Estimation population size peccaries *(Tayassu Pecari)*, in the "Rio Negro" farm - Brasilian Pantanal, during 2003 - 2004, by means capture and recapture multiple method

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Abstract

The Tayassu *pecari* are predominantly distributed in conserved biomes and the maintenance of the species is very susceptible to human activity. In this context, it is important the search for methods of population estimation as well as apply robust methods that allow more accurate estimative. Therefore, this work aims to estimate the population of peccaries, on the Rio Negro farm (Aquidauana-MS) through the multiple captures and recapture method during the years 2003 and 2004, considering the assumption that the population is closed. The estimate of the population size was obtained by the computational resampling and three procedures are compared. It was verified the marked difference between males and females for both years. The population size it was estimated in 134 and 192, however, by means the bootstrap method, a notable change in the distribution pattern of estimates was verified, being positively asymmetric and symmetric, for 2003 and 2004 respectively.

Keywords: Bootstrap, Ecology, environmental balance, random sampling, statistical methods

Introduction

White-lipped peccaries (*Tayassu* pecari) are widely distributed in South and Central America, most of the population is in the rainforest, but they can also occur in drier habitats, such as the savannas of Venezuela (OLIVER, 1993). Predominantly found in Brazil, in conserved biomes such as the Pantanal and the Amazon (Figure 1) and they live in in large groups, usually from 50 to 100 individuals (KEUROGHLIAN et al., 2012).

The diet of the species depends on the variety of habitat, including roots, tubers, fruits, nuts and palm fruit (OLIVER, 1993). Thus, white-lipped peccaries provide an important ecological service in seed dispersal and conservation of plant species.

Figure 1. White-lipped peccaries illustration (*Tayassu peccary*)

Source: Santos & Itapetinga (2016).

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Like other species with a wide geographic distribution, white-lipped peccaries suffer different impacts and are under different degrees of threat throughout their distribution in the Brazilian territory (KEUROGHLIAN et al., 2012). The conservation status of the species is very susceptible to environmental impacts, only in the Amazon is the conservation status less worrying, as it presents a more conserved biome (KEUROGHLIAN et al., 2012).

Bearing in mind aspects related to the behavior and distribution of white-lipped peccary, it is important to use methods to estimate the size of the population, considering the necessary assumptions for its application, so that the methods used are more robust, allowing estimates to be obtained. more accurate (OLIVEIRA, 2007). In the work carried out by Araújo et al. (2008) the linear transection method was used, with the objective of estimating the density and population size of game mammals in two conservation units in Rio de Janeiro, among the species that were the target of the investigation, *Tayassu peccary* was not detected. Chiarello (2000) researched different fragments of the Atlantic Forest in the Espírito Santo region, using the Census methodology, which consisted of visual observation of animals on trails traveled, in addition to vocalization, footprints and feces that were also used as evidence. It was concluded that in 3 out of 6 fragments the peccaries are still found.

One of the statistical methods used to estimate population size is capture and recapture, which consists of obtaining an initial sample of individuals that will be marked or identified, and then returned to the population. Subsequently, a second sample is taken, independent of the first, where the recaptured individuals are counted, in this way the total estimate of individuals in the population is made through the relationship between the proportions (OLIVEIRA, 2007).

According to Schwarz and Seber (1999), the type of method used depends on the nature of the investigated population, namely whether it is closed or open. A closed population is one that remains effectively unchanged during the investigation, whereas an open population can change through processes such as birth, death, and migration. Methods can be categorized by the type of information provided by the sampling process used.

Thus, when the population is closed, the most used estimators are those of Petersen (1896), Chapman (1952) and Bailey's (1951) for the case of capture and recapture simple. However, sometimes there are cases that are not limited to just two samples, as there may be more than one marking and more than one capture. In this situation, the multiple capture and recapture method is used, which was initially discussed by Schnabel (1938). And for this case, the estimator used is the Schnabel method, which is an extension of the Petersen estimator, as it allows for a greater number of occasions (SEBER, 1994). These estimators are considered the most accurate methods because they ignore population variability such as migration and recruitment, so the quantification would be applied to a theoretically stable population (BAUMART et al., 2018).

