First wild boar density data from araucaria forest in Patagonian Andes (#94486)

First revision

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First wild boar density data from araucaria forest in Patagonian Andes

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As *Sus scrofa* is an invasive species in South America, it may have a potentially devastating impact on biodiversity. To evaluate the threat to the environment it is necessary to have comparable data, which, in terms of population size, could be the population density. However, there is no such data for the south Andean region. Hence, we monitored wild boar density in an area of the National Park Villarrica, in the Andes of south-central Chile. The study site not only stands out because of its rough climatic conditions, but also through a forest of the endangered *Araucaria araucana* tree, which offers a high food availability through the seed fall in Autumn. The calculated density was lower than the compared European data, and we found strikingly different monthly encounters. Since this is the first density calculation of wild boar in this region and not a low number, it should demonstrate the importance of further monitoring actions, as the population can be a danger to the ecosystem and especially to the already endangered araucaria.

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Abstract

As *Sus scrofa* is an invasive species in South America, it may have a potentially devastating impact on biodiversity. To evaluate the threat to the environment it is necessary to have comparable data, which, in terms of population size, could be the population density. However, there is no such data for the south Andean region. Hence, we monitored wild boar density in an area of the National Park Villarrica, in the Andes of south-central Chile. The study site not only stands out because of its rough climatic conditions, but also through a forest of the endangered *Araucaria araucana* tree, which offers a high food availability through the seed fall in Autumn. The calculated density was lower than the compared European data, and we found strikingly different monthly encounters. Since this is the first density calculation of wild boar in this region and not a low number, it should demonstrate the importance of further monitoring actions, as the population can be a danger to the ecosystem and especially to the already endangered araucaria.

Introduction

The wild boar can have detrimental effects on biodiversity, agriculture, and livestock (Barios-Garcia & Ballari, 2012). They are described as ecosystem engineers, as they can significantly impact habitats. This occurs in their native habitats (Croft et al., 2020) as well in non-native environments (Risch et al., 2010). Population density plays a crucial role in the extent of their impact on biodiversity, agricultural damage, and epidemiological risk (Fulgione & Buglione, 2022).

The first introduction of wild boar to South America occurred in 1904 in Argentina with animals from Europe. They were soon relocated to different parts of the country including the southern Andes. A contingent also arrived directly in Chile many years later, and the first population of wild boars in Chile likely existed around 1950 and is attributed to the direct import of some animals from Germany (Skewes & Jaksic, 2015). The main reason for the release of these animals was for hunting, but some individuals also escaped from farms by accident. The Argentinian and Chilean populations intermixed and formed the basis of the present wild boar population of the southern cone of America (Cuevas et al., 2021).In 2014, the first outbreaks of African Swine Fever, affecting wild boar in the European Union, increased public concern (Jori et al., 2021). Following, experts of the EU under the ENETWILD Consortium selected a method to estimate wild boar density (Enetwild-Consortium et al., 2018). As a result, they adopt the procedure based on images captured by camera traps and processed with the Random Encounter Model (Rowcliffe et al. 2008, Palencia et al., 2022). Thus, wild boar density values in Europe ranged from 0.35 ~~individuals per square kilometer (~~individuals/km^2~~)~~ to 15.25 individuals/km^2 (Enetwild-Consortium et al., 2022).

But it is exactly this varying range of density in Europe that shows the impact of different environments on the species.

Therefore, it is necessary to have data about the density of this species, to evaluate and possibly take further management actions. However, there is no information on the density of wild boar in

Chile, even though it extends to important habitat for many threatened and endangered species and is also considered one of the 36 Biodiversity Hotspots in the world (Myers et al., 2000). Consequently, we studied the population density of wild boar in an *Araucaria araucana* forest.

