Colours and Spots: Do they Tell the Story of an Ocelot's Origin?

Kerresha Khan[1], Saiyaad Ali[2] and Ryan S. Mohammed[1]

1. Department of Life Sciences, The University of the West Indies (UWI), St. Augustine Campus.
2. Serpentarium, Aranguez, Trinidad and Tobago
Corresponding author: *kerresha@gmail.com*

ABSTRACT

Morphological differences in ocelots were suspected to occur between Trinidadian and South American populations. Data for 49 individuals inclusive of camera trap photographs and captive ocelots in private and zoo collections was collected. Observations of spot size and colour, spot outline thickness, dorsal stripe and nose colour were noted. These were then compared to the origins of the respective specimens. Lastly, camera trap photographs of wild ocelots in Trinidad and live specimens were compared to test the hypothesis. Of these parameters, only spot outline thickness and nose colour were significantly different with specimens from Venezuela having mostly pink noses and Trinidadian ocelots having mostly black noses. To a lesser extent, there were no Trinidadian ocelots with thick spot outlines.

Key words: *Leopardus pardalis*, Trinidad, Venezuela, South American, dorsal stripe, pelage colour

INTRODUCTION

The ocelot is a small to medium sized spotted cat and is the largest of the small cats in Latin America (Murray and Gardner 1997). The Aztecs and other Native Americans respected the ocelot (*Leopardus pardalis*) for its overwhelming beauty and hunting skills. The word 'ocelot' comes from the Mexican Aztec Nahuatl word "*thalocelot"* with various meanings, including tiger of the field and jaguar (Murray and Gardner 1997). Due to increasing demands for pelts and furs, the ocelot is one of many felids that had long been hunted for their coat patterns (Khan, 2008).

Ocelots historically ranged from Southern United States throughout Central and South America to Northern Argentina, including the islands of Margarita (Venezuela) and Trinidad (Nowell and Jackson 1996, González *et al.* 2003). In Trinidad the ocelot is classified as an 'Environmentally Sensitive Species' (Environmental Management Act, 2013). It is considered endangered in the US where currently the remaining populations reside within forested portions of Texas, however it is rated on the International Union for the Conservation of Nature (IUCN) Red list as 'least concern'(Paviolo *et al.* 2016).

The patterns found on the flank, shoulder, forehead, and across the body of ocelots vary among individuals. The pelage colour of ocelots varies as well, sometimes even within populations (Kitchener *et al.* 2006; Murray and Gardner 1997). It was noted by Murray and Gardener (1997) that ocelots north of the Rio Grande, are more greyish than those to the south, with black markings being reduced to the width of the space between them. The ground or base colours are also variable from greyish to buff, with colouration from head to shoulders being a deeper tone than the lower half of the dorsal area, and the sides also being paler than the back. The most distinguishing marks would be expected along the flanks of the felids (Kitchener *et al.* 2006) Underparts are generally white and spotted with black (Murray and Gardner 1997).

Many studies examining the adaptive functions of felid coat patterns indicate that the main purpose is for camouflage (Eizirik *et al.* 2010; Ortolani 1999). Since felids stalk their prey, they benefit considerably from being camouflaged for as long as possible before capturing prey (Allen *et al.* 2011; Godfrey *et al.* 1987; Ortolani 1996). Additionally, small cats such as ocelots tend to utilise camouflage from prey as well as potential predators (Allen *et al.* 2011; Ortolani and Caro 1996). In Costa Rica, studies have shown that during the rainy season ocelots have been included in the diet of the jaguar (*Panthera onca*), which is the top felid predator in that region (Gonzalez-Maya *et al.* 2010). In Trinidad, the ocelot, is the only native feline predator (Reid 2012).

In a study by Ortolani and Caro (1996), spots on felids were found to be significantly associated with forested habitats; additionally, they found that dark spots on carnivores are associated with closed habitats and arboreal locomotion. In general, it was found that felid flank patterns evolved to match the visual appearance of the background, a finding further supported by Allen *et al.* (2011). They concluded that particular patterns evolved to resemble the various shapes and sizes of the natural patterns that exist in their habitat background. In addition, felids that reside within closed arboreal environments would tend towards more complex camouflage patterns on their coats with especially irregular patterns, such as on the ocelot (Allen *et al.* 2011).

Allen *et al.* (2011) also found that felid patterning and camouflage adapts to ecology over relatively short time scales. Since the ocelot is the top predator in Trinidad, camouflage type would be definitive of both the landscape ecology, as well as potential prey type. However, it is theoretically possible that a recent habitat shift, which might result from Trinidad separating from the mainland, would produce outliers and camouflage changes.

