Original Research Article

Population studies of *Pecari tajacu* collared peccary (Artiodactyla:Tayassuidae) in Tzucacab, Yucatán, México

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ABSTRACT

Aims: To estimate the population density of *Pecari tajacu*, determine the distribution pattern of this population in the sampling sites, determine habitat preference and evaluate the sustainability of the harvest in the three-year period.
Study design: Population study of collared peccaries in the wild, descriptive, and vertical in the municipality of Tzucacab, Yucatan, Mexico, during the years 2003-2004, 2007-2008 and 2008-2009.
Methodology: Seven linear transects of 5 km each were installed randomly in the municipality in 2003-2004 and 18 in each year from 2007 to 2009. The population estimate was made by direct sighting and counting of footprints in the same transects. The comparison of densities with the footprints' counting method was by analysis of variance and t-student for samples paired with the sighting method. The distribution pattern was analyzed by the standardized Morisita index; habitat preference was analyzed by Bonferroni intervals and the harvest model was applied to evaluate sustainability.
Results: Population densities decreased significantly ($P < 0.01$) by the footprints´ counting method from 2003-04 to 2007-09, from 1.16 to 0.26 animals/km^2 respectively, with the sighting method was 1.87 and 1.78 animals/km^2, the years 2003-04 and 2007-08 respectively, without significant difference ($P = 0.05$); In 2008-09 there was only one record. Local populations are distributed by clusters and prefer the acahual habitat between 2008-09. The sighting records and footprints are distributed mainly in the limits of the municipality of Tzucacab with the surroundings and the state of Quintana Roo. Harvest indices are within sustainability values but show a tendency to increase as the years progress.
Conclusion: Local populations of collared peccaries show vulnerability, if the trend of the harvest index increases progressively.

Keywords: collared peccary, Pecari tajacu, population density, harvest, subhumid tropics.

1. INTRODUCTION

The conservation and sustainable use of game species such as the collared peccary (*Pecari tajacu*) are necessary because this species has ecological, economic and social importance in the places where it is distributed. From the ecological point of view, it plays the role of prey for wild cats such as the jaguar (*Panthera onca*) and puma (*Puma concolor*) [1, 2] is also a seed disperser [3]. In the economic aspect, its role is to be a source of income for some

peasants who take advantage of it in subsistence hunting mode and therefore obtain some extra money to meet their basic needs [4], and in the Management Units for the Conservation of Wildlife under the modality of free-fauna management, with authorization to carry out the hunting activity, represents a hunting trophy [5, 2]. Regarding the social context, in some rural communities they use it as a source of food or to control them when they act as a pest in the crops where they eventually enter [6, 7, 8], it can also be mentioned that it has cultural importance, that is, the Mayan communities consider it an important resource as a material for tools, symbolic, pet, etc., with Cultural Significance Index (CSI) of 38.6, which is the second place in the group of mammals, only below the white-tailed deer (*Odocoileus virginianus*) [9].

It is necessary to characterize the populations of *P. tajacu*, to carry out the management of these populations at the local and regional level [10]. To achieve this, it is pertinent to carry out population studies for several annual periods and thus describe the trends of population changes, to propose appropriate decisions that allow maintaining viable populations in the long term [11]. With this information, it is possible to determine sustainable harvest rates [12, 13], and precise information would also be available to formulate population dynamics models, such as what was done in Colombia for the capybara *Hidrochaeris hidrochaeris*, these models serve to generate feasible scenarios that help identify important factors to take into account for decisions on the management of free populations [14].

Population studies on *P. tajacu* in Mexico and several sites in Latin America have generated specific information, that is, they are short-term studies and do not show population trends [3, 15, 16, 17, 18] Therefore, the following objectives are proposed in this research: to estimate population densities, determine the distribution pattern, evaluate habitat preference and the sustainability of the harvest of local populations of *P. tajacu* in the municipality of Tzucacab, Yucatán, Mexico in three annual periods.

2. MATERIAL AND METHODS

2.1 Study Site.

It was carried out in randomly selected areas within the municipality of Tzucacab, located between the coordinates 19° 38´ and 20° 09´ North latitude; 88° 59´´ and 89° 14' West longitude, at 36 meters above sea level [19], south of the state of Yucatán. The climate of the study area is Aw1 (i')g, warm subhumid with rainfall in summer and sporadic in winter [20].

Figure 1 shows the location of the municipality of Tzucacab and the different types of vegetation that existed. The native vegetation in the study area is the medium sub-deciduous and medium sub-evergreen forest [21, 22], due to the fragmentation of the native habitat in the municipality, patches of secondary vegetation are found in different stages of secondary succession, pastures, agricultural crops, and urban area [23].