However, in practice, during the collection of samples, some problems that arise during the experiment cannot be avoided, such as the case of obtaining small samples, [this is due to the environment in which these animals are]. Thus, one way to solve this problem is the bootstrap (EFRON & TIBSHIRANI, 1994) methodology. This methodological approach considers a certain observed sample of the population of white-lipped peccaries and through the resampling obtained, an estimate of the size of the population is obtained (parameter of interest).

Therefore, this work aims to estimate the size of the white-lipped peccary population in the region of Fazenda Rio Negro located in the Pantanal, through the methodology of multiple capture and recapture, considering the estimator proposed by Schnabel (1938) and the bootstrap procedure (EFRON &TIBSHIRANI, 1994), characterizing the number of males and females in the region.

Material

The experiment was carried out at the Rio Negro farm, located in the Center - West region of Brazil, in the municipality of Aquidauana (19º 34' 29.2"Lat S and 56º 14' 37.1"Long W). The property is inserted in the biome of the Pantanal and has an area of 7 thousand hectares (Figure 2).

Between 2003 and 2004, the white-lipped peccary population was subjected to the capture and recapture method using fixed traps. Captured animals were immobilized with zolazepam and tiletamine hydrochloride (Zoletil 50; Virbac, São Paulo, Brazil) and tagged with a radiofrequency identification microchip (Biomark, Boise, Idaho). After chipping and recovery from anesthesia, all animals were released at the capture site. The identification of the sex of the marked animals were tabulated for later recapture conference. The animals captured with identification were considered recapture, the animals that did not have identification were marked with a numbered chip. The capture sequence was given according to the Table1.

Figure 2.
Rio Negro farm, where the *Tayassu pecari* sampling by means capture and recapture were carried out

	Months											
Years	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
2003	X	X	X		X		X	X	X	X		X
2004	X	X		X		X				X		

Table 1.
Sequence of capture and recapture of white-lipped peccary (*Tayassu Peccary*) at the Rio Negro farm in the Pantanal, in 2003 and 2004.

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Methods

In this work we have used the multiple capture and recapture method, taking into account some assumptions such as a closed population, that is, one in which there are no births, deaths, migrations and emigrations in the study. It is also necessary to consider that all elements have the same capture probability, that is, it is assumed that simple random samples of the population were selected and that the samples collected during the study are independent of each other. The population in this study refers to the individuals complaining who frequent or stay around the Rio Negro farm.

For this purpose, the estimator proposed by Schnabel (1938) was considered, which is a modification of Petersen's estimator in each of the samples used. Thus, for each of the s samples of dimension $n_1,n_2,...,n_s$ respectively, the modified Petersen estimator of N is given by:

$$\hat{N}_i = \frac{(M_i + 1)(n_i + 1)}{(r_i + 1)} - 1, \quad i = 2,3,\cdots,s. \tag{1}$$

$\widehat{N}$ is the estimated total size of the white-lipped peccary population, s number of selected samples, n_i size of the i-th sample, $i=2,3,...,s$, i.e., number of animals captured in the *i-th* sample, r_i number of animals marked in the *i-th* sample of size n_i, i.e., the number of recaptures in the *i-th* sample, M_i just before the *i-th* sample was taken.

The estimator of variance for each of the estimates of the size of the white-lipped peccary population obtained by equation (1) is given by:

$$\widehat{Var}(\hat{N}_i) = \frac{(M_i + 1)(n_i + 1)(M_i - r_i)(n_i - r_i)}{(r_i + 1)^2(r_i + 2)} - 1, \quad i = 2,3,\cdots,s. \tag{2}$$

For the case of multiple captures and recaptures, considering the assumption that the population is closed, the estimate of the size of the white-lipped peccary population is given by the average of the different estimators obtained in equation (2), that is, the following estimator (CHAPMAN, 1952):

$$\bar{N} = \frac{\sum_{i=2}^{s} \widehat{N}_i}{(s-1)} \tag{3}$$

which allows us to construct the γ% confidence interval for the sample size, expressed by:

$$\mathrm{CI(N,\gamma\%)} = \left(\bar{N} \pm z_{\left(\frac{\alpha}{2}\right)} \sqrt{\frac{\sum_{i=2}^{s} \widehat{Var}(\widehat{N}_i)}{(s-1)^2}} \right) \tag{4}$$

Where where z is the quantile of a standard normal distribution, with 95% confidence z =1.96.

