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BEHAVIOURAL STUDY OF DICE'S COTTONTAIL

Sylvilagus dicei

Abstract:

Little is known about the Dice's Cottontail (*S. dicei*) which resides only in the Talamanca Mountain range of Costa Rica and Panama. This research aimed to shine a light on the unexplored behaviour of cottontails within Cloudbridge Nature Reserve in Costa Rica, as camera traps deployed across the site had recorded individuals of this species. Factors that could influence behaviour analysed in this report showed that increased levels of behaviour occurred at higher altitudes within the reserve and in regenerative forest types. Additionally, an activity budget identified four key behaviours caught across the camera trap footage and a peak in activity during twilight hours. Data should continue to be collected for this species so that long term monitoring and further research can be explored to aid its conservation.

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Introduction

Dice's Cottontail (*Sylvilagus dicei; S. dicei*) is endemic to Costa Rica and more specifically inhabits the mountain range of Cordillera de Talamanca. Originally rabbits in this area were referred to as the Common tapeti or forest cottontail (*Sylvilagus brasiliensis*) until a morphometric study conducted by Diersing (1981) confirmed measurable taxonomic distinctions and geographical distributions (Appendix 1) therefore defining *S. dicei* as its own species. In 1932 Harris compiled a paper containing four new mammals found in Costa Rica, the first being *Sylvilagus dicei* identified through skin and skull remains. *S. dicei* was therefore established as the largest Central American Forest rabbit within the *Sylvilagus gabbi* group until later reduced to subspecies level by Hershkovitz (1950) (Diersing, 1981).

The conflict in defining this species has likely contributed to the current vulnerable and decreasing status of *S. dicei*, as indicated on the IUCN (International Union for the Conservation of Nature) red list (Mora et al. 2016). The lack of existing conservation actions (Smith et al. 2016) and widely diminutive understanding of its biological and ecological status (Chapman and Flux, 1990) also point to the decline.

This study aims to provide more information on the daily activity patterns and behavioural activity budget of *S. dicei* to aid future conservation efforts. Sutherland (1998) highlighted the importance of behavioural studies in conservation as they can identify specific risks associated with small population extinction, species isolation, response to fragmented habitats, mating systems and inbreeding, in addition to environmental change. Many studies concerning rabbit behaviour base themselves on captive individuals, as lagomorphs are an ideal laboratory species that are easy to maintain, handle and as an iteroparous species, reproduce quickly (Leach et al. 2009; Farnworth et al. 2011). The data collected from this project will instead provide insight into natural and wild behaviours, where additional variables will be explored regarding behavioural diversity regarding time of day, forest type, altitude and camera trap location. Behaviour is a particularly interesting area of study that can provide an insight into an animal's exclusive sensory bubble or 'Umwelt' defined by Uexküll (1909) (Yong, 2022). This term refers to an individual's perceptual world of sense and experience to which behaviour can be the first step to understanding and ultimately conserving a species.

Methods

Study site

Cloudbridge is a private Nature Reserve located in Pérez Zeledón (San José Province), Costa Rica. The reserve spans 330 hectares, inclusive of regenerated and primary forest and climbs from 1550m to 2600m within the Talamanca Mountain range (Cloudbridge, 2023). Active conservation of the cloud forest through planting, natural regeneration, combined with education and research are core to the actions and values of the reserve. Sustainable tourism is maintained with public trails around the reserve. Private trails are restricted to staff, volunteer, and research use only which reduces footfall and overall disturbance on the reserve.

Camera locations

The camera trapping project has been ongoing at Cloudbridge since 2015. For the duration of this project, ten camera traps placed in January 2023 with focus on mammal abundance and diversity across the reserve were used (Appendix 1). Eight of these camera traps captured footage of *S. dicei* and were applicable to this study (D1, D2, E0, E1, G1, R4, Q1, M2) (Appendix 2). Site locations of cameras represented all forest types present on the reserve, including one planted (E0), two young growth (D1, Q1), two old growth (E1, M2) and three Primary (R4, G1, D2). Each camera was also

located at a different altitude with a total range of 1524m to 2098m (Appendix 2). Cameras S1 and M1 were not included as no cottontails were present in the video footage history.

Study species

S. dicei (Order: Lagomorpha, Family: Leporidae, Genus: *Sylvilagus*) is locally restricted to the Talamanca mountains with an altitudinal range spanning 1100m to 3500m (Mora et al. 2021). Due to their high elevation range the main food source of *S. dicei* is high elevation bamboo. Previous literature estimates the inhabited range of this species to be 10,313km2 with individuals predominantly residing in shrublands and oak dominated cloud forest (Mora et al. 2021). Hunting traditions in Costa Rica are associated with declines in the species population, which have subsequently been illegalised (Mora et al. 2021). An alternative contributor to the decline is accredited to the increase and elevational spread of coyote (*Canis latrans*) populations as *S. Dicei* heavily contributes to their diet (Mora et al. 2021). Geographic barriers as well as adaptations to distinct altitudinal niches have likely influenced diversification events of Lagomorpha in this region (Mora et al. 2021). A further probable archipelagic population was also identified in the Tilaran mountain ranges which was likely isolated by human actions that caused fragmentation (Mora et al. 2021). Using scenarios based on information from the Intergovernmental Panel on Climate Change (IPCC, 2015) Mora et al. (2021) estimates a 48% loss of the aforementioned range by the year 2100 based on a 500m retraction of suitable habitat (Appendix 3).

Ethogram

An ethogram (Table 1) was compiled from studies focussed on laboratory housed rabbits. These studies provided intense detail regarding rabbit behaviour in response to post-operative pain and medication as well as general rabbit behaviour. Behaviour categories, distinctions and descriptions were predominantly influenced by Farnworth et al. (2017). Contrary to many behavioural studies found on groups of wild European rabbits, *S. dicei* individuals are often solitary and social behaviours were not applicable.