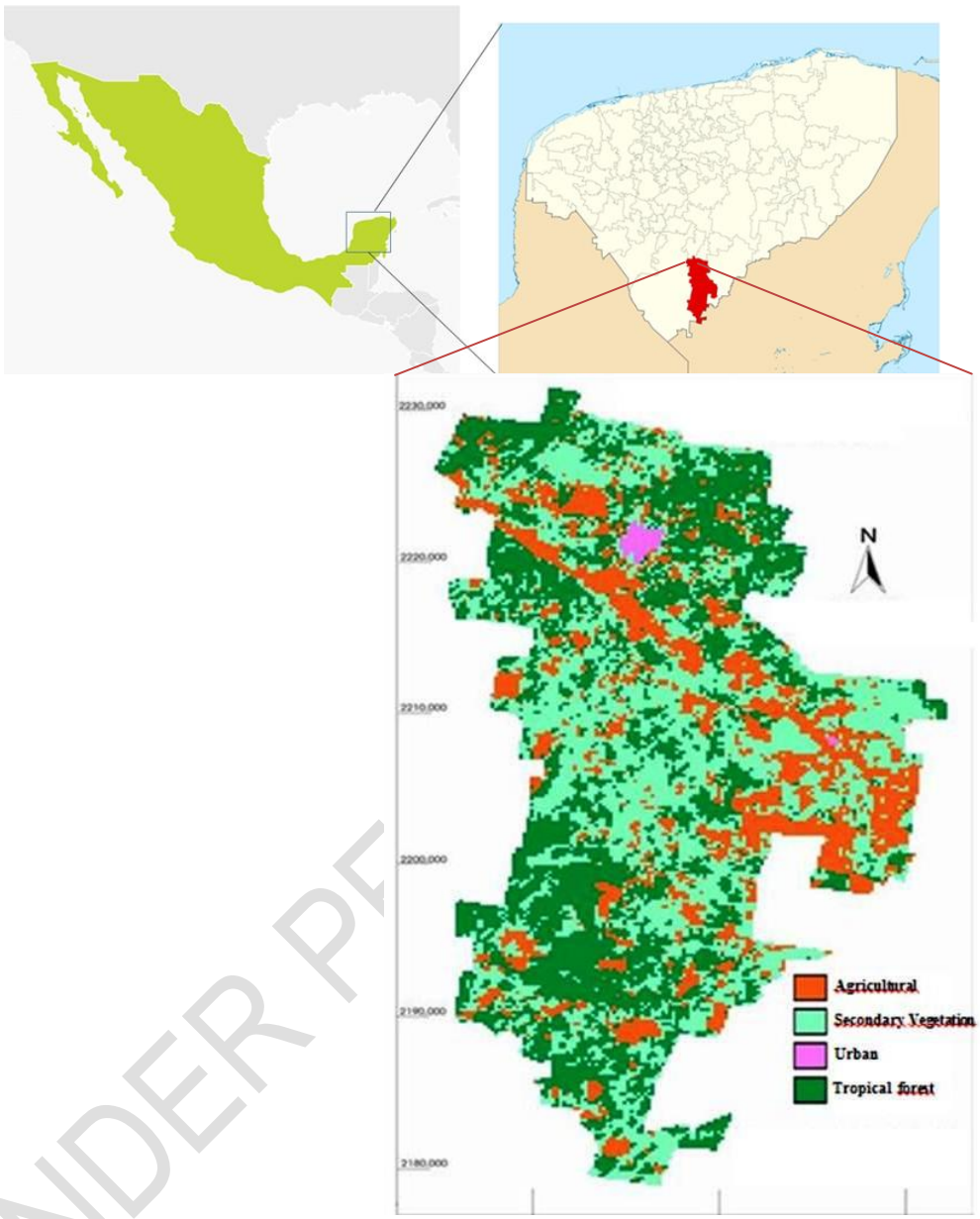

Figure 1. Location of the municipality of Tzucacab in Yucatán. Three types of patches of vegetation and urban area. Source: Landsat ETM. Path 20 row 46. Date 23/07/2002. GIS Laboratory, Center for Scientific Research of Yucatan (CICY).

2.2 Sampling sites

The municipality of Tzucacab was divided into quadrants of 36 km^2 (6 x 6 km) based on geographical maps obtained from the office of the National Institute of Statistics, Geography, and Informatics in 2003, Figure 2 shows the location of all the quadrants, the dark shaded ones are those that were randomly selected to install transects.

The size of the quadrants was not arbitrary, on the contrary, it was tried to minimize the effect of counting the same peccaries in adjacent quadrants, because the habitat reported by [24] for this species is 52 to 156 ha (0.52 to 1.56 km^2). By delimiting quadrants of 3600 ha, the risk of overestimating traces or individuals counted between linear transects in each quadrant is minimized. Quadrants were then chosen using the simple random sampling method using a random number table.

