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Short Note

From exploration to establishment: Activity changes of the first collared peccary (*Pecari tajacu*) group reintroduced in South America

Cindy M. Hurtado[1,2,*], Harald Beck[1], Paporn Thebpanya[1]

[1] *Towson University*
[2] *University of British Columbia*

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Abstract

Reintroduction has become an increasingly common approach for conservation of endangered species. However, reintroductions can be logistically challenging and expensive, with uncertain outcomes, making it a priority to establish effective post-release monitoring techniques. In north-eastern Argentina, collared peccaries *(Pecari tajacu)* have been locally extinct for over 50 years. As part of a multi-species rewilding project, seven captive-born collared peccaries were released into Ibera Nature Reserve in 2015. Using radio telemetry and camera traps, we evaluated temporal changes in the peccaries' post-release activity budget and activity patterns as indicators of reintroduction progress and potential establishment into the new area. Collared peccaries changed their activity budget and peak periods of activity towards a more natural pattern a year after release, from 30% to 49% foraging time and 18% to 2% traveling time. Our results highlight the potential of using activity budget assessments and camera trapping data to monitor the progress of introduced individuals and inform managers' decision-making process after reintroductions.

Reintroductions are increasing in popularity as a tool for mitigating the negative effects of biodiversity loss (Taylor et al., 2017). The success of mammal reintroductions is still difficult to assess; however, some authors have offered indicators to guide managers towards better post-release decision-making (Berger-Tal and Saltz, 2014). After release, animals need to adjust their behaviour to the new environment. These changes can decrease foraging, resting time, and social interactions, which may cause low reproductive success and alter the stability of social groups (Dunbar, 1992). Behavioural changes over time can potentially be used to assess whether an animal is established and interacting with its environment in a way that will increase fitness, with the expectation that early behaviour profiles may be maladaptive and potentially indicative of stress (Teixeira et al., 2007).

Over 50 years ago, several large vertebrate species, including jaguar (*Panthera onca*), giant anteater (*Myrmecophaga tridactyla*), tapir (*Tapirus terrestris*), and collared peccary (*Pecari tajacu*) became locally extinct in the Corrientes Province, north-eastern Argentina (Chebez et al., 2008). Collared peccaries are highly social, gregarious animals, found from southern USA to northern Argentina, in habitats ranging from deserts to tropical forests (Taber et al., 2011). They are categorized as Least Concern by the IUCN (Gongora et al., 2011) but represent one of the largest biomasses harvested by rural human populations in South America (Peres, 2000). Collared peccaries also offer several ecosystem functions such as seed dispersal and predation and seedling trampling, affecting over 200 species of plants across their range (Beck, 2005); also, they function as ecosystem engineers (Beck et al., 2010).

The main cause of the extirpation of peccaries was over-hunting (Giraudo et al., 2006) which was banned in the area after the establishment of the Ibera Nature Reserve in 1983. In this context, the Conservation Land Trust initiated a rewilding program in 2007, starting with the reintroduction of giant anteaters and pampas deer (*Ozotoceros bezoarticus*), followed by collared peccary and other species (Zamboni et al., 2017).

We hypothesized that released individuals rejecting their new area would allocate a greater time to moving or traveling behaviours (i.e. homing), reducing foraging and potentially affecting their fitness. However, individuals establishing or adapting to their new site would show positive changes in behaviour such as allocating more time to foraging compared to traveling and walking and with defined peaks of activity, reflecting constant foraging and resting times. Thus, our objective was to assess the activity and behavioural changes of collared peccary after reintroduction. This information could be used as indicators of reintroduction progress and related to establishment and familiarity of released individuals to their new environment.

In May 2015, 7 captive-bred peccaries (2 males and 5 females) were released into the Ibera Nature Reserve (28°32′ S, 57°10′ W). A detailed description of the study area and reintroduction protocol can be found in Hurtado (2017). Prior to release, each animal was fitted with a MOD-500 or MOD-400 VHF radio-collared transmitter (Telonics Inc., Mesa, Arizona) and numbered ear tags. From June to August 2015 and May to August 2016, the individuals were radio-tracked with the "homing in" procedure (White and Garrott, 2012) and following the ethical guidelines from the Institutional Animal Care and Use Committee (IACUC Protocol: 05152014HB-01). Using the scan sampling method with continuous recording (Martin and Bateson, 2007), we recorded the peccaries' activity budgets based on the following six mutually exclusive activities. 1) Foraging, animal is searching for food followed by rooting, chewing, and eating. 2) Resting, animal is laying or sitting on the ground (not engaged in any other behaviours). 3) Trav-

*Corresponding author
Email address: cindymeliza@gmail.com (Cindy M. Hurtado)