Table. 1 Behaviour ethogram for data collection of S. dicei (Leach et al. 2009; Farnworth et al. 2011)

Behaviour	**Code**	**Description**
General		*General rabbit behaviour*
Active	AC	Engaged in activity or behaviour
Alert	AL	Instant reaction to disturbance, current behaviour ceases and ears likely erect
Body shake	BS	Entire body shaking
Forage/Explore	F/E	Nose touching surfaces or objects in the immediate environment
Dig	D	Digging ground in immediate environment
Gnaw	GN	Gnawing/chewing on object in immediate environment (note object if possible)
Eat/Drink	E/D	Consuming food or drink from source within camera shed view
Inactive/Stationary	I/S	Stays in one spot for more than five seconds
Stretch	ST	Stretching, elongation, or twisting of body
Yawn	Y	Mouth gapes and lips drawn back
Twitch	TW	Rapid movement of fur along back
Head movement	HM	Rapid lifting, turning, or dropping of head
Locomotion		*Active movements*
Hop	H	Hopping at average or comfortable pace
Leap	L	Jumping forward or upwards whilst hopping
Turning jump	TJ	Jumping and turning while stationary
Run/Bounding	R/B	Hopping at a fast pace
Flee	F	Hopping at a fast pace in escape or pursuit (note effector if possible)
Shuffle	SH	Walking at a slow pace, with potential injury

Self-directed		*Self-directed action*
Grooming	GR	Cleaning/licking an area of the body, including belly/flank, head/ears, front/hind legs
Scratching	SCR	Scratching an area of the body using hind legs
Postures		*Position or pose of rabbit*
Dog	DO	Upright posture with forelimbs extended vertically
Stand	SND	Bodyweight on all four feet with abdomen off the ground
Sit	SIT	Sitting relaxed with all limbs tucked under body
Rear	R	Upright position on hind legs
Elongated	ELO	Body stretched horizontally with front legs as far forward as possible
Lying	LY	Sitting with hind legs tucked under body and forelimbs stretched in front
Postural Change		*Adjustments to posture while stationary*
Ears erect	EER	Ears erect and pointing in a certain direction
Ears flat	EFL	Ears flat on individuals back
Ears relaxed	ER	Ears between flat and erect
Major	MJO	Complete body adjustment
Minor	MNR	Small changes or limb movement
Partial ease	PE	Slow postural change
Other	*O*	*Infrequent behaviour not detailed on ethogram*

Data entry

In total, 306 camera trap videos were processed and checked for 33 different behaviour distinctions across eight cameras on the reserve (Appendix 1). The videos were accessed through Cloudbridge Nature Reserve's shared Google Drive, in which recent camera trap data has been stored since February 2023. Each ten second video was watched by one person for consistency and behaviours were recorded in seconds for the duration that they were displayed. Some behaviours were performed simultaneously, meaning that the total of recorded behaviours exceeded ten seconds. Additionally, some individuals were present in the frame for less than ten seconds, reducing the behaviour total to below the full video length. Data was entered into a table within excel, where camera, date, time, and rounded time were recorded for each entry alongside behaviours presented. Later, forest type and altitude were also incorporated for data analysis from previous research at Cloudbridge (Bevilacqua, 2023) (Appendix 2).

Results

Daily activity

Camera trap

Cameras D1, D2, and Q1 display a common increase of activity at 18:00, with D1 and Q1 exhibiting much higher frequencies of camera triggers than any other site. Individuals seem to be more consistently active at sites D1 and Q1 throughout the day in comparison to other camera sites that are more intermittent. R4 and E0 have the least activity, making up 1% of all triggers.

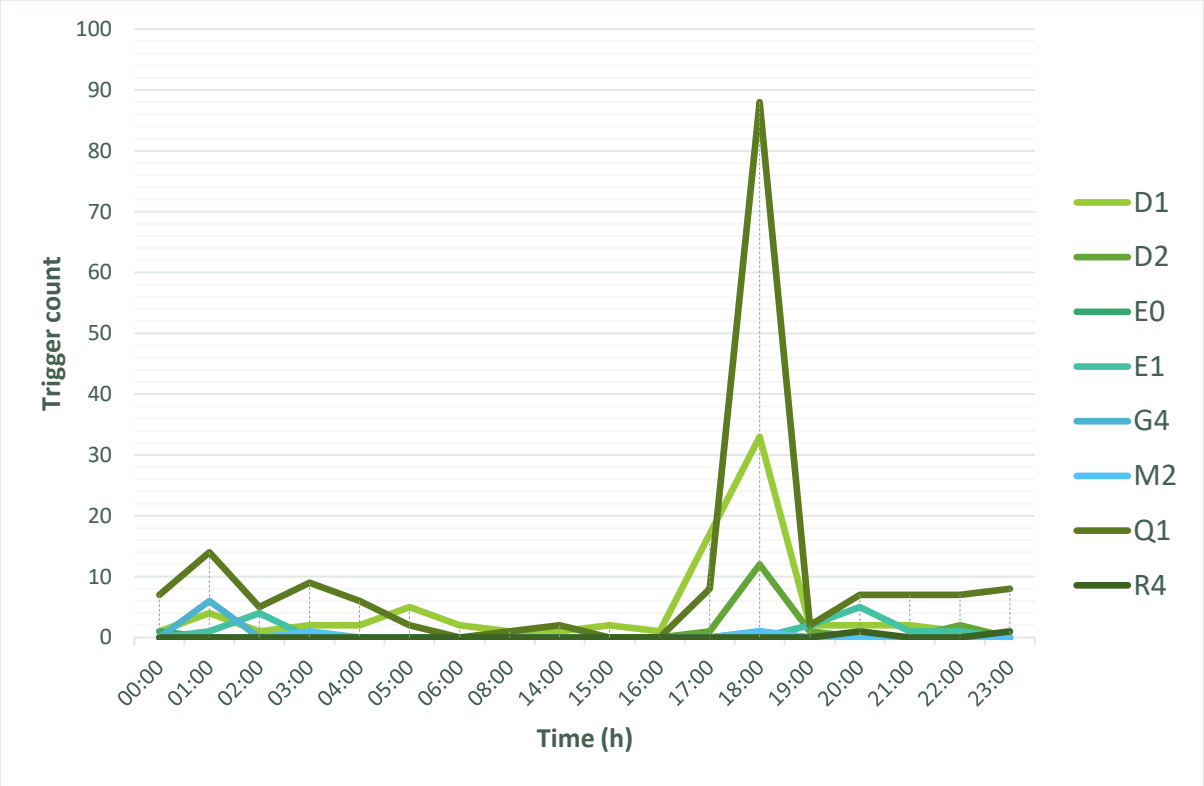


Figure 1. Daily activities shown by hour through trigger count at each camera trap.

Monthly

Activity is shown between January and September 2023 with every month consistently triggering at 18:00 (46% of total occurrence) which does not occur at any other time. March, April, and May have the highest frequencies of camera triggers compared with other months. Triggers are more consistent throughout the day for all months in comparison to being more sporadic at each camera trap in Figure 1. January and September have the lowest trigger incidences likely due to incomplete data.