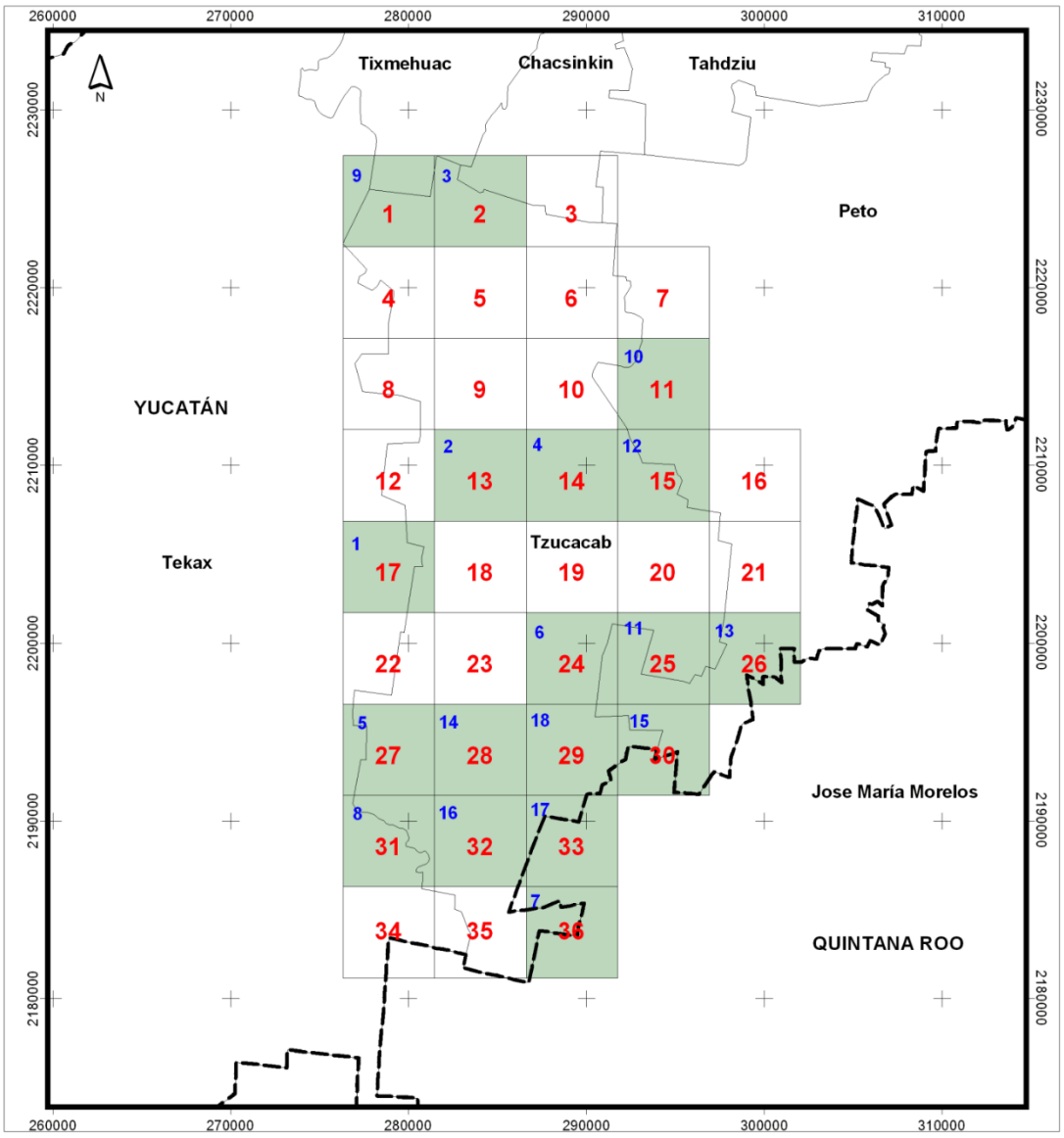

Figure 2. Map of the municipality of Tzucacab zoned by quadrants of 6 x 6 km. The dark quadrants were randomly selected for population sampling of peccaries. Small numbers in blue are the order in which they were sampled. The shaded lines are the borders of the municipality of Tzucacab. The dark-dotted lines are the borders between the state of Yucatan and Quintana Roo with the municipality of Jose Maria Morelos.

From October 2003 to June 2004, seven quadrants were randomly chosen; from October 2007 to June 2008, and the same months in 2008 and 2009, 18 quadrants were chosen in each period. In each quadrant a transect of 5 km in length was installed by opening a linear trail, which was previously located on the map with its respective coordinates. The installed transects were recorded with the help of GPS (Garmin etrex, USA) in units of degrees and minutes with the WGS 84 datum, as well as the geographical coordinates where footprints and sightings of peccaries were detected.

