe)
Agricultural	0.22	0.08	0.02 ≤ 0.08 ≤ 0.13 (Po <Pe)*

** Indicates a significant difference (P = 0.05)*

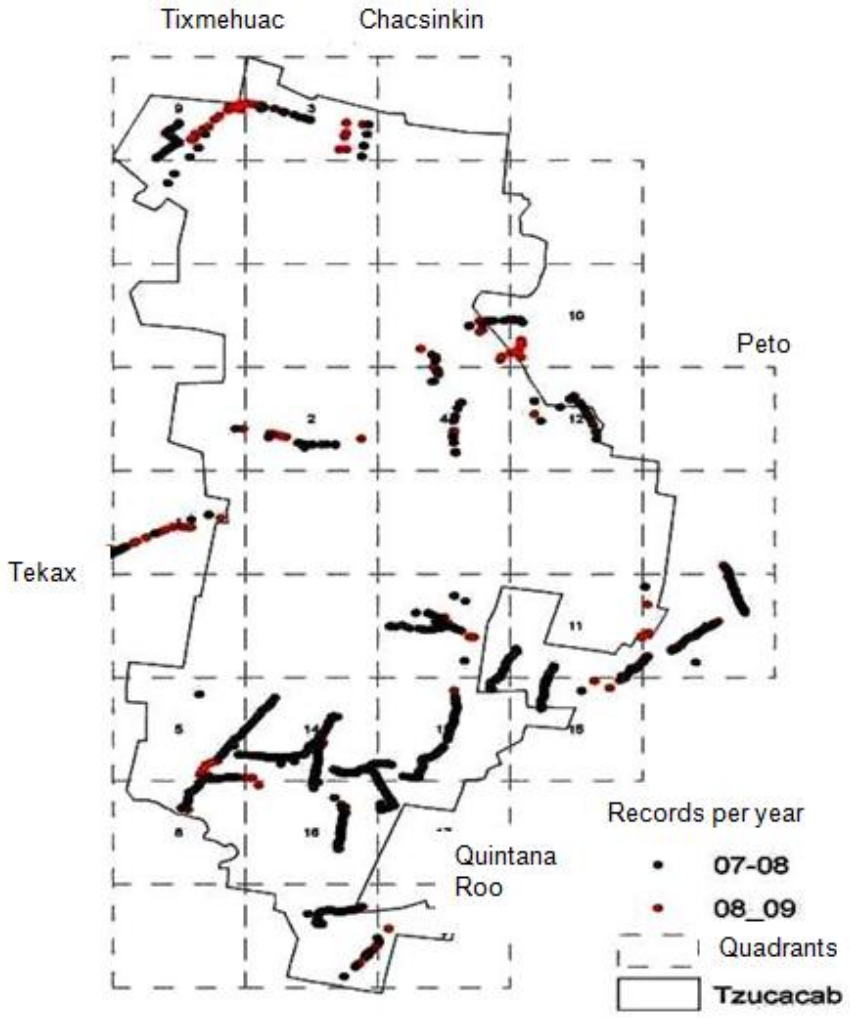

Fig. 6. Map of the location of the sampled quadrants where deer records (sightings, excreta and tracks) appeared, in the municipality of Tzucacab, during the period 2007-2008-2009

The location of tracks and excreta in the deer plot indicate that there is no defined spatial pattern; However, it can be noted that there are numerous deer records that are located in the quadrants of the limits of the municipality of Tzucacab with four municipalities that surround the state Yucatán as well as the state of Quintana Roo; They tend to be distributed mainly in the southern zone of the municipality of Tzucacab, where there is less presence of human settlements and agricultural-type patches in those years.

It is found, in the spatial distribution of the tracks and excreta of cervids in the transects located in the municipality of Tzucacab and the area of influence, that these are not randomly distributed in each year, but are grouped especially at the edges of the municipality, that is in the limits with the territory of the municipalities of Peto, Tekax, Chacsinkin, Tixmehuac and the state of Quintana Roo; even the sightings are not distributed in the center of the town area, but in the outer limits, being consistent towards the four cardinal points of the territory of Tzucacab.

The deer harvest analysis with the tracks and sighting methods showed some periods that the harvest is sustainable but without any defined pattern, in part due to the high variability of the population estimates; However, the trend of population densities by the method of counting excreta in the plot tends to decrease alarmingly, based on this method, the trend of the deer harvest from 2007 to 2009 indicates that it is not sustainable, because the calculated value is greater than 0.2 (Fig. 7).