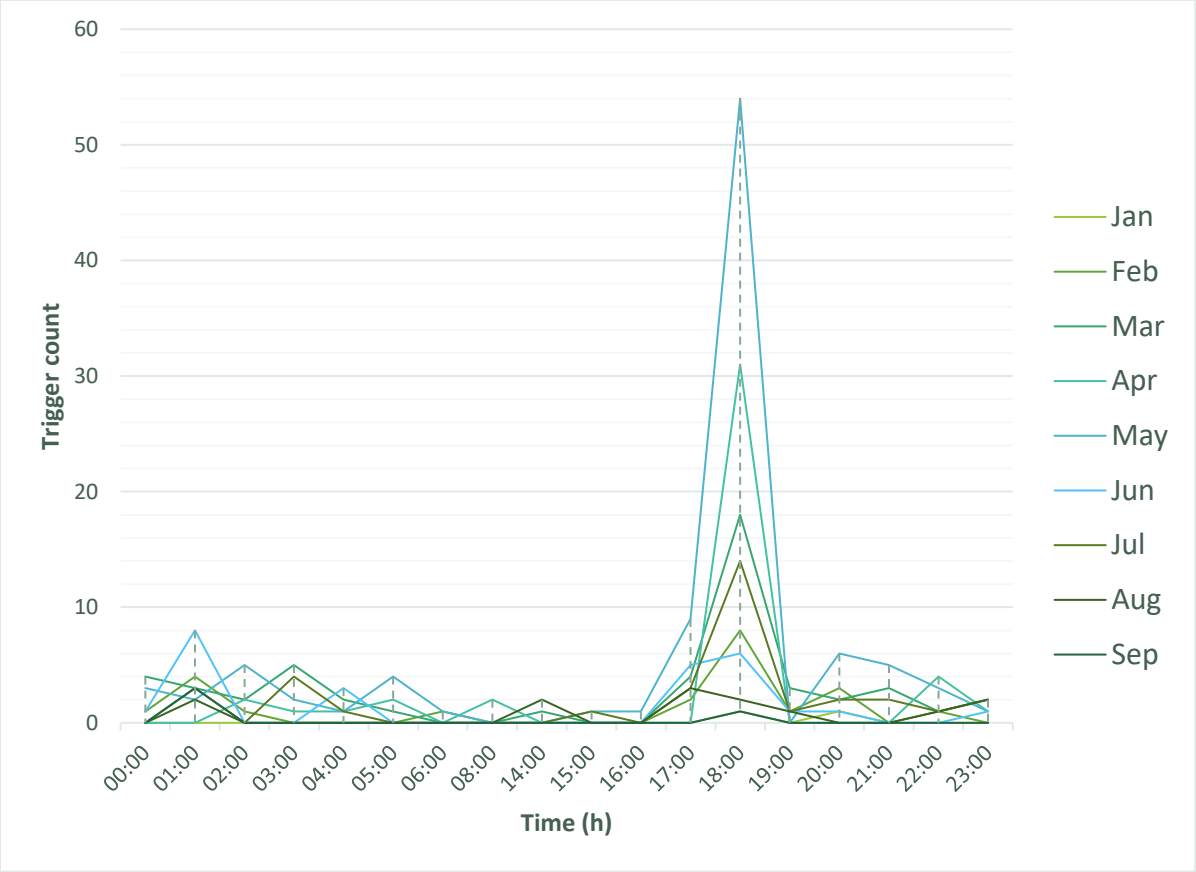


Figure 2. Daily activities shown by hour through trigger count from each month.

Activity budget

Four behaviours dominated this study and were representative of all behavioural categories, these included Hop, Dog, Forage and explore, and Stand (Figure 3). Behaviours that contributed less than 1% to the overall budget (BS, GN, ST, L, TJ, F, SCR, R, EFL, ER, MJO) are shown in the legend and not included within the chart. Not all behaviours from the original ethogram are present as ten of the 33 were not observed at any point during data input (AC, D, Y, TW, HM, O, SH, ELO, LY, PE).

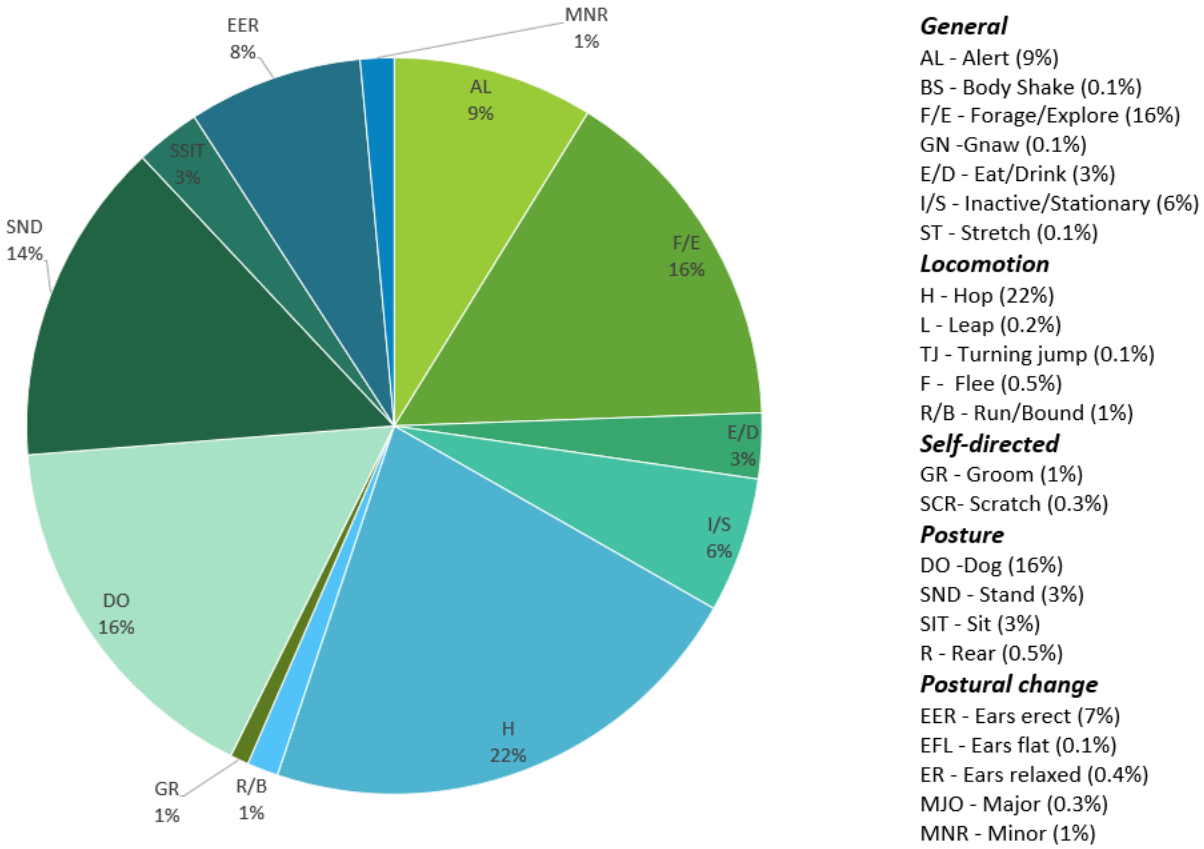


Figure 3. Overall activity budget compiling all 23 present behaviour distinctions and relevant categories, shown as percentages.