2.3 Population estimation methods

In the installed transects, all previous footprints were erased. The transects were monitored after a month of installation, to count the new records. The identification of footprints was carried out based on what was reported by [25]. The estimation of population density by means of footprints was made using the Tyson model [26].

The method of sighting animals in linear transect was also applied, data on sighting angle and radial distance were recorded, to subsequently calculate the perpendicular distance. Direct animal count data were processed with the model of [27], the parameters of the model were calculated with the Fourier series.

The records of sightings and identification of footprints on the previously established transects, were covered from 7:00 a.m. to 11:00 a.m., at an average speed of 1.25 km/hour.

2.4 Statistical analysis of densities

To compare the densities by the footprints' counting method in each year, the one-way analysis of variance was applied, then multiple comparisons were made using the Tukey's test. The student's t-test was used for paired samples, to compare the densities by sighting of peccaries, because only the results in two years were recorded. All statistical calculations were performed using the Statgraphics Centurion XVI software [28].

2.5 Habitat preference and distribution pattern

The records of sightings and footprints were associated with three types of vegetation, according to the dominant plant species at the site: Forest, agricultural and acahual. The Forest was defined as the type of vegetation that presents characteristic strata of medium sub-deciduous and medium sub-evergreen forest. Acahual, refers to the vegetation in different stages of secondary succession and Agricultural, refers to the vegetation that was replaced to be used for livestock and agriculture [29].

During the review of the transects, a data matrix was developed, based on the records, in which the sightings and footprints in transects of each quadrant were related to the type of vegetation, now called habitat. The relative areas for each habitat type were then calculated based on the hectares measured in the Landsat ETM image. The Chi-square test and

Bonferroni intervals were applied to determine statistical differences about habitat preferences based on sighting and footprint records [30]. The evaluation of the distribution pattern of peccary populations was estimated using the Standardized Morisita Index of Dispersion, and using the Chi-square as a significance test with the Ecological Methodology software [31].

2.6 Harvest assessment

The harvest model reported by [29], which generates a harvest index with values from 0 to 1.0, was used to evaluate the impact of the extraction of specimens reported in the study sites. The integrated variables applied in this model are productivity and harvest density, based on peccary hunting data according to [6]; reproductive behavior of peccary according to [32]; population densities of the years 2003-2004, 2007-2008, 2008-2009, and area available for each habitat type; the total available area is 760.3481 km^2 [29]. The results of the application of the model were plotted regarding each of the three years studied vs. harvest index. The harvest index is based on the long-life expectancy for this species, therefore it should not exceed 0.2, to be sustainable [33].

3. RESULTS AND DISCUSSION

3.1 Population estimate

From 2003 to 2004, 27 individuals were observed in 10 groups, the average was 2.7 individuals per group. The total number of footprints recorded was 105 in 35 km of seven transects.

Between 2007 and 2008, 22 peccaries were sighted in eight groups, the average number of animals per group was 2.75, and 51 footprints were recorded in 90 km traveled by 18 transects.

Between 2008 and 2009, only one solitary specimen was detected at 0 meters of perpendicular distance. Due to insufficient information, it was not possible to estimate the population density, so it is assumed that the value is indeterminate, and much lower than that recorded from the past period 2007-2008. The total number of footprints recorded in this period was 38 in 90 km covered.

Tables 1 and 2 show the population densities of collared peccary by sightings and footprint registration respectively. The densities per sighting in the years 2003-04 and 2007-2008 indicate that they are statistically equal ($P = 0.05$). However, using the fingerprint counting method, the densities are different between the years 2003-2004 with the following ($P < 0.01$); the contrary happens in the last two periods of 2007-08 and 2008-09 ($P = 0.05$).

Table 1. Estimate of the population density of collared peccary by recording sightings in linear transect in two annual periods

Year	Mean ± standard error (peccaries/km^2)

2003-2004	1.87 ± 1.09 a
2007-2008	1.78 ± 0.63 a

The same literal between lines, indicates that there is no significant difference (P = 0.05)

Table 2. Estimation of the population density of collared peccary by registering footprints in the three annual periods.