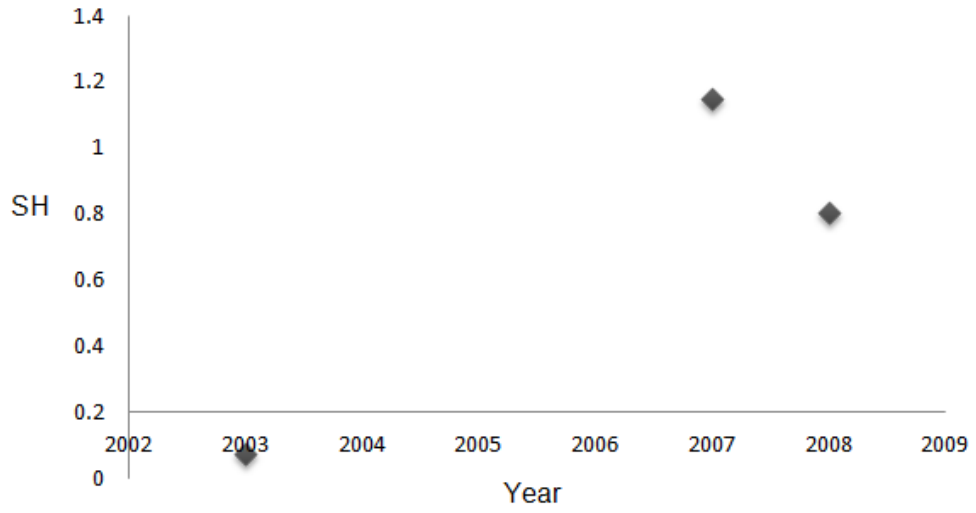

Fig. 7. Estimated Sustainable Harvest (SH) for deers (*Odocoileus virginianus, Mazama americana*), in three study periods in the municipality of Tzucacab, Yucatán from 2003-2004, 2007-2008, 2008-2009

Diamonds are sustainable harvest (HS) values. Value greater than 0.20, means unsustainable harvest

In the population study from 2007 to 2009 in Tzucacab, the total number of sightings was relatively low, according to [18] the recommended sample size to obtain estimates with low coefficients of variation (less than 20%), should be at least 40, which was not reached, probably due to the low detectability [28] of specimens in numerous parts of the municipality, especially in the acahuales areas and in patches of MSDF, also in small portions of the transect grasslands were found that were approximately 1 meter high, which greatly diminished the ability to detect deer that would be found at these sites when the transect was monitored. The literature has reported [29] that the application of direct sighting in a linear transect has the following limitations: low number of observed animals, low visibility due to the type of tropical forest vegetation and difficulty in measuring radial distances.

Since the sighting data generate low-precision information, then the densities of the populations fluctuate noticeably. [30] points out that not much emphasis should be placed on the refined determination of a sample size, due to the risk of it being inappropriate in some circumstances, such as the hunting that takes place during the year in this municipality. [31] due to this important factor, it was decided to sample 50% of the municipality, which corresponds to 18 quadrants out of 36 in total.

The estimate of deer density ranged between 0.0 and 7.12 deer / km^2, depending on the method used. In other studies, with deer, differences have also been reported between the different methods used [19]. Although the values obtained are different, the tendency to obtain low densities is maintained. With the direct method of sightings in linear transect, the density found in this study is lower than those reported by [32] in the El Edén Ecological Reserve in Quintana Roo where they estimated 5.5 ± 4.1 deer / km^2 and reported by [19] in the Chamela Reserve in Jalisco, with densities of 9.6 to 14.9 deer / km^2 and standard error (SE) between 1.4 to 2.2. In the study carried out by [11] in another municipality in the state of Yucatán, they obtained densities of 3 to 4 deer / km^2 through sightings in a strip transect.

Few observations were obtained with the method of counting excreta in plots and tracks in transect, it generated the lowest population density in the period from 2007 to 2009, even when the method of counting excreta showed the highest precision due to its lower coefficient of variation (CV). However [19] in the years 1989 to 1991 reported high densities of deer in dry tropical forest, similar to that of Yucatan, with the excreta counting method they estimated densities of 27.1 and 28.1 with SE of 3.8 and 6.7; With the tracks count method, they reported densities of 1.3 to 2 / km^2 with SE between 0.2 to 0.3, but the highest density report was in the Laguna de Términos de Campeche Flora

and Fauna Protection Area [33] with 45 deer / km^2.

These population densities of cervids show that in Tzucacab, where hunting takes place throughout the year [24], the number of animals is lower than in sites with harvest restrictions [25, 34,32], since, in the case of deer, hunting modifies the behavior of the animals, which seek other refuge sites, moving away from inhabited sites, modifying their movement, activity and habitat selection [35]. This is confirmed by their greater use of the tropical forest, while in habitats with anthropogenic activity (agriculture and acahual) they suffer loss of plant cover or change in land use, leading to deer using these sites to a lesser extent than expected. In Tzucacab, the tropical forests are cut down to convert them to grass lands or agricultural sites [36]. But in the case of the white-tailed deer, it is a generalist species, inclined to adapt to disturbed sites such as agricultural fields or secondary vegetation) [37], this factor probably would not be the cause of its low density, but it is the hunting pressure on them [38]. So, the tropical forest sites that are still available house most of the small population that remains in the municipality and in the disturbed sites their presence is infrequent.