Shannon-Wiener Index and Evenness

Camera trap

Behavioural Diversity and evenness were calculated for each camera site using excel (Figure 4). Minitab statistical software found no significant difference for either Diversity or Evenness utilising a Kruskal-Wallis test. The graph below shows that diversity was particularly high for cameras D1, G4, and Q1 which all had an index of 2 or more. The camera with the lowest behavioural diversity was E0 followed by M2.

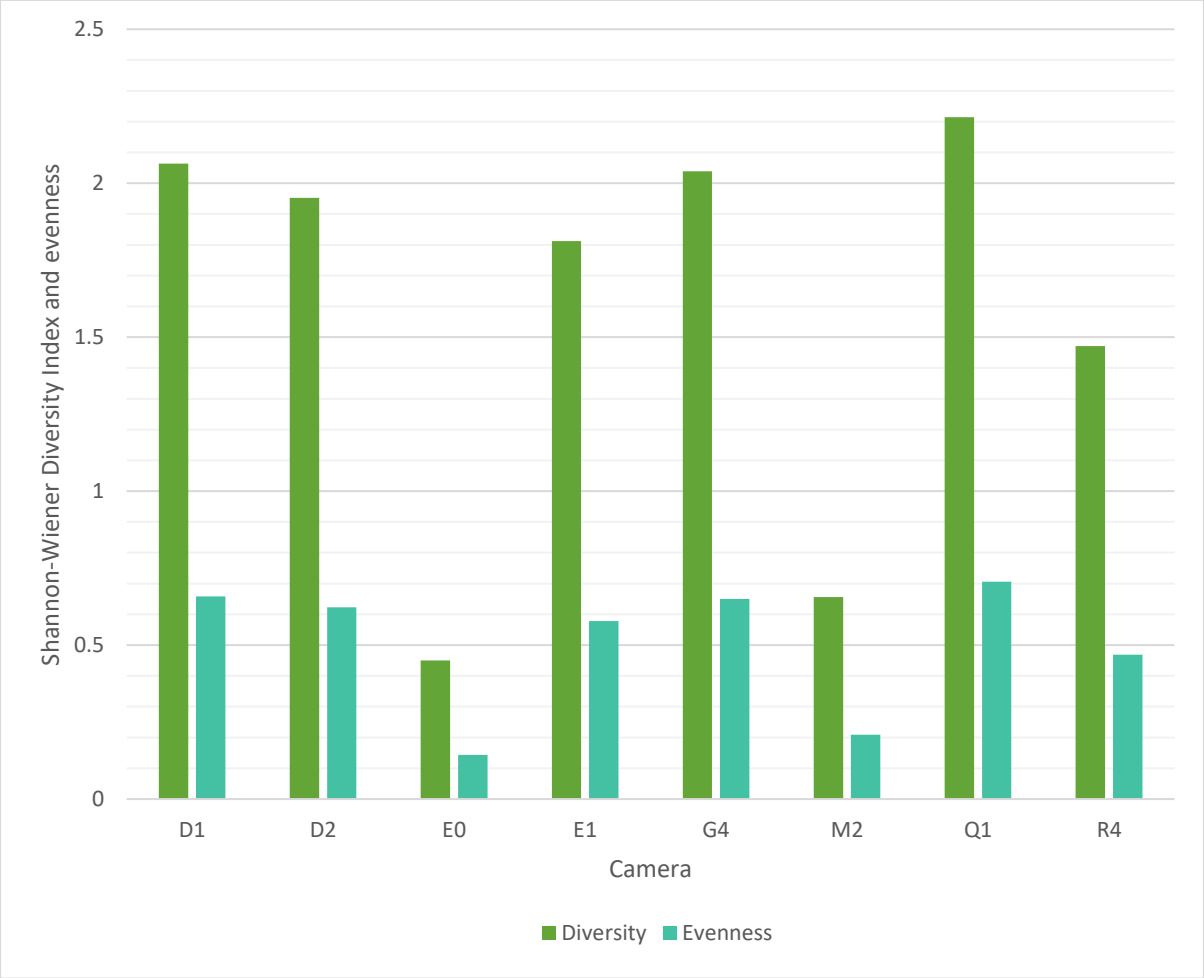


Figure 4. Shannon-Wiener Index and Evenness for behavioural diversity at each camera trap.

Forest Type and Altitude

Insufficient footage of *S. dicei* across camera trap sites made effective statistical testing unattainable for this project aim. However, the graph in Figure 5 provides a clear indication that young growth forest is a popular forest type as most data was obtained here. In conjunction with the young growth forest type, the second highest altitude (1832m) was where most behaviours were observed on the reserve.