Notably, A. araucana is a gondwana long-lived coniferous and endangered species with a small range (Premoli et al., 2017). It is not only important for conservation value, but also because the seeds are collected by the indigenous groups of Chile and Argentina and also serve as food for native birds and rodents (Sanguinetti et al., 2023). The species was classified as endangered by the IUCN in 2013, which was mainly caused by fires, years of logging and invasive species. Although wild boar is present in these forests for decades (Skewes & Jaksic, 2015), the impact of wild boar as depredator of seed may shift from individual trees to stand scale, threatening Araucaria Forest regeneration (Sanguinetti & Kitzberger, 2010).

Hence, we studied the density of the wild boar population over an area of 15 km2 and at 1,200 to1,400 m asl in the Villarrica National Park. Chilean law forbids hunting in national parks and human disturbance by tourists or peasants is negligible. However, the presence of a wild boar predator, the puma *Puma concolor* (Skewes et al., 2012) in the area must be considered, as predators can have an impact on the daily range just like hunting.

Considering the multiple impacts of an enlarged wild boar population, investigating the population density is important for estimating this danger for humans and nature, especially for the endangered A. Araucana.This study aims to provide, for the first time, an estimate of wild boar density in A. araucana forests. Based on these results, conservation actions for this endangered forest species and wild boar management measures can be proposed in the future.

Material and Methods

Study area

The study site named "Puesco" is in the Andes of south-central Chile (39° 35' S, 71° 31' W) at elevations of 1,200 to 1,400 m asl and covers 15 km2. It is located on the north side of the Lanín volcano in the Villarrica National Park (permission N° 03/2015 CONAF) in the Araucanía Region, Chile (Fig.1).

Figure 1: Map of the study area (created with Free and Open Source QGIS. Geographic Informationsystem QGIS. Open-Source-Project of Geospatial Foundation. http://qgis.org)

There is no hunting, visitors circulate along trails and in autumn the neighboring indigenous communities collect Araucaria fruits. According to the climatic station "Ea. Mamuil-Malal" (39°64´739" S, 71°26´955" W) at 900 m asl and circa 20 km east, the mean annual precipitation is 1,081 mm and the mean annual temperature is 9.3 °C. The coldest month is July with a mean of 1.3°C and the warmest is February with 15.5 °C (http://www.aic.gov.ar/sitio/estaciones). In the site snow falls from June to September, the snow cover stays for approximately 45 days with a maximum height of up to 0.9 m (Author observation).

Figure 2: Pictures of wild boars captured by CTs in the study area

The site is dominated by forests of the long-lived monkey puzzle tree *A. araucana* mixed with lenga beech *Nothofagus pumilio*. The understory is composed of poaces *Festuca gracillima*, *Alstroemeria aurea*, and patches of dense bamboo *Chusquea* spp. thickets, *Gaultheria* sp. and *Nothofagus antarctica* shrubs (<5 m height). The *A. araucana* seed fall starts in March and ends in June, but seeds are also available in spring after the thick snow cover melts. As there are no other fruit bearing trees in the study area and the other occurring plants are not as remotely comparable nutritious, the food availibilty changes drastically over the year.

Data capture

We conducted a camera trap (CT) study from May 2020 to April 2022. It was carried out by the deployment of 10 Ltl Acorn® 6210 CT's. The location of the CT´s were set randomly on the Google Earth® platform with a 1,000 to1,400 m distance between each CT on the map. At each site, an area with 10 m of clear vision in front of the camera lens was selected. CTs were attached to a tree (diameter > 20 cm) at 1 m above ground, facing north or south, to prevent the sun flare from the sunrise or sunset that results in overexposed photos where animals become challenging to identify (Apps & Mc Nutt, 2018). Even though Palencia et al. (2021) suggested that the height level should be at shoulder height, which would be 80cm in case of the wild boar, we had to attach the cameras at 1m height, as there can be up to 1m snow in winter (author observation, compare Fig. 2).

Despite two CT's being moved from the initial place, maintaining the restrictions already described. CTs were programmed to capture three consecutive images, with no delay and with normal PIR sensitivity. We did not use bait or attractors at the site. The CT's were maintained every 3 to 5 months, depending on the weather conditions.