The population densities of deer (*Odocoileus virginianus, Mazama americana*) for the periods 2003-2004, 2007-2008 and 2008-2009 are different according to the monitoring technique used. This result is as expected, because direct and indirect methods were used that have totally different foundations and assumptions. However, the monitoring techniques by tracks and sightings showed that the population densities are statistically equal with the confidence interval of 95%, but not so for the densities estimated with the parcel excreta counting technique, which showed a very noticeable difference between the periods of 2003-04 vs 2007-08 and 2008-09.

Starting from the general hypothesis that there would be no population changes of cervids in the municipality of Tzucacab based on the population densities with the sighting and track counting methods, the result that would confirm this hypothesis would be when the confidence intervals (CI) of 95 % with the three techniques will give statistically equal intervals. The contrary situation was obtained in this work, according to the estimates generated by counting fecal or excreta groups. Therefore, if the Precautionary principle [39] is assumed, then a warning should be given to the fact that the population density with the excreta counting method differs significantly from the other two, taking into account that the sampling effort was lower during the period 2003-2004 than from 2007 to 2009, in magnitude of 2.6 times (350 plots vs 900, respectively), the sampling effort, highlights the reliability of the excreta counting method in plots to determine the abundance of cervids in the study site, given that they were carried out under the same conditions of time (from November to June of the following year), methods (linear transect, tracks and excreta in the plot) and place (municipality of Tzucacab). The main factor that reduces the strenght of sighting samplings is the low detectability of individuals in tropical forest [28]; however [11] mention that the method of estimation of deer population by tracks in Tzucacab is adequate, because in the year 2007-2008, the population estimates have the lowest variance, which is true, but this result was only during the 6-month period (October 2007 to February 2008) of the three years evaluated.

The population changes between 2003-2004 vs 2007-2009 show a statistically significant decrease, based on the 95% confidence intervals. Therefore, local populations seem to be highly vulnerable, because if they follow a uniform downward trend, populations will decrease to amounts that put their existence at risk in the medium or long term [40,38].

But, if the number of deer tends to decrease, then a question arises, what is the reason why deer are still being detected and extracted in the area where they are scarce? A possible cause of this situation is that there are no physical barriers between the limits of Tzucacab and the surrounding municipalities, then there is a flow of animals between Tzucacab and the municipalities that surround it and the state of Quintana Roo. This argument is based on the distribution of the excreta and tracks of the cervids in the border areas, as shown in Fig. 6; so that the concept of source-sink habitat can be applied [41], which means that the habitats of other municipalities and the state of Quintana Roo function as a source, it means that as long as these habitats provide deer that migrate to the Tzucacab sink habitats, cervids will continue to be there.

It was found that the distribution of deer is by clusters, this means that they form groups isolated from each other, which is to be expected, since in the study area there is fragmentation of the habitat and therefore the reduction of breeding and protection areas. for these populations, which in both periods showed

a preference for the tropical forest, because they find the conditions for the reproduction and rearing of fawns in this habitat [42]. The distribution of the vegetation patches also has an impact, which is a consequence of creating agricultural areas, therefore smaller fragments are generated by the appearance of rural smallholdings, there were 1983 patches whose average size is 15 ha, the rate of change of land use to pasture and agricultural crops is continuous [36]. An important factor that leads to the fragmentation of the native habitat to another is to increase the agricultural and livestock activity that, it is assumed, can generate monetary income to the peasants. But the increase of smallholdings also produces greater formation of isolated patches, whose surfaces are increasingly reduced and therefore local populations of deer tend to be separated from each other. This geographic isolation would result in a lack of gene flow between populations, and therefore the genetic composition of wild populations can be altered, since according to [43] when populations tend to isolate themselves from each other, gene exchange through emigration and immigration is reduced. If it is added that the population sizes of deer also decrease, then it is possible that these local populations suffer gene drift and therefore loss of genetic variation in these populations [44]. Therefore, it is necessary to establish ecological corridors between the patches in this region, to maintain the connectivity of the local populations of deer and with this also other populations that are found there.

Given this scenario, it is important to plan the formation of biological corridors between the patches that are still relatively large and at the same time encourage support for owners who still have relatively large areas to conserve tropical forest habitat, which is adequate to offer refuge, deer breeding and mating areas [42]. In the information from SIG [21], it showed that there was still a total of 37.43% of tropical forest, 41.55% of acahual and 21.02% of agricultural area, considered as available habitat for deer.