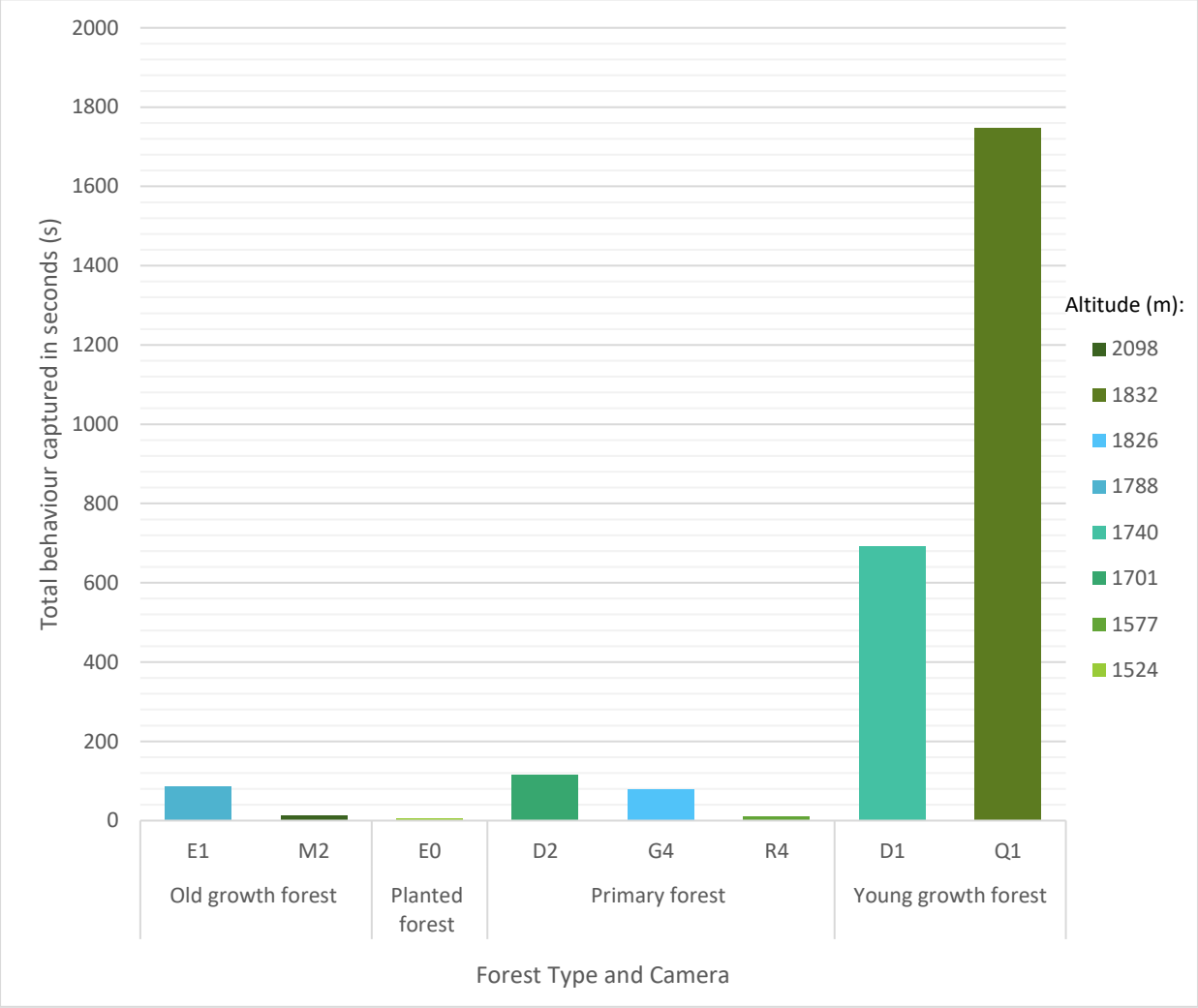


Figure 5. Behaviour duration in seconds in relation to Forest type and altitude (m) at each camera trap.

Discussion

Daily activity patterns revealed a higher incidence of *S. dicei* individuals at 18:00 hours which is usual for Lagomorph species due to high occurrence during twilight. A study conducted with populations of wild rabbits (*Oryctolagus cuniculus*) in semi-wild conditions demonstrated similar results where greatest activity peaks corresponded to twilight (Diez et al. 2013). A prior study undertaken in 2005 (Diez et al.) found high occurrence of activity during night-time as well as twilight and no activity during middle hours of the day, similarly, shown on the graph in figures one and two. Camera Q1 was located on the Los Quetzales trail and had the most consistent nocturnal and twilight activity, likely due to the high amounts of data obtained from this site compared to others. This may be attributed to the altitude being second highest of all camera traps (1832m) as the elevational range of *S. Dicei* exceeds 1100m.

Lagomorphs walk on the toes of their feet, with five toes on their forefeet and four on their hindfeet known as digitigrade which enables them to run with efficiency (Wainwright, 2007). *S. dicei*, like other Leporidae, has limbs almost exclusively designed for terrestrial locomotion, linking to a high contribution of hopping behaviour (22%) in the activity budget shown above. With no means of defence in response to predators they are well adapted to fleeing and escaping at high speeds. An activity similarly described by Wainwright (2007) was shown extensively in the footage captured within Cloudbridge which demonstrated hopping and sitting behaviours in conjunction. Usually, this combination of hopping and dog posture (16%) confuses predators as many rabbits have white tails that are visible whilst moving and hidden when stationary (Semmann et al. 2013). This white flash whilst hopping is also used as a warning notice to other individuals nearby (Smith et al. 2009). In addition to this alert behaviours also contributed 9% to the total activity budget highlighting the significance of cottontails' innate response to predation in their environment.

As outlined above not all behaviours were observed from the ethogram that was originally compiled. This was likely due to overlap of behaviours observed in the footage combined with an oversaturated ethogram which needed to focus on broader descriptions. Overcomplicating the ethogram meant that eleven behaviour distinctions contributed less than 1% of observations to the activity budget, making them inconsistent, likely as isolated or misinterpreted events. Additionally, the lack of data and camera video quality in some cases may have affected the ability to clearly identify behaviours effectively.

There was no significant difference in behavioural diversity between sites. This is likely due to the dominance of four behaviour types in the activity budget and low instances of other more specific behaviours. Although each camera trap site provided a different forest type and altitude that may have influenced types of behaviours presented, the lack of data contributed suggests that these areas were not sought out by *S. dicei*. Since this species is still particularly understudied and requires further review (Chapman and Flux, 1990), an effort to identify activity may be required to determine camera placement and potentially a more intimate insight.

The results from this study signify an inclination by *S. dicei* for young growth forest, as cameras D1 and Q1 located in this habitat type captured the highest camera trap triggers with 260 videos of the total 306 at these sites (85%). This may be due to the abundance of high elevation bamboo in these areas which is evident when visiting the camera trap sites. This corresponds to previous research at Cloudbridge by Redman (2019) in which young growth forest was associated with light-requiring pioneer species such as bamboo that grow quickly filling the shrub layer, typically cottontails inhabit such successional and transitional habitats with consistent areas of refuge (Chapman et al. 1990).

Mora et al. (2021) also states that *S. dicei* prefers bamboo (*Chusquea subtessellata*) at greater altitudes such as those within Cloudbridge.

Videos captured at primary forest habitat sites made up less than 1% of the total videos captured, however camera D2 which was situated in this forest type may have been underrepresented due to technical failures with the camera trap between August and September 2023. The young growth edge habitat adjacent to primary forest present at camera site D2 is largely comprised of bamboo; however, the angle of the camera trap faces a bare area of ground with an animal run further ahead. The position of all cameras used in this study were not biased towards capturing footage of cottontails, but in this case the direction of the camera may have missed more individuals. Other research has revealed that bamboo seedlings might be unable to colonise open areas due to light intolerance and competition, and a plausible hypothesis is that adult bamboo in the adjacent primary forest understory may have invaded the edge habitat (Stern, Goodell and Kennard, 1999).