This ~~camera trap~~ study was authorized by the national forestry corporation CONAF in Chile. Field permit to conduct the study in the National Park of Villarrica was given by Ministerio de Agricultura (Chile), Depto. Areas Silvestres Protegidas Region de la Araucaria. The Bioethics commission of the University of Concepcion approved the study. The pictures of people were handled following the guidelines of Sharma et al. (2020), which means, that the privacy of individuals inadvertently photographed by camera traps was strictly protected. Photos of unknown people were securely stored and not disclosed. Suspected researchers in photos were consulted on whether to destroy or receive the images. Wildlife images were shared with and credited to the relevant agencies overseeing the National Park, ensuring proper use and acknowledgment.

Data processing

All photographs were screened by the authors to identify those that contained wild boar (~~compare~~ Fig. 2). For the Random Encounter Model (REM) method we followed Palencia et al. (202~~1~~). The REM (Random Encounter Model) by Palencia et al. (202~~1~~) estimates animal densities using ~~camera trap~~ data. It models random encounters between animals and cameras, factoring in animal movement and detection probability. Density is calculated using the following formula:

$$D = \frac{y}{2vkt}$$

where y is the number of captures, v is the animal's average speed, k is the camera's detection zone, and t is the sampling effort.

Activity level was estimated after Rowcliffe et al. (2014) using the R package ‘activity’ (Rowcliffe, 2023). The REM density was calculated for all CT’s and then averaged for season. The activity level between seasons was tested with 1000 Bootstrap replications. To establish the angle and radius of detection, we carried out thorough walk tests at our CTs (Cusack et al. 2015).

Day range, which is the average daily distance traveled by an individual was calculated based on speed and activity level (Palencia et al., 2019). The speed of the wild boars was obtained from information from CT and processed as described by Rowcliffe et al. (2016). In this method, we divided the distance traveled by the duration of the sequence (the difference in time between the timestamps on the first and last picture). To the end of the study, we recorded the location of every captured wild boar in one single image for each CT. Then, in the field, with the diagram in hand, we measured the corresponding locations with tape. Subsequently, the CT images were reviewed, and the distance traveled, as well as time were noted for each animal sequence. Those sequences in which animals reacted to the CT or in which there was only one image of wild boar were considered for encounter rate but not for speed (Rowcliffe et al., 2016). The encounter rate is number of (nº) contacts/nº camera traps/days. To analyze differences in monthly encounter rates, the Chi-square test for independence was carried out with 95% confidence level. Also, the Kruskal-Wallis's test was carried out.

All the statistical analysis were performed on the Infostat software (Di Renzo, 2020).

Results

The total effort for this study involved 4703 24h-periods/, with 2516 in the cold season and 2187 in the warm season. We had a total number of wild boar encounters of 370. Our CT had a detection angle of 0.741 radians and a detection radius of 8.0 m. From analyzing 280 image sequences, we estimated the speed of movements to be 0.43, 0.49, and 0.42 m/s for the two years, cold and warm seasons, respectively. The cold season included the months May until October, and the warm season was between November and April. We found significant differences in speed between the seasons (p value=0.0334, Kruskal-Wallis’s test)

In terms of encounter rates, there are significant differences among months. March and April had significantly the highest rates at 0.24 and 0.25, respectively (Chi square, df =11, $p<0.05$). The lowest encounter rates were in September with no pictures at all during the study and in August with only 0.005 (2 pictures) ($p<0.05$).. The overall group size was 2.0 (SE±0.6), with a group size of 1.9 (SE±0.25) in the cold season and 1.9 (±0.80) in the warm season (Fig. 3).

Figure 3: Monthly encounter rate (encounter (y)/ time (t)) of wild boar in Villarrica NP (Chile) from May 2020 until April 2022 (n = 370).

The activity index was determined by analyzing 370 pictures. The overall activity index was calculated to be 0.44 (SE±0.03). ~~Whereas~~ during the cold season, the activity index was 0.44 (SE±0.06), while during the warm season it was 0.39 (SE±0.03) (Table 1).