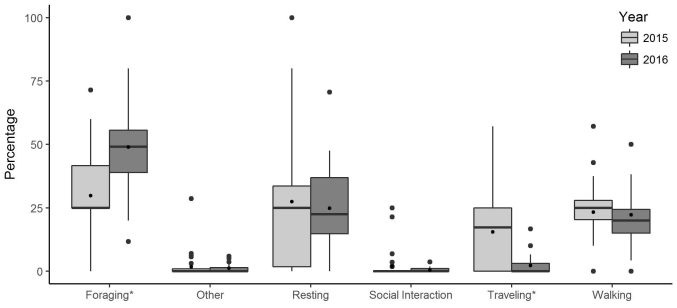

Figure 1 – Collared peccaries' behaviours in the Ibera Natural Reserve, Corrientes, Argentina, right after reintroduction (2015) and one year later (2016). Box and whisker plots show median (horizontal line within box), 25% and 75% percentiles (box) and range (whiskers). Circles inside boxes indicate mean, while others indicate statistical outliers, n=101, p<0.01 indicated with * on the axis label.

eling, referred to the animals moving at a fast pace with the group or by itself, following a specific direction, i.e., going from one foraging patch to another or from resting site to foraging site. 4) Walking, the individual is moving at a slower pace than when traveling and is not engaged in foraging. 5) Social interactions, which included affiliative behaviours (e.g. mating, rubbing or smelling other individuals) and aggressive behaviours (e.g. fighting, chasing or teeth gashed followed by hair raised). 6) Others, any rare behaviour not yet listed (e.g., wallowing, drinking). We used the Wilcoxon rank test for paired samples to compare differences in mean percentages of time spent in each behavioural category (Altrichter et al., 2002) between the periods, immediately following reintroduction (June to August 2015) versus one year later (May to August 2016). To be able to record social interactions and have a good representation of the peccaries' behaviour, we only included in our analysis the days in which radio-tracking occurred for more than three hours after the group was located, and with at least three individuals per scan. The peccaries were used to human presence; however, if disturbed, the observer would wait until its presence was ignored before recording the scans.

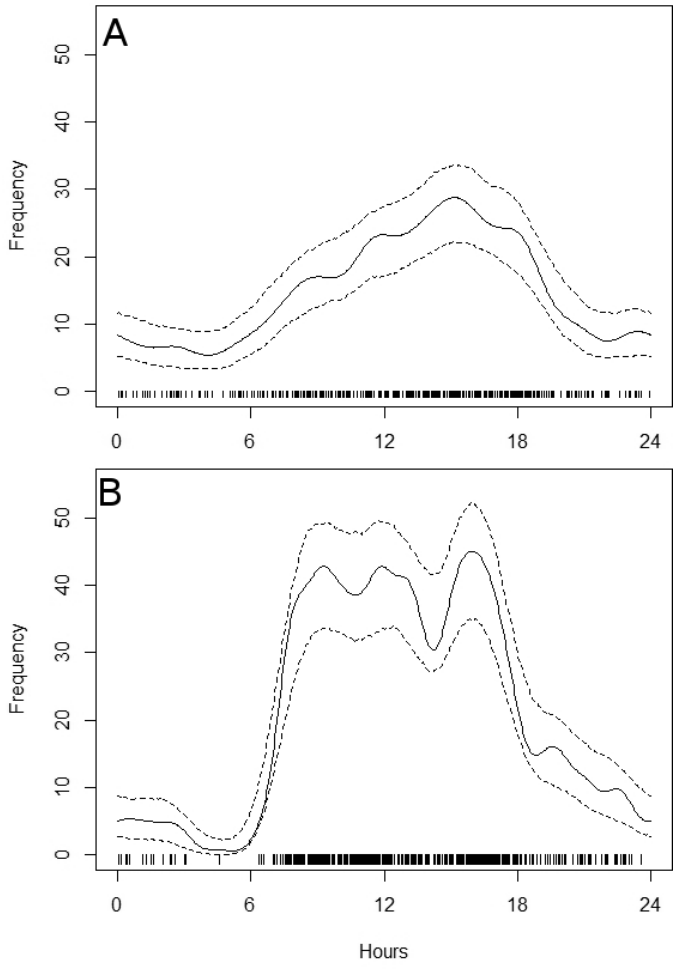

Figure 2 – Daily activity pattern of released collared peccaries in the Ibera Natural Reserve, Corrientes, Argentina. Shortly after release, 2015 (A) and a year after release, 2016 (B). Black line indicates kernel density estimates, confidence internals showed in dashed lines.