On the other hand, in the capture and recapture method, during sample collection it is not always possible to avoid some problems that arise during the experiment, such as the case of obtaining small samples. In this experiment, this fact occurred due to the characteristic of the species and the logistical difficulty of finding it at the study site. When this occurs, one way to solve this problem is to use the bootstrap methodology, in which a certain observed sample of the population of white-lipped peccaries is considered and through re-sampling, thus obtaining an estimate of the parameter of interest. When applying the bootstrap method to the situation in which the multiple capture and recapture approach is used to estimate the dimension N of a closed population, the samples bootstrap, are obtained through the resampling $\boldsymbol{x}_i$, of dimension $n_i,(i=2,3,...,s)$ where s represents the number of samples taken, that is, the number of captures. In this context, each of these samples obtain B independent bootstrap samples with replacement, $\boldsymbol{x}_{i1}^*, \boldsymbol{x}_{i2}^*,$

...,$\boldsymbol{x}_{iB}^{*}(i=2,3,...,\ s)$, which may or may not contain repeated individuals.

To calculate the estimate of the size of the white-lipped peccary population, as there are no individuals marked for the first observed sample, that is, m_1= 0, using the bootstrap methodology, one must take into account the samples bootstraps independent with replacement in which, $i=2,...,\ s$ as these are the ones that will originate new values of marked individuals (m_i) which will influence the calculation of the estimate of the population size.

The B bootstraps samples will generate B values for the number of marked individuals (m_i), that is, for each of the bootstrap samples of the second sample of dimension n_2, gets a new value m_3, and so on. Consequently, you will get B estimates for the population size.

Thus, applying bootstrap to the method proposed by Schnabel (1938), we obtain B resampling bootstrap that generate B values of $r = M_s+1$,i.e. $\boldsymbol{r}_{i1}^{*}$, $\boldsymbol{r}_{i2}^{*}$, ..., $\boldsymbol{r}_{iB}^{*}$, where $r = M_s+1$ which is the total number of different individuals captured during the study. In this way, the maximum likelihood equation, for each of the replicas, is defined by:

$$\left(1-\frac{\boldsymbol{r}_j^{*}}{N}\right)=\prod_{i=1}^{s}\left(1-\frac{n_i}{N}\right),\qquad j=1,\dots,B$$

where each of the solutions obtained, $\widehat{N_1}^{*},\dots,\widehat{N_B}^{*}$, is a maximum estimator, likelihood of the population dimension, $\widehat{N}$ (OLIVEIRA, 2007). The average of these B values of $\widehat{N}$ will be the estimator bootstrap of the total dimension of the population for the proposal of Schnabel (1938),

$$\widehat{N}^{*}=\frac{1}{B}\sum_{b=1}^{B}\widehat{N}^{*}(b)$$

Therefore, in this work to the population size estimate, in addition to the Schnabel method, the methodological approach bootstraps not parametric with two types of calculation for confidence intervals, the percentile method and bootstrap-t was used. In both the methods were used all individuals, regardless of sex information. 10,000 new samples arising from the original data from the method of iterative random choices, with replacement, in which all observations had the same probabilities of selection were generated. To compare with the analytic interval estimate calculated by the Schnabel method, 2 methods for calculating confidence interval with γ confidence level were used. Percentile method is based on the empirical distribution of bootstrap estimates, the intervals are the amounts of resampling. With assumption of asymmetry of the estimates generated.

$$\mathrm{CI(N,\gamma\%)}=\left(F_{inf}^{-1}\left(\alpha/2\right),F_{\sup}^{-1}\left(\alpha/2\right)\right)$$

where, F_{inf}^{-1} , F_{sup}^{-1} are the amounts of the reamos generated by computational simulations. Standard method involves the assumption that estimators tend to a normal distribution, thus we have:

$$\mathrm{C.I.\ (N,\gamma\%)}=\left(\widehat{N}^{*}\ \pm\ z_{\left(\frac{\alpha}{2}\right)}\sqrt{Var_{boot}(\widehat{N}^{*})}\right)$$

in whom, $Var_{boot}\left(\widehat{N}^{*}\right)$ is the variance of the averages of resampling and $z_{\left(\frac{\alpha}{2}\right)}$ is a quantile of normal distribution.