Table 1: Estimated activity index for SE wild boar in study area

Using the activity index and estimated animal speed, we were able to determine that the animals had a day range of 16.5 km over two years. Accordingly, throughout the entire study period, the estimated population density was 1.39 individuals/km² (Table 2). In the cold season, the density was 0.52 individuals/km², while in the warm season it was 2.59 individuals/km² ~~(Fig. 4~~).

Table 2: Estimated random encounter model (REM) parameter values for each period.

Figure 4: Comparative densities of cold and warm seasons on an individual CT basis

Discussion

While interpreting our results, it is crucial to acknowledge certain limitations. Firstly, the relatively small number of camera traps (CTs) used was due to budget constraints. Surveys range from 1 to 1000 CTs (Burton et al. 2015). Typically, 20 to 30 CTs are recommended (Kays et al., 2020). Our small sample size likely caused wide confidence intervals for encounter rates and density, reaching 0.09 (mean 1.55) and 1.82 (mean 0.09), respectively. The variability in CT captures may be due to random placement or the small number of CTs.

Massei et al. (2017) suggested a minimum of 9 cameras per km² for evaluating wild boar density, while our study had a much lower density (0.7 cameras per km²). According to Guerrasio et al. (2022), higher camera density would reduce error related to the contact rate. Thus, our data should be interpreted cautiously due to high confidence intervals. The nested CI analysis showed that adding more CTs decreases CI width without stabilization, indicating the need for more CTs for accurate results. Overestimating precision could undermine management practices (Guerrasio et al., 2022).

Second, the detection angle and radius of our camera trap (CT) might have influenced the data collected. The detection angle of 0.741 rad and a detection radius of 8.0 m could have potentially missed some animal movements, leading to an underestimation of the actual movement speed and activity index. However, the CTs used have detection probabilities similar to other models, such as Bushnell, with near 1 detection probability for wild boar (Palencia et al., 2021). Our CTs, still almost covered by snow, continued to capture images, for example, of *Lepus europaeus* during the harsh winter.

To evaluate the meaning of our results, it is essential to compare our findings with previous studies. Our study's unique contribution is the quantification of population density, which has not been investigated in prior research in this geographical area. Most previous studies have focused on estimating population abundance, but our research provides an added dimension by considering the seasonal variation in movement speed, activity index and therefore density, thereby enriching the understanding of animal behavior in different climatic conditions.

The estimated density of 1.39 individuals/km^2 is the first ever camera data-created density for wild boar in South American temperate forests. However, our calculated density is still difficult to evaluate. Compared to the European average density of 7.8 individuals/km^2 (Guerrasio et al., 2023), our density may seem rather low. Also considering there is no hunting in the area and the availability of the nutritious seeds of the Araucaria.

This low density can presumably not be explained by the later introduction of the species in South America, as the species is highly adaptable and reproductive. The first introduction in this area was 70 years ago (Skewes & Jaksic, 2015), the population could be at a higher level just by reproductive rate. The different environmental factors are surely causing this disruption.

When comparing the European data to ours, it must be taken into account that most of the studies have not been conducted in extreme ecosystems, but in ones that are native to the wild boar and in areas of known wild boar abundances. This difference includes the low food availability at the study site, which is caused by the rough environmental conditions at 1400m altitude. We suggested that March and April were the months with the highest densities because of the araucaria seed fall, but the other months did not have that lower densities. Having the effects of invasive species on ecosystems in mind, the density could still be more than the ecosystem's capacity and a great danger to the Araucaria regeneration. We propose a continuing survey of the wild boar population and possibly even management actions, if further population growth is observed.