Limitations

The camera trap footage used in this study was taken from previously active research on mammal abundance and diversity across the reserve. This meant that camera traps were not biased towards *S. dicei* and therefore more footage could be captured for this specific species. Being unbiased provided a realistic view however on the capture rate of *S. dicei* as explored by Ilott-Baudon (2023).

Camera trap maintenance was challenging due to the accessibility of certain sites and wet weather conditions. In addition to this camera trap or SD card failures as well as human disturbance proved difficult. Technological failures contributed to missing data which proved difficult when trying to compare information between sites as capture rate was also a limiting factor. Human disturbance on extensively used trails was another factor that likely affected capture rate and could be considered when re-positioning cameras.

Recommendations

Other studies relating to habitat segregation in rabbits and hares used pellet characteristics to distinguish between species (Beltrán et al. 2022). This methodology could be utilised in future studies as cameras could be set up in locations specific to *S. dicei* for more behavioural footage capture. As rabbits are known to eat their own faeces (cecotropes) for optimum nutrient and water absorption the use of pellet identification could lead to additional behavioural distinctions.

Difference in monthly activity across the year could be explored regarding seasonal patterns with fluctuations in sunrise and sunset. This was done in a previous study on the Iberian Peninsula with *Oryctolagus cuniculus* where activity indexes increased in later months of the year and were associated with reproduction. Biorhythmic information can therefore be important in relation to behavioural studies and the target species' greater environment. This concept could be used in relation to the wet and dry seasons that occur in Costa Rica and regarding yearly activity of this species.

Conclusion

This study is still preliminary regarding the information gathered on *S. dicei* so far, and more data should continue to be collected for effective analysis as well as to monitor long term population trends. Considering the limitations and recommendations listed above may aid in directing future research, and if planned accordingly could aid in understanding the unique requirements of this species' conservation.

References

Bevilacqua, Oliver. (2023). Factors that influence mammal abundance and diversity using camera trapping. Available at: https://www.cloudbridge.org/publications/reports/#Zoological%20Studies%20-%20Mammalian

Bell, D., Endean, J., & Mountjoy, P., (2021). Techniques to encourage European rabbit recovery: A toolkit for landowners. University of East Anglia. Available at: https://research-portal.uea.ac.uk/en/publications/techniques-to-encourage-european-rabbit-recovery-a-toolkit-for-la

Beltrán, J.F., Rau, J.R., Soriguer, R.C., Kufner, M.B., Delibes, M., & Carro, F., (2022). 'Effects of population declines on habitat segregation and activity patterns of rabbits and hares in Doñana National Park, Spain', Land, 11(4), p. 461. doi:10.3390/land11040461.

Chapman, J. A., & C., F. J. E., (1990a). Chapter 5: The Cottontails. In Rabbits, hares, and pikas: Status survey and conservation action plan. essay, International Union for Conservation of Nature and Natural Resources.

Cloudbridge (2023). Welcome to Cloudbridge!, Cloudbridge Nature Reserve in Costa Rica . Available at: https://www.cloudbridge.org/

Diersing, V.E., (1981). 'Systematic status of sylvilagus brasiliensis and S. insonus from North America', Journal of Mammalogy, 62(3), pp. 539–556. doi:10.2307/1380401.

Díez, C., Perez, J.A., Prieto, R., Alonso, M.E., & Olmedo, J.A., (2005). 'Activity patterns of wild rabbit (oryctolagus cuniculus, L.1758), under semi-freedom conditions, during autumn and Winter', Wildlife Biology in Practice, 1(1). doi:10.2461/wbp.2005.1.6.

Díez Valle C., Sánches-GarcÍa C., Perez J.A., Bartolomé D.J., Gonzáalez V., Wheatley C.J., Slonso M.E., &Gaudioso V.R., (2013). 'Behavioural activity of wild rabbits (oryctolagus cuniculus) under semi-natural rearing systems: Establishing a seasonal pattern', World Rabbit Science, 21(4). doi:10.4995/wrs.2013.1332.

Farnworth, M., Walker, J., Schweizer, K., Chuang, C.-L., Guild, S.-J., Barrett, C., Leach, M., & Waran, N. ,(2011). Potential behavioural indicators of post-operative pain in male laboratory rabbits following abdominal surgery. Animal Welfare, 20(2), 225–237. doi:10.1017/s0962728600002712

Ilott-Baudon, L., (2023). Analysing Camera Trap Results on Mammals at Different Locations within Cloudbridge Nature Reserve. The University of West England. Available at: https://www.cloudbridge.org/wp-content/uploads/2023/09/Louise-CB-CT-Report-Final.pdf

Johnson-Delaney, C., & Orosz, S., (2011). Rabbit Respiratory System: Clinical Anatomy, Physiology and Disease. The veterinary clinics of North America. Exotic animal practice. 14. 257-66, vi. 10.1016/j.cvex.2011.03.002.

Krempels, D. M., (1998). What do rabbits see? https://web.as.miami.edu/hare/vision.html

Leach, M. C., Allweiler, S., Richardson, C., Roughan, J. V., Narbe, R., & Flecknell, P. A., (2009). Behavioural effects of ovariohysterectomy and oral administration of meloxicam in laboratory housed rabbits. Research in veterinary science, 87(2), 336–347. https://doi.org/10.1016/j.rvsc.2009.02.001

Le Gros Clark W. E., (1956). Observations on the structure and organization of olfactory receptors in the rabbit. The Yale journal of biology and medicine, 29(2), 83–95.

Michigan's Animals, (2022). Eastern Cottontail Rabbits Mini Documentary https://www.youtube.com/watch?v=dPPRDFej3Mc.