Results and Discussion

This section presents the results regarding resampling in the years 2003 and 2004. Initially, they were conducting a graphic analysis.

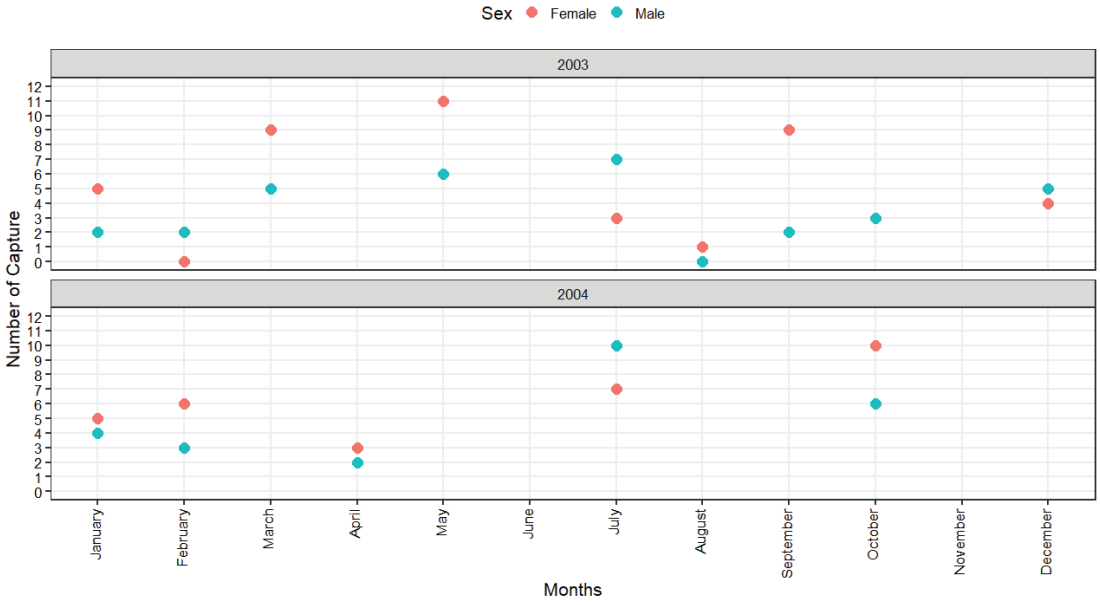

Figure 3. Point chart with capture counts (*Tayassu Pecari*), performed during the months of 2003 and 2004, at Rio Negro Farm, Pantanal, Brazil.

captured during the months of 2003 and 2004 are presented in the Figure 3. In 2003, there was a "well-distributed" number of captures during the months, with absence only in April, June and November. In contrast, in 2004 there was a capture occurrence in January, February, April, July and October. However, this year it was noted that for the male there was a high number of captures in July.