Year	Mean ± standard error (peccaries/km^2)
2004-2005	1.16 ± 0.27 a
2007-2008	0.35 ± 0.09 b
2008-2009	0.26 ± 0.09 b

The different literal between lines, indicates significant difference (P < 0.01)

The population density estimated in this study cannot be compared with abundance records in Chiapas, which were 0.346 ± 0.562 footprints/km [34] and average density of 1.2 peccaries km^{-2} day^{-1}, with the trap-camera methodology [15], the first in the southeast region and the second in northern Mexico. In Quintana Roo, the absolute density was recorded by [35] reporting density of 1.9 ± 0.8 specimen/km^2, using population estimation by strip transect. The different estimation methods used are based on different assumptions and mathematical models, therefore the comparability between their results is not valid. The use of two methodologies simultaneously is recommended, so that some of these are comparable with similar studies; this reason was also expressed by [36] who proposed the methods of sighting in linear transect and registration of images by camera traps for the Mayan jungle, which is the area that corresponds to Yucatan.

The density of the collared peccary using linear transect sighting methodology was probably influenced by the low detectability of specimens in jungle vegetation and even in acahual at different stages of secondary succession [29]. Another factor that affects the results of the population estimate, regardless of the technique used, is the intensity of hunting at each sampling site, especially in places where extractive exploitation is not controlled, as in Yucatan [6]. [37] report that the collared peccary is the third most hunted species within the municipality throughout the year, which represents a factor that affects the accuracy of the population estimate.

In the present study the method of counting footprints was the most accurate, however the densities with both methodologies are low in the period 2007 to 2009 compared to the years 2003-2004, probably due to the intense hunting of medium mammals such as deer and collared peccary, as reported by [6, 37, 38].

But if the amount of collared peccary tends to decrease, then the question arises: What is the cause that they are still detected and extracted collared peccary in the area where they are scarce?, a possible reason for this situation is that since there are no physical barriers

between the municipality of Tzucacab and the surrounding municipalities, then there is a flow of animals between Tzucacab and the municipalities of Peto, Tekax and the state of Quintana Roo. This reason is based on the distribution of sightings and footprints of peccaries in the bordering areas of the east and southeast of Tzucacab, as shown in figure 3, so that the concept of source-sink habitat can be applied, which means that the habitats of other municipalities and the state of Quintana Roo function as a source, as long as these habitats provide collared peccaries that migrate to the sink habitats of Tzucacab, collared peccaries will exist.

But another question arises: how long, or until when, the other source habitats will be able to provide collared peccaries to the municipality of Tzucacab?, It is not possible to answer such question with the information collected in this project; But, based on this work it is necessary to carry out intermunicipal and interstate approaches, so the management of populations free of collared peccary become sustainable. Regarding this aspect, it is necessary to evaluate the strengths, weaknesses, opportunities and threats, that provide alternative management strategies; these evaluations must be raised by different participants in the management and use of free wild populations; including scientists who study disciplines related to this topic, also civil society organizations, government institutions related to wildlife management, and rural communities that directly carry out continuous management of these faunal resources, due to the importance of local knowledge, traditional practices, socioeconomic, and political contexts that determine the impact of the decisions made on the conservation of populations of wild collared peccaries [39].

3.2 Distribution pattern and habitat preference

The distribution obtained with the Standardized Morisita Index by clusters, as shown in Table 3, has high significance value; therefore, they form separate groups. During the population monitoring we noticed that, in the study periods, the fragmentation of the forest had increased, due to wildfires and deforestation, so the trend of population distribution by clusters was expected. Table 4 presents the data matrix and Bonferroni intervals, which show the expected and observed use ratios of each habitat. The use of any of the available habitats by peccaries was less than expected, except acahual in 2008-09.

Table 3. Values of the Morisita estimators and the statistics that tested the type of distribution presented by collared peccaries in the municipality of Tzucacab, during the two sampling periods.

Year	Standardized Morisita index	Chi-square (Pr; gl)	Accepted hypothesis
2007-2008	0.5238	90.901 (0.00; 18)	Cluster distribution
2008-2009	0.5263	64 (0.00; 17)	Cluster distribution

Table 4. Matrix of proportions of use, by collared peccaries in Tzucacab, Yucatan; and availability of each habitat type, during the study periods, to evaluate habitat preference.

Year	Habitat	Expected Used Ratio	Observed Used Ratio	Bonferroni interval
2007-2008	Forest	0.35	0.17	0.031 ≤ 0.17 ≤ 0.309 (Po<Pe)*
2007-2008	Acahual	0.22	0.00	0.00 ≤ 0.00 ≤ 0.00 (Po<Pe)*
2007-2008	Agricultural	0.43	0.08	0.02 ≤ 0.08 ≤ 0.18 (Po<Pe)*
2008-2009	Forest	0.65	0.26	0.09 ≤ 0.26 ≤ 0.43 (Po<Pe)*
2008-2009	Acahual	0.13	0.74	0.57 ≤ 0.74 ≤ 0.91 (Po>Pe)*
2008-2009	Agricultural	0.22	0.00	0.00 ≤ 0.00 ≤ 0.00 (Po<Pe)*