We quantified changes in daily activity patterns using five non-baited remote cameras. Cameras were separated by at least 200 m and set to take 3 photos per trigger at 5 min intervals; any records one hour apart were considered independent (Tobler et al., 2009). During the sampling period, we placed the cameras along trails highly used by peccaries which changed with their shifting home range, about 2.5 km^2 after settlement (Hurtado, 2017). We quantified activity levels by fitting a Kernel circular distribution to the data to calculate the proportion of time active; standard errors were estimated using non-parametric bootstrap (Rowcliffe et al., 2014). Comparisons of activity levels through time were made using the Wald test for proportion of time active in the package `activity` from the R software version 3.3.1 (Rowcliffe, 2016).

Right after release, one sub-adult male dispersed 10 km away from the release site and lost the collar five months later. One year after reintroduction, the remaining adult male died and another adult male (from captivity) was introduced to the group of females. Thus, we obtained data on six individuals during 2015 and 2016.

After 246.5 observational hours (100 h in 2015 and 146.5 h in 2016), we obtained 1940 scan entries. During 2015, immediately after release, the group's mean activity budget was divided into 30% Foraging, 27% Resting, 23% Walking, 16% Traveling, and 2% Social Interaction, and 2% Others. In 2016, one-year post-release, the group's activity budget changed to 49% Foraging, 25% Resting, 23% Walking, 2% Traveling, 1% Social Interaction, and 1% Others (Fig. 1).

The relative importance of behaviours, as indicated by the peccaries' time allocation was primarily for Foraging, followed by Resting, Walking, Traveling, Social Interactions, and Others, and was consistent within both years. However, we found significant differences in the time spent in Foraging and Traveling behaviours immediately after release compared to one-year post-release (W=848.5, p<0.01 and W=162, p<0.01). A year after release, foraging time increased while traveling time greatly reduced.

Additionally, 843 independent records of peccaries were obtained from 928 camera-days. Right after release, the activity period of peccaries was concentrated in the afternoon without any defined activity peak (Fig. 2A). Two distinct peaks emerged a year later: one in the early morning and the other in the late afternoon (Fig. 2B). However, the proportion of time active during the first three months after release was similar when compared with one year after release, 52% (SE 0.04) in 2015 and 48% in 2016 (SE 0.09), (W=1.11, p=0.294, SE=0.05).

Our measures of behaviour and activity indicate the released peccaries are adapting to their new environment. Activity budget assessments for collared peccaries are scarce in the literature. Bigler (1974) evaluated three main behaviours on collared peccaries in Arizona: feeding, traveling, and resting; he found that the peccaries spent most of their time feeding, except when constrained by high temperatures.

Altrichter et al. (2002) used activity budget as a measure of nutritional stress in a population of white-lipped peccaries in Costa Rica, where individuals increased time traveling and decreased time engaging in social interactions during periods of low food availability, indicating high levels of stress. Similarly, reintroduction is also a stressful process. The individuals' cognitive abilities may be affected by stress reducing their opportunities of survival (Teixeira et al., 2007). The peccary's change in foraging time may indicate less stressful conditions as they got used to their novel environment.

Additionally, the lack of significant differences in the proportion of time active between years indicate that animals were sacrificing foraging time for traveling time, shortly after reintroduction. This is consistent with exploration-exploitation trade-off where animals would face the dilemma of exploiting already known resources or invest time gathering information about new ones (Berger-Tal et al., 2014). When

animals are reintroduced, they first need to explore and gain information to become successfully established into a new area (Berger-Tal and Saltz, 2014). A year after reintroduction the peccaries showed a potential increased familiarity of the new location, thus, reducing their traveling time and resting time while increasing foraging.

The activity patterns of the released individuals were consistent with studies from South America (Galetti et al., 2015), where peccaries were mostly diurnal. However, differences in the activity peaks after release vs one year are potentially related to the change in their behaviour, from greater activity across the entire day shortly after release towards more selected times for foraging in the early morning and late afternoon a year later. This pattern also resembles the activity pattern of the peccaries' populations of a similar ecosystem, the Brazilian Pantanal, where the peccaries' activity peaks were at the early morning and late afternoon (Hofman et al., 2016).

Monitoring time allocation to different activities of peccaries with radio-telemetry followed by direct observation provides valuable insights of reintroduction progress (survival and behavioural changes). Radio-tracking animals can additionally provide information on individual's condition, mating behaviour, intra-specific interactions, and help anticipate potential problems with collared animals (Hurtado, 2017). For example, several mating events were seen during radio-telemetry and four out of the five females successfully reproduced in 2016 and early 2017 (Zamboni et al., 2017). When radio-tracking is not available or when monitoring nocturnal mammals, camera trapping can provide a cost-time effective way to reflect behavioural changes through changes in the activity patterns of the released individuals. Thus, monitoring changes in activity levels after reintroduction is another informative method to assess post-release progress (e.g. foraging stress and dispersal behaviours) and guide management decisions in peccary reintroductions.

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