The reference harvest value is 180 deer per year [24], but the decrease in population density based on the excreta count in the plot between 2003 and 2007, indicates that the amount harvested was probably higher than reported by [24]. According to the calculations of the expected population size, assuming a population scenario whose birth rate and natural mortality, immigration and emigration rates were equal, which would result in a stable general population balance, the expected density should be in 2007 -2008 of 4.63 deer / km^2, which would be equal to the density estimated in 2003-2004 by the excreta counting method, but the estimate showed a mean value of 0.294 deer / km^2. This indicates that the number of deer harvested is higher than expected; The average size of the deer population in the Tzucacab territory would be around 3,600 deer in 2003-2004, but for 2007-2008, the estimated population is 400 deer, that is, there are 3,200 fewer deer, which means that 800 deer are harvested annually, during the period of 4 years. This hunting pressure would be on the base population and on recruitment, that is, the individuals harvested are those that maintain the viability of the population. This is based on the information provided by [31], they reported that in four commissariats in Tzucacab hunt 12 specimens are hunted in four months, with a total biomass of 512 kg, being 455 kg of meat from *O. virginianus* and 57 kg of *M. americana*. In an optimistic scenario, 468 deer would be hunted per year, which represents 3 deer per commissariat per month, for 12 months, in 13 commissariats that make up the municipality; It should also be considered that deer hunting includes those animals killed but not captured; because of a bad shot, that is, the animal could not be captured but was injured by the shooting, therefore they are lost pieces for the hunter. These pieces are subtracted from the total population and therefore affect the total number of living deer and the number of potentially reproductive males and females.

It is important to note that hunting occurs throughout the year, putting these populations at risk of extinction [24], because, there are no periods of population recovery, when females need the opportunity to gestate, give birth, lactate and allow the growth and weaning of the young, of which there is a proportion that die from other factors such as parasitosis, diseases, predation or severe climatic changes [45], which decreases the recruitment rate of the population by birth. However, white-tailed deer are a generalist species and have the ability to adapt to highly modified habitats, therefore they withstand human management, being able to complete their biological cycle under artificial rearing conditions, that is, kept in pens, with an average population density at 25 m^2 per animal [13], which means that changes in land use probably would not represent a serious limitation to continue with their reproductive cycle, as long as there are favorable space conditions, food, cover and water in the habitat [46].

If the availability of plant biomass, represented by plant species consumed by deer, is not limiting for these populations, as reported for Campeche [47], which has similar vegetation as Tzucacab, where the carrying capacity was estimated to be 0.04 to 1.08 deer / Ha (4 to 108 deer / km^2). On the other hand, the natural predation of deer by felines is 2.5 deer / puma / year [48]; the density of jaguars of 2.6 animals / 100 km^2 (0.026 jaguars / km^2) reported in Yucatán [49], then 37.43% (482.4727 km^2) [21] is the tropical forest territory of Tzucacab, which is the natural habitat of jaguars [48], there would be a population of 13 jaguars. This possible population of jaguars would be predating 33 deer a year; But if the anthropic hunt is 180 deer a year [24], then 5.45 times more deer would be removed than what should support the population of jaguars or pumas in Tzucacab; consequently, the population of deer that should support the population of jaguars or pumas in Tzucacab is being removed. On the other hand, the survival rates from young to juveniles is 79% and from juveniles to adults is 63% [8] with these values the deer population would have a population growth trend, mainly if it is assumed that, generally, the young, sick or old animals are the most susceptible to mortality, this situation is consistent with that reported by [10] that according to the simulation of a population dynamics model in the Colombian Orinoquia; which concludes that the intensity of anthropic hunting is the main factor that could decrease the deer population, therefore the determining factor seems to be the pressure of anthropic hunting, this is also supported by [38], who reported that deer hunting by peasant-hunters in Tzucacab could lead to the extinction of local deer population.

Now, if the increase in the deer population is analyzed, from the intrinsic growth of this population, without considering migration, and from the fact that the finite growth rate for deer is from $\lambda max = 1.49$ to 1.63 [26], it would mean that the study population would grow despite hunting, as long as the harvest rate was less than the finite population growth rate. But, given that the density results estimated at a 4-year interval (2003 -2004 to 2007-2008) indicate that the population is decreasing; therefore, it is probable that the number of animals hunted is greater than that reported by [24] it would be assumed that the harvest rate exceeds the λmax, and natural mortality rate.

4. CONCLUSION

The population densities of deer in the municipality of Tzucacab are relatively low, with respect to that reported for tropical forests of the Yucatan Peninsula, with any of the three techniques used. The decrease in deer populations in Tzucacab is significant, between the periods 2003-2004 to 2007-2009. Deer use the tropical forest more than other habitats. The deer tracks are mainly found to the south in the limits with the municipalities that are around Tzucacab and the state of Quintana Roo, which suggests that there is migration of deer between these territories. The deer harvest in the period from 2007 to 2009 is not sustainable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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