* Indicates significant difference less than 0.05

It is worth mentioning that, possibly, the local populations of peccary, are affected by the distribution of vegetation patches on the pattern of distribution and preference of habitats. This claim is based on figure 1, which shows a greater proportion of patches of forest with different sizes in the southern part of the municipality, which is a consequence of the opening of agricultural areas and acahual, so there is a tendency to create much smaller fragments. There were 1983 patches with an average size of 15 Ha, at that time, due to the continuous rate of changing from land use to pastureland type and agricultural crops [40]. The fragmentation of the native habitat to different ones, is due to several factors, one of these were the agricultural development programs, such as the Direct Support Program to the Countryside called PROCAMPO, which was supposed to result in economic benefits to the peasants, by promoting financing so that subsistence producers could move to higher level producers, in order to supply the market, in the context of the North American Free Trade Agreement [40], therefore, the opening of the agricultural frontier was encouraged; consequently numerous increasingly-isolated patches of native vegetation appeared, and such surfaces were increasingly reduced; therefore, the local populations of ungulate animals tend to be separated dispersed.

The isolation of small populations can potentially create patterns of inbreeding, decreased genetic variation and gene drift [41]. In Mexico, molecular analyses have not been carried out to determine the population genetic status of peccaries, however, when observing population trends and scarce sightings of individuals in wildlife in the last study period, it is possible to assume that local populations could experience these genetic processes. 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 encouraging support for owners, who still

have relatively large areas of jungle habitat, which is appropriate as shelter, breeding areas and mating of wild ungulates, this is one of the public policies expressed by the System of Management Units for the Conservation of the Wildlife [29, 42].

According to the information of the Lansat ETM image of 2002, provided by the GIS laboratory of CICY, there was still a total of 37.43 % of forest, 41.55 % of acahual and 21.02 % of agricultural area, considered in this research as available habitat for collared peccary.

Figure 3 shows the locations of sightings and footprints of collared peccaries in transects installed in the quadrants sampled in Tzucacab, from 2007 to 2009. The location of sightings and footprints shows that there are records of peccaries that are located in the quadrants of the east and southeast of the municipality of Tzucacab, which border the limits of other municipalities of Yucatan such as the state of Quintana Roo.