Mora, J.M. & Ruedas, L. and Smith, A.T., (2016). Sylvilagus dicei. The IUCN Red List of Threatened Species 2016: e.T21209A45180947. Available at: http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T21209A45180947.en

Mora, J. M., Silva, S. M., López, L. I., Burnham–curtis, M. K., Wostenberg, D. J., French, J. H., & Ruedas, L. A., (2020). Systematics, distribution, and conservation status of dice's cottontail, sylvilagus dicei harris, 1932 (mammalia, Lagomorpha, Leporidae), in Central America. Systematics and Biodiversity, 19(1), 74–88. https://doi.org/10.1080/14772000.2020.1827075

Rowcliffe, J. M., Kays, R., Kranstauber, B., Carbone, C., & Jansen, P. A., (2014). Quantifying levels of animal activity using camera trap data. Methods in Ecology and Evolution, 5(11), 1170-1179. https://doi.org/10.1111/2041-210X.12278

Semmann, D., Capelle, T. and Russell, Y., (2013). A rabbit's tail: conspicuous rump patch causes predator confusion. Behaviour 2013: International Ethological Conference.. Newcastle, UK

Smith, A., Ruedas, L., & José Mora, H., (2016). The IUCN Red List of Threatened Species. IUCN Red List of Threatened Species. https://www.iucnredlist.org/species/21209/45180947

Smith, M., Meehan, C., Ma, J., Hisakawa, N., Dasher, H., Camarillo, J., & Techanun, J., (2009). Rabbits - From the Animal's Point of View, 1: What Does It Mean to Be a Rabbit?. 10.3733/ucanr.8374.

Stern, M. J., Goodell, K., & Kennard, D. K., (1999). Local Distribution of Chusquea tomentosa (Poaceae: Bambusoideae) before and after a Flowering Event. Biotropica, 31(2), 365–368. http://www.jstor.org/stable/2663799

Sutherland, W.J., (1998) 'The importance of Behavioural Studies in Conservation Biology', Animal Behaviour, 56(4), pp. 801–809. doi:10.1006/anbe.1998.0896.

Wainwright, M.D., (2007) 'Rabbits (order Lagomorpha)', in The Mammals of Costa Rica a natural history and field guide. Ithaca (N.Y.): Cornell University Press, pp. 233–243.

Xi, J., Si, X. A., Kim, J., Zhang, Y., Jacob, R. E., Kabilan, S., & Corley, R. A., (2016). Anatomical Details of the Rabbit Nasal Passages and Their Implications in Breathing, Air Conditioning, and Olfaction. Anatomical record (Hoboken, N.J. : 2007), 299(7), 853–868. https://doi.org/10.1002/ar.23367

Yong, E., (2022). An immense world: How animal senses reveal the hidden realms around us. New York: Random House.

Appendices

Appendix 1 - Geographic distribution of S. dicei in Costa Rica and Panama (Diersing, 1981)

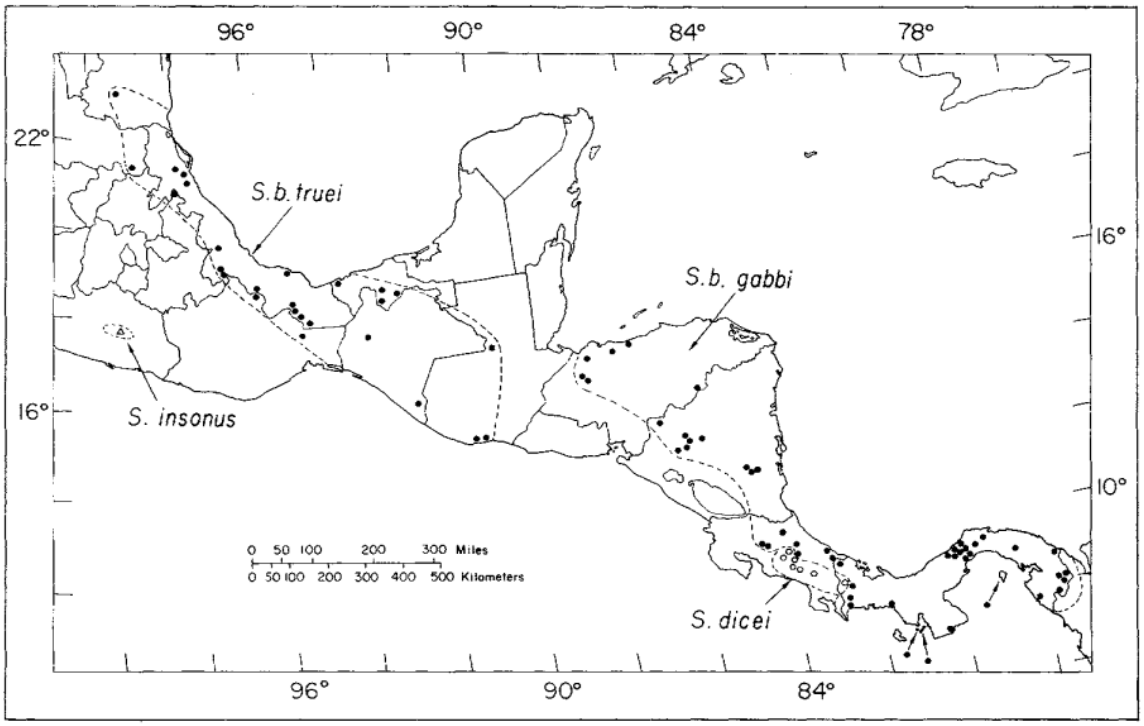
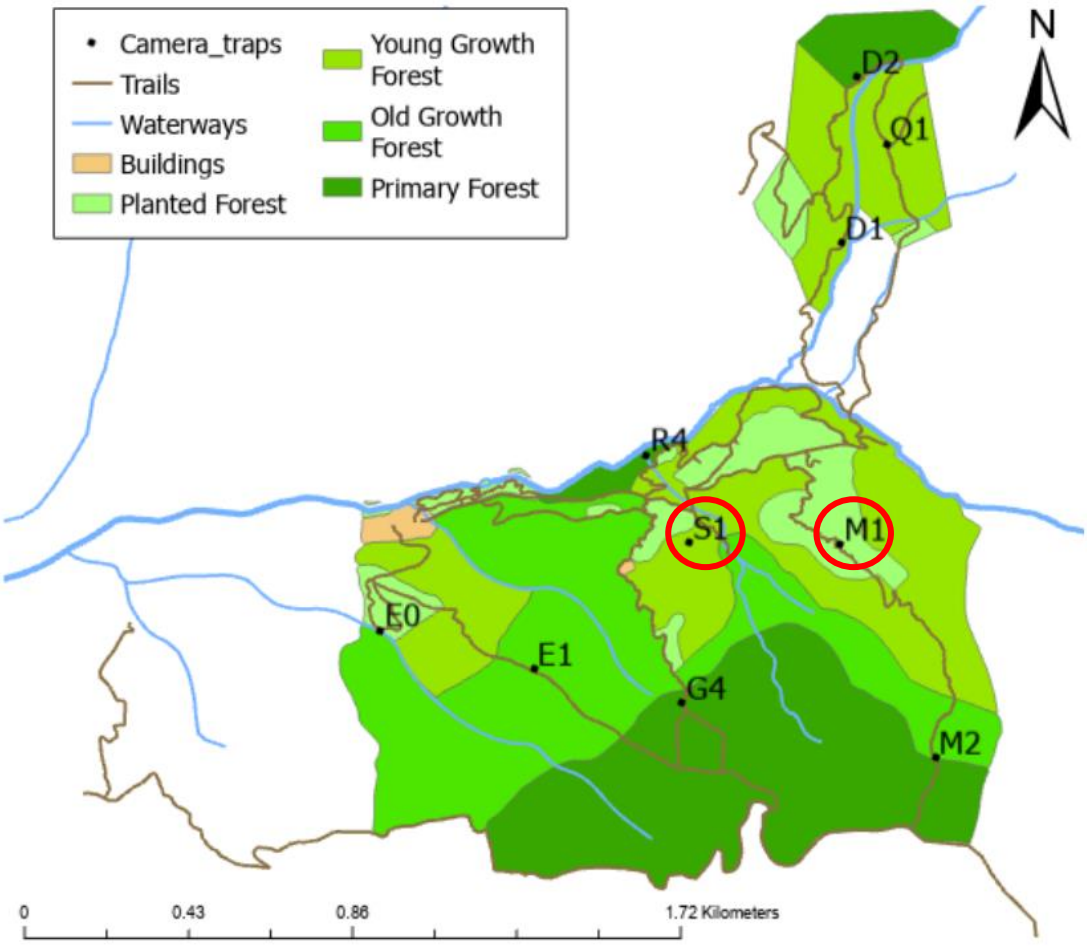