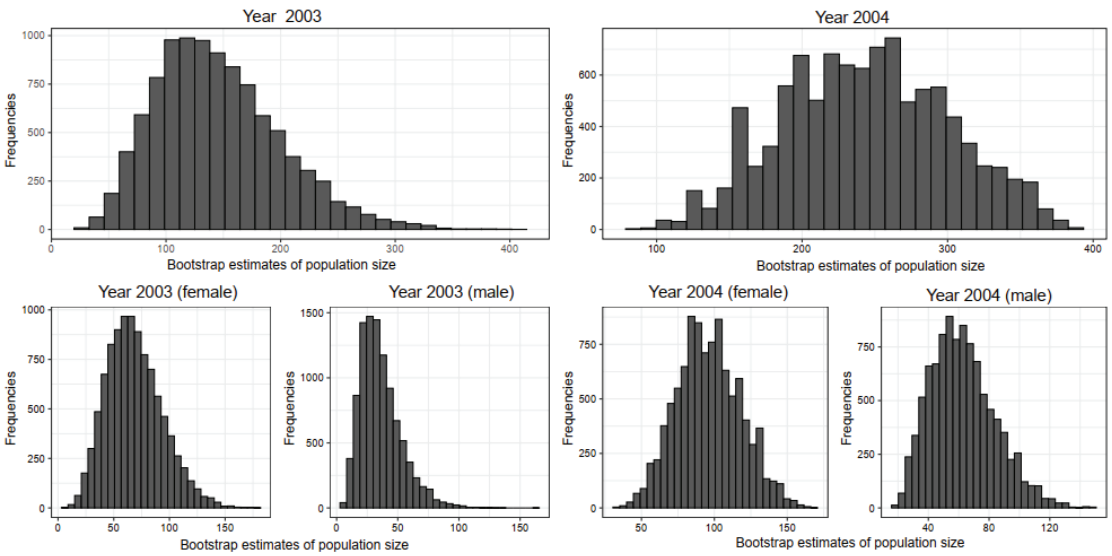

Figure 4. Histogram of population size estimates by the Schnabel method for each gender, calculated by 10,000 resampling (bootstrap), for the years 2003 and 2004 at Rio Negro Farm Pantanal, Brazil.

The results (for 10,000 resamplings) according to bootstrap procedure are showing in the Figure 4. It is possible to see that in 2003, the distribution of estimates is asymmetry on the right, with higher frequencies of values between 100 and 200. For the other hand, in 2004, there was a symmetry tendency and greater frequency between the values of 200 to 300. In practical terms, the distributions show the transition to a greater number of individuals in the population, with a tendency towards normal distribution.

Considering the sex effect, it was observed, in 2003, the male histogram presented a greater asymmetry on the right when compared to the female. In 2004, the histogram presented less asymmetry than in 2023, but still a little difference of distribution between female and male. In both years, there is a lower incidence of males, but showing a growing tendency for the number of individuals.

Regarding point estimates, we obtained the population sizes: 134, 192 in 2003 and 2004 respectively, using Schnabel's method, while by the bootstrap method presented higher values 145, 243. The point estimates, as well as the respective confidence intervals, are presented in Table 2. In the year 2023, the intervals obtained by the percentile and t bootstrap method showed smaller interval amplitude than those constructed by the Schnabel method. Whereas in the year 2023, the bootstrap intervals were wider, but this variation is random. Although the number of females is greater in both years, overlapping confidence intervals can be observed, signaling a possible equality between the number of individuals in both genders.

In any case, there is an increase in the number of individuals in the population in this region, which can guide ecologists and biologists in the management of ecosystems, prioritizing the balance of fauna and flora. This corroborates the statement by (TRINCA., 2014) who state that data collected on more than one occasion tend to vary in population size. However, despite the indication of population growth, the study region has stability due to the high degree of biome conservation. Rio Negro Farm is a private reserve that has a management plan, so the low presence of agricultural activity would have little impact on the number of animals in the region.

Methods	Year 2023		
	Male	Female	Total
Schnabel	34 (17 a 50)	68 (35 a 99)	134 (62 a 205)
Percentis	36 (12 a 77)	69 (27 a 123)	145 (59 a 269)
Bootstrap-t	36 (03 a 69)	69 (20 a 117)	145 (38 a 252)
Methods	Year 2024		
	Male	Female	Total
Schnabel	57 (06 a 107)	82 (23 a 140)	192 (60 a 323)
Percentis	63 (28 a 110)	96 (55 a 140)	243 (132 a 356)
Bootstrap-t	63 (21 a 104)	96 (53 a 139)	243 (132 a 355)

Table 2.
Point estimation and confidence interval of the population size of *Tayassu Pecari*, in 2003 and 2004, at Rio Negro Farm, Pantanal, Brazil, using the Schnabel and bootstrap method.

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Conclusion

In the area of Ecology, a technique very useful to estimate population size is the capture and recapture, especially when one is interested in finding out the conservation status of a given species and a given study site. Despite the importance of the sampling procedure, one must also consider the methods for point and interval estimation, as well as the distribution pattern of the population. In this context, we present some alternative procedures to the classic one, which can be used in situations where there is missing data over time, or even for reasons of better understanding the variability of the estimates. In our application these procedures were necessary due to the environment in which the white-lipped peccaries live, and because we had few samples were collected during the period and missing data.

The results obtained under an overview biological point were very satisfactory since white-lipped peccaries are very susceptible to changes in their habitat, whether due to human activity or climate change. As a perspective for future work, variations of the methods studied can be considered, as well as the incorporation of exogenous variables, which make it possible, via correction and regression methods, to improve the precision of estimates and predictive intervals.

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