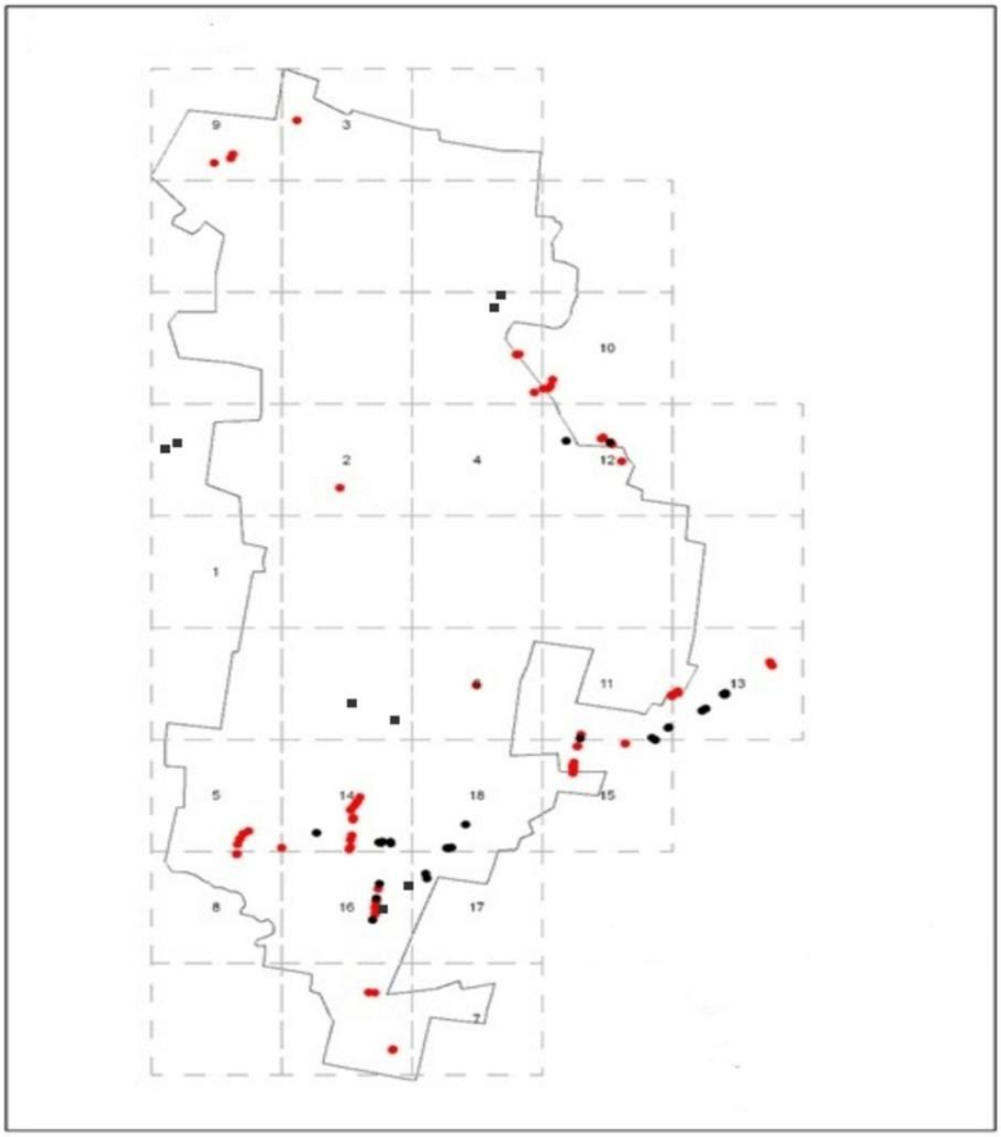

Figure 3. Location of records of collared peccary sightings in 2007-2008 in dark squares; Collared peccary footprints in 2007-2008 in red circles, and in dark circles in 2008-2009, in Tzucacab Yucatan.

3.3 Evaluation of the sustainability of extractive use of peccaries

The analysis of the peccary harvest index shows values with increasing tendency. In none of the years under study there is a risk of vulnerability of the population, however, the densities tend to decrease significantly. The correlation coefficient between the years of study and the Harvest Index was r = 0.995 (P = 0.06). Figure 4 shows the upward trend towards harvest

unsustainability, because it approaches the value of 0.20, which, for this long-lived species, is the sustainability limit value mentioned by [33].

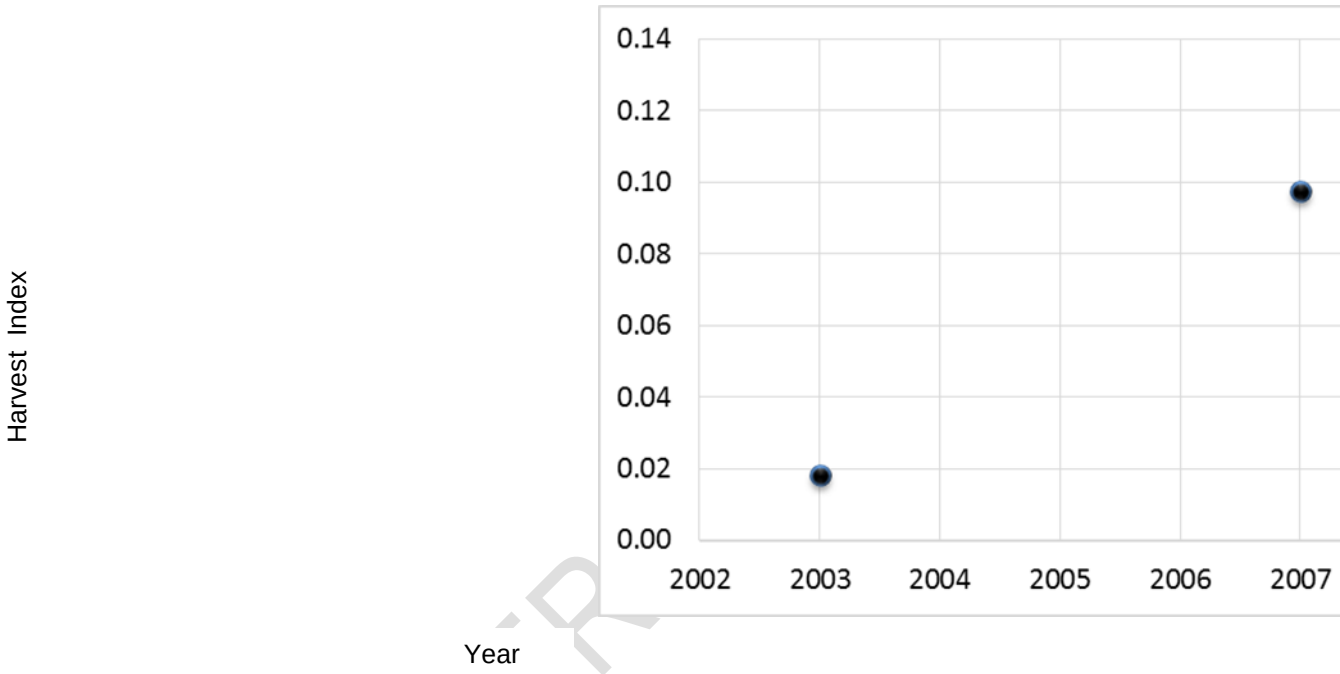

Figure 4. Trend of the Harvest Index of collared peccary, in the municipality of Tzucacab in three annual periods.