To be considered here is the fluctuation between the cold and warm seasons. To further evaluate them, the climatic conditions need to be analyzed. Snow is present from June to September, including July being overall the coldest month with an average of 1.3° C (http://www.aic.gov.ar/sitio/estaciones). The changes in temperature in the cold season not only generate a drastic decrease in edible flora, but also impede movement through up to 90 cm of snow. Even though wild boars decrease their activity in winter, the high snow layer hinders them from any longer movement in these months. Due to these conditions, the population could be migrating between the areas. We observed indirect signs of wild boar migration during the cold season in our research area. These findings are consistent with research conducted in Poland, as well as in mountainous regions in Italy and Spain (Andrzejewski & Jezierski, 1978; DÁndrea et al., 2004; Sarasa & Sarasa, 2013). As a result, it is important to conduct additional studies to analyze the extent to which this declining population trend occurs on a spatial scale.

Although hunting is prohibited in our study area, the presence of puma can have some effect on the daily movement, as they hunt the wild boar as well (Skewes et al. 2012).

We suggest that the reason for April being the month with the highest ~~density~~ is on the one hand, that it is the rutting time of wild boar in Chile (Skewes, 1990), which causes a higher mobility of animals (Morelle et al., 2015). On the other hand, because in March it is the Araucaria seed fall, which leads to higher food availability (Sanguinetti & Kitzberger, 2008). The Araucaria mast attracts not only humans, like the indigenous people that collect the seeds, but also animals like wild boars and rodents. So, the main component of the 3–4 g weight *Araucaria* seeds is starch (about 88.0 g/100 g solids) (Henríquez et al., 2008) followed by protein (about 7.0 g/100 g solids). The protein of this seed has a high nutritional quality, like that of soy protein (Conforti & Lupano, 2011). Also, the Araucaria seeds as a food item for wild boar have been described (Pelliza-Sbriller & Borrelli, 2008).

In consequence, it can be assumed that the wild boars migrate to the Araucaria Forest for the enlarged food availability. In other words, this can be considered a problem for the already endangered tree, as the seeds become ungrowable by the chewing of the wild boars. In Europe (Jezek et al.,2021), the damaging of seedlings through wild boars has been described, which could be possible with the Araucaria seedlings as well. This would imply an even higher damage to the already endangered species.

Considering the limitations to our study, we propose a continuing survey of the wild boar population with more CT`s and possibly even management actions, if further population growth is observed.

Conclusions

In conclusion, our study provides ~~novel~~ insights into ~~animal~~ movement speed, activity index, and population density ~~across different seasons.~~ However, the results should be interpreted with caution due to the limitations associated with the detection capabilities of the CT and the estimation methods used. Further research with more advanced tracking technologies and larger sample sizes would be beneficial to validate and expand upon our findings.

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Table 1(on next page)

Activity index of wild boar in NP Villarrica, Chile.

act = activity index Activity package Rowcliffe 2023, lcl 2.5% = lower confidence limit, ucl 97.5% = upper confidence limit

Table 1: Activity index of wild boar in NP Villarrica, Chile.

	Entire period	Cold season	Warm season
act	0.441	0.448	0.393
Se	0.040	0.066	0.039
lcl 2.5%	0.363	0.314	0.321
ucl 97.5%	0.523	0.573	0.475

act = activity index ~~Activity package Rowcliffe 2023,~~ lcl 2.5% = lower confidence limit, ucl 97.5% = upper confidence limit

Table 2 (on next page)

Estimated random encounter model (REM) parameter values for each period.

where y/t is the encounter rate (nº contacts/nº camera traps*days); *v*, the average distance travelled by an individual during a day (day range); r, the radius of detection. We present standard error, 95% confidence intervals and coefficient of variation (CV, %) for density.

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where y/t is the encounter rate (nº contacts/nº camera traps*days); *v*, the average distance travelled by an individual during a day (day range); r, the radius of detection. We present standard errors (SE), 95% confidence intervals and coefficient of variation (CV, %) for density.