FIG. 8.—Geographic distribution of *Sylvilagus brasiliensis* in Mexico and Central America. Also included are the distributions of *S. insonus* from Guerrero, Mexico, and *S. dicei* from Costa Rica and Panama. Solid circles represent specimens examined of *S. brasiliensis*, open circles *S. dicei*, and triangle *S. insonus*. The dashed lines encircle the general distribution of each designated taxon.

Appendix 2 – Map of forest types and camera trap locations on Cloudbridge nature reserve. S1 and M1 are circled in red to highlight that they were not relevant to this study (Ilott-Baudon, 2023).



Appendix 3 – Information on elevation, gradient, canopy cover and forest type for each camera trap location (Bevilacqua, 2023).

Cam name	Elevation (m)	Gradient (%)	Canopy cover (%)	Forest type
E0	1524	67.1	82.58	Planted forest
E1	1788	47	77.77	Old growth forest
G4	1826	23.3	78.46	Primary forest
M2	2098	32.9	81.94	Old growth forest
R4	1577	54.2	80.85	Primary forest
D1	1740	15.28	81.54	Young growth forest
D2	1701	52	65.58	Primary forest
Q1	1832	11.9	74.61	Young growth forest

Appendix 4 – Potential future distribution reduction of *S. dicei* (Mora et al. 2020).

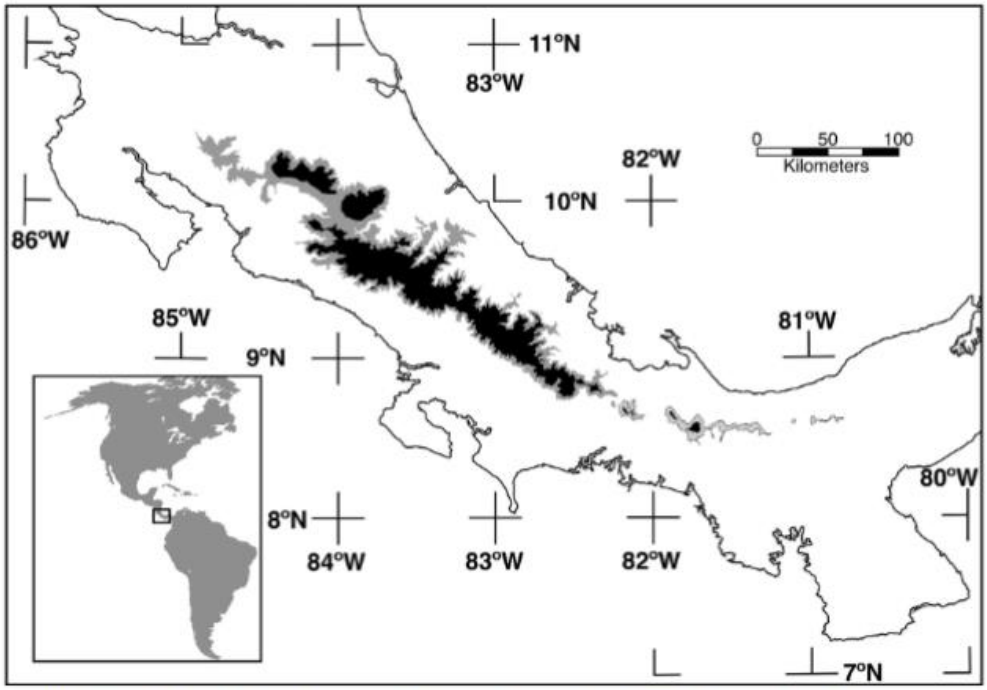


Fig. 4. Potential distribution of *Sylvilagus dicei* in Costa Rica and Panama (from Figure 3, grey) with a hypothesized retracted range based on a 2 °C increase in temperature (black). Under this scenario, the range is estimated to retract ca. 500 m in elevation (see text for details). The remaining distributions are projected to have areas of (from NW to SE) 552, 464, 4247, 16, 13, and 34 km^2. Thus, by 2080, *S. dicei* could see its range reduced from 10,980 km^2 to 5,262 km^2, a contraction in area of 52%.

Appendix. 5 – Shannon-Wiener diversity index of behaviour by camera trap.

Camera	D1	D2	E0	E1	G4	M2	Q1	R4
S-W Div	2.1	1.9	0.5	1.8	2.04	0.7	2.2	1.5

Appendix. 6 – Shannon-Wiener diversity index of behaviour by time of day.

Time	3PM	4PM	5PM	6PM	7PM	8PM	9PM	10PM	11PM
S-W Div	1.8	1.9	2.2	2.3	1.8	1.9	2.01	2.01	2.3

Time	12AM	1AM	2AM	3AM	4AM	5AM	7AM	8AM	1PM	2PM
S-W Div	2.2	2.2	1.8	2.1	1.8	1.7	0	1.6	1.04	0

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