The collared peccaries, correspond to generalist species and have the ability to adapt to highly modified habitats, even they can endure human management, being able to complete their biological cycle in artificial breeding conditions, that is, kept in pens, they endure population densities from 20 m^2 to 5 m^2 per animal [43] and can be fed with native fodder, fruits and vegetables [44]. This means that changes in land use would probably not represent a limitation to continue with their reproductive cycle, if there are favorable conditions of space, food, shelter and water in the habitat.

The hypothesis that hunting could be the main factor in the decline in the collared peccary population is based on the studies by [6] who reported that in Tzucacab, a total of 93 hunting events happened in 10 months of study. Of the 30 hunters, 32 % go daily, 28% every week and 40 % every month.

Regarding hunting by peasants [37] reported that in Yucatan, 58 % of local hunter-peasants surveyed (731) take advantage of wildlife for self-consumption, 15 % to protect their crops and 24 % for both purposes, they also mention that subsistence hunting by hunter-peasants can cause the local extinction of the main species of wildlife they extract, which are white-tailed deer (*Odocoileus virginianus*), Temazate deer (*Mazama americana*), collared peccary (*Pecari tajacu*), tepezcuintle (*Cuniculus paca*) and White-nosed Coati (*Nasua narica*). Additionally, they report that poaching by hunters who come from the cities should be

controlled, since they have better economic conditions and equipment, they extract specimens to market them as meat, illegally. The effect of hunting intensity has been reported by [45], and they describe a dynamic simulation model for white-tailed deer populations, where three factors are important: population density, availability of plant biomass as food and number of hunters, the conclusion was that, of the three scenarios generated by the model, greater intensity of anthropic hunting is the factor that produces the disappearance of the local population.

Assuming that the hypothesis that anthropical hunting would be the main factor that decreases the population of peccary in Tzucacab, is valid; then the following question arises: Why do 58 % of local hunter-peasants extract specimens of wildlife for subsistence? The answers are complex because they concern economic, political, and cultural factors. The analysis in this section corresponds to the socio-economic factor. The annual report of the National Council for the Evaluation of Social Development Policy [46] reported that in Tzucacab, 78.1 % of the population is suffering from moderate and extreme poverty. On the other hand, [47] said that the municipalities of the southeast of the state of Yucatán, are categorized with high levels of marginalization, therefore higher levels of poverty and demographic patterns characteristic of underdevelopment are revealed. [48] report that in 2005 the primary sector of the Yucatecan economy generated an average of 100186 employed people, representing 13.2 % of the economically active population (EAP) of the entire state, which is lower than in 1990 when there was 17.4% of the EAP, so agricultural activities in the population are vulnerable, especially since the main type of agriculture practiced is subsistence [40], in addition the Average Annual Growth Rate in the period 1993-2004 of the primary sector showed negative values up to 1.2 % in five of 11 data compared, the same authors mentioned that the agricultural sector historically presents a bad economic situation and in recent years has worsened, so the economic policies of government for the rural sector of Yucatan are inefficient; consequently, the people at productive age prefer to migrate to other places such as the United States of America and urban centers within the Yucatan Peninsula like Mérida or Cancun. This situation has remained in the decade from 2000 to 2010 in Mexico, this situation was described by [49], who found that in the Mexican agricultural sector there is loss of employment, and precarious conditions.

4. CONCLUSION

The population densities of collared peccary in Tzucacab are different between the estimation methods, however with the footprint's counting method it was found that there is a significant decrease in populations from 2003-04 to 2007-09. Peccaries use acahual land more than other habitats in 2008-09. Local populations of collared peccaries are distributed by clusters. Sightings and peccary footprints are found within Tzucacab, especially in the south and southeastern boundaries with other municipalities and the state of Quintana Roo, suggesting that there is migration of collared peccary between neighboring municipalities of Tzucacab and Quintana Roo. The harvest of collared peccary is sustainable in the study periods, but shows a tendency to be unsustainable in the following years after this research.

5. ACKNOWLEDGEMENTS

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6. COMPETING INTERESTS

Authors have declared that no competing interests exist.

7. AUTHORS' CONTRIBUTIONS

Author 1 designed, directed and evaluated the research. Author 2 carried out the field studies and evaluated results, Author 3 carried out the field studies, Author 4 carried out the field studies.

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