Season	Entire period	Cold season	Warm season
y/t [ind/CT day]	0.07 (370/4703)	0.035 (88/2516)	0.128 (282/2181)
***v* [km/day]**	16.5	18.9	14.1
r [km]	0.008	0.008	0.008
Group size (±SE)	2 (0.13)	1.9 (0.36)	1.9 (0.2)
Density [indiv/km2] (±SE)	1.389 (0.402)	0.518 (0.279)	2.590 (0.726)
Range [indiv/km2]	0.39-4.43	0.0-2.89	0.16-6.33
95% Conf. interval	0.82	0.57	1.42
CV [%]	81.9	113.6	86.2

Figure 1

Map of the study area (created with Free and Open Source QGIS. Geographic Informationsystem QGIS. Open-Source-Project of Geospatial Foundation. http://qgis.org)

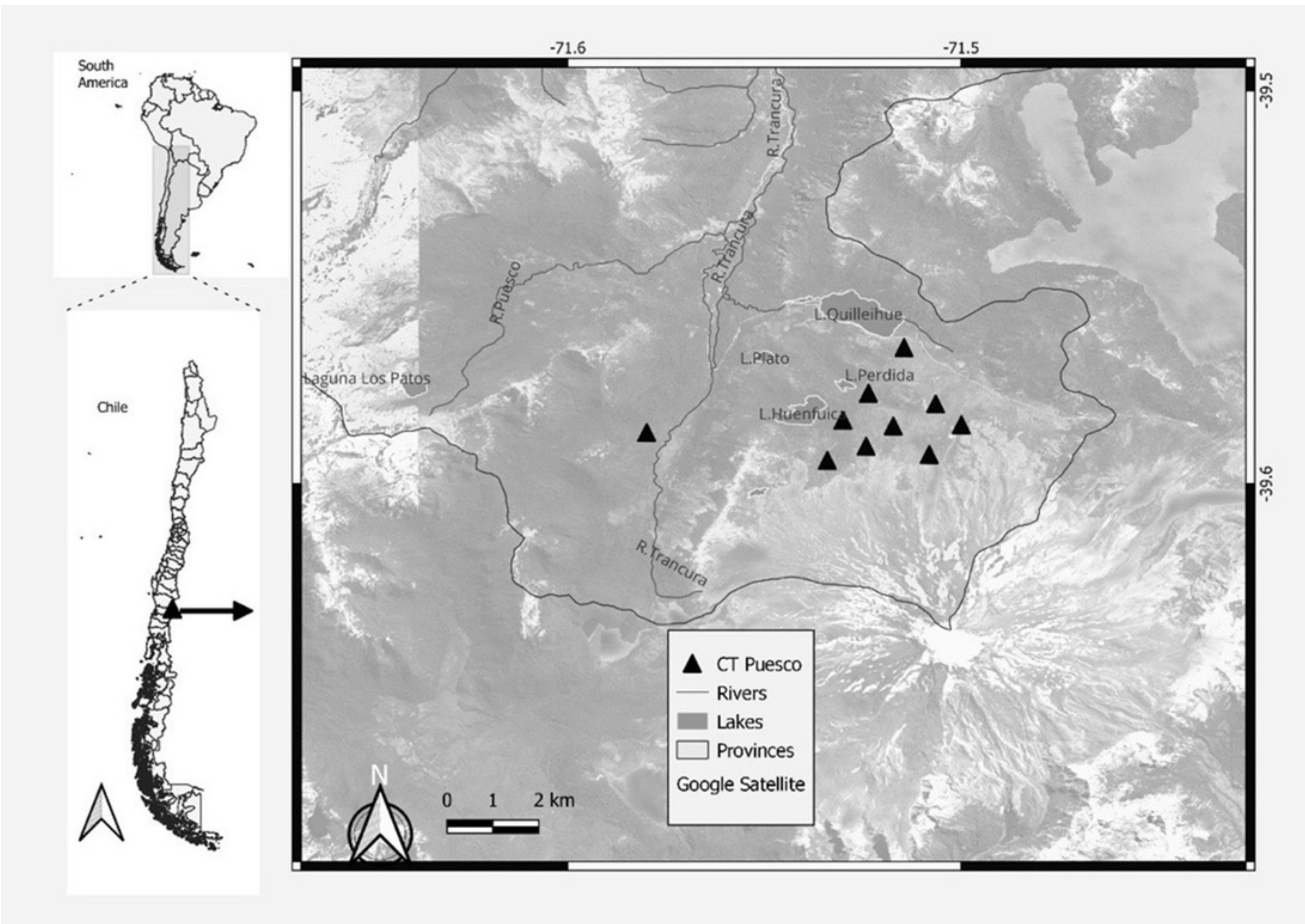

Figure 2

Pictures of wild boars captured by CTs in the study area

Figure 3

Monthly trapping rate (y/t) of wild boar in Villarrica NP (Chile) from May 2020 until April 2022 (n = 370).

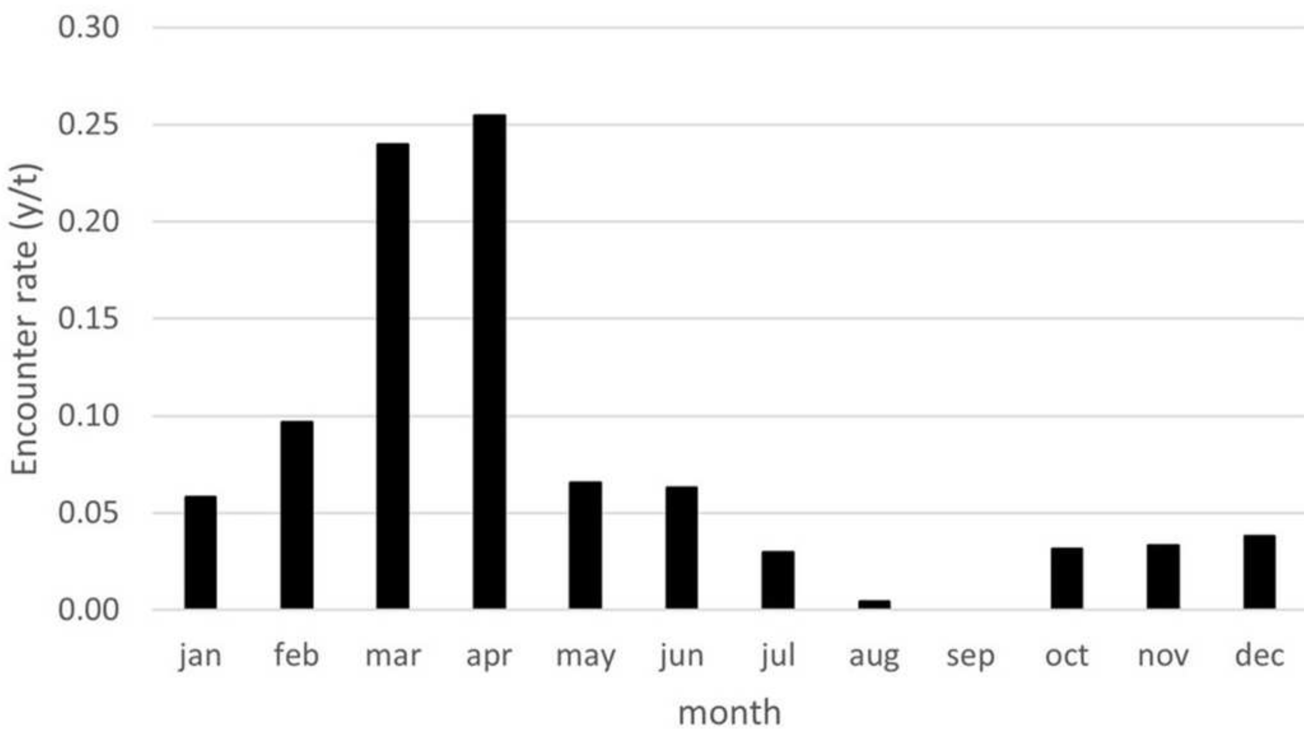

Figure 4

Comparative densities of cold and warm seasons on an individual CT basis