Numerous zoological researchers have employed the use of various natural markings on organisms as a means of identification of individuals (Eizirik *et al.* 2010, Ortolani 1999, Godfrey *et al.* 1987). Animals such as gorillas (*Gorilla gorilla beringei*), chimpanzees (*Pan troglodytes*), orangutans (*Pongo pygmaeus*), deer (*Cervus elaphus*), rhinoceroses (*Diceros bicornis*), elephants (*Loxodonta africana*), zebras (*Equus burchelli*), tigers (*Panthera tigris*), lions (*Panthera leo*), giraffes (*Giraffa camelopardalis*), servals (*Felis serval*) and even swans (*Cyguns bewickii*) could be individually identified through the natural markings on each organism (Miththapala *et al.* 1989).

In studies done on another felid species, the clouded leopard (*Neofelis nebulosa)*, morphometric analyses of the pelage of these cats showed that there were two distinct morphological groups, each of which showed differences in size and colour of the cloud markings on their coats. The clouded leopards with large clouds tended to have fewer markings than others with smaller cloud markings. The former were often lighter in colour and were tawny coloured, whereas the clouded leopards with small clouds tended towards having many distinct spots, greyer in colour. It was demonstrated that two clusters of clouded leopards could be differentiated based on their pelage characteristics (Kitchener 2006). These morphological variations were later on verified through genetic analyses showing that these were two distinct species with one in mainland Asia, and the other in the Sunda or Indo-Malay Archipelago (Kitchener 2006; Wilting *et al.* 2007).

Currently, little is known about the natural breeding populations of ocelots in Trinidad. Previous studies done by Nelson (2004) and Khan and Mohammed (2015), have not addressed the population ecology or distributions of ocelots throughout Trinidad's landscapes, although the first major research project on ocelot ecology is currently underway in at least three or four study sites (pers. comm. A.J. Giordano). No studies however have been conducted on ocelot morphological patterns and variations. Here we hypothesised there are variations in coat and facial patterns of ocelots originating from Venezuela and Trinidad.

METHODOLOGY

To investigate our hypothesis of morphological variations between Trinidadian and Venezuelan ocelots, we examined 49 ocelots visually through camera-trap photographs of wild specimen, as well as live captive specimens. Pictures were taken of the flanks, dorsal regions, and face of live ocelots. Firstly, nine ocelots housed at the Emperor Valley Zoo (EVZ) were examined without our prior knowledge of the origins of the cats. Once data was collected we tested whether we were able to successfully match the origin of the specimens based on morphological data. The actual origins were verified after data collection. These verifications were done by reviewing the records as well as communications with zookeepers and the curator of the zoo. Secondly, four ocelots housed at Serpentarium (Aranguez, Trinidad), three from El Socorro Centre for Wildlife Conservation, and three from a private permitted owner, were examined and the geographical source of the animals were recorded. All captive animals were confiscated by the Forestry Division, Wildlife Section, Trinidad and Tobago or were born in captivity.

Observations were made on variations in coat and facial patterns and these were scored ordinally. We recorded spot size [small (1), medium (2), large (3)], spot shape [circular (1), elongated (2), chainlike (3)], dorsal stripe [present (1), absent (2)], spot outline thickness [thin (1), intermediate (2), thick (3)], nose colour [pink (1), pink and black (2), black (3) and lastly specimen origin [Trinidadian (1), Venezuelan (2). Pearson's Chi square analyses were done using SPSS version 22.0 to evaluate the likelihood of any observed differences between independent variables (origin) and these dependent morphological variables.

Once the data was obtained, the hypothesis was then tested by examining and comparing with camera trap photographs (source UWI, K.S, M.R) of wild ocelots from the Northern Range and southern parts of Trinidad. Mostly black and white (infrared) photographs of ocelots were obtained from camera traps in Trinidad, which limited the analysis of coat and spot colour. Nonetheless, we were still able to estimate spot size, thickness of spot outline and nose colour from these images. Based on the camera trap photographs, individual ocelots were differentiated and analysed based on location, date of image, interval time between shots and patterns on individual ocelots (looking at the same side of the flank) to ensure there was no pseudo-replication of individuals.

Finally, we ensured that no animals were harmed during the examining and photographing of the specimens, and all captive specimens were housed using permits provided by the Wildlife Section of Trinidad & Tobago's Forestry Division.

RESULTS

In total 49 ocelots were observed which included 30 wild specimens from camera trap photographs and 19 individuals housed in captivity. We determined 12 individuals (24.5%) were of Venezuelan origin and 37 (75.5%) were Trinidadian.

Our analysis of several morphological features on ocelots yielded varied results. Parameters such as spot size, spot shape and dorsal stripe did not indicate significant differences between individuals of Trinidadian and Venezuelan origins. However, spot outline thickness were significantly greater for Venezuelan ocelots (Pearson's Chi-square test: χ^2=12.22; d.f. =2, p=0.002) (Fig 1a). Trinidadian ocelots did not have relatively thick spot outlines. There was also a significant difference in nose colour (either pink or black) between both populations (Fig 2A-C) (Pearson's Chi-square test: χ^2=23.77; d.f. =2, p < 0.001) (Fig 1b), with Trinidadian ocelots having mostly black noses, and Venezuelan specimens having mostly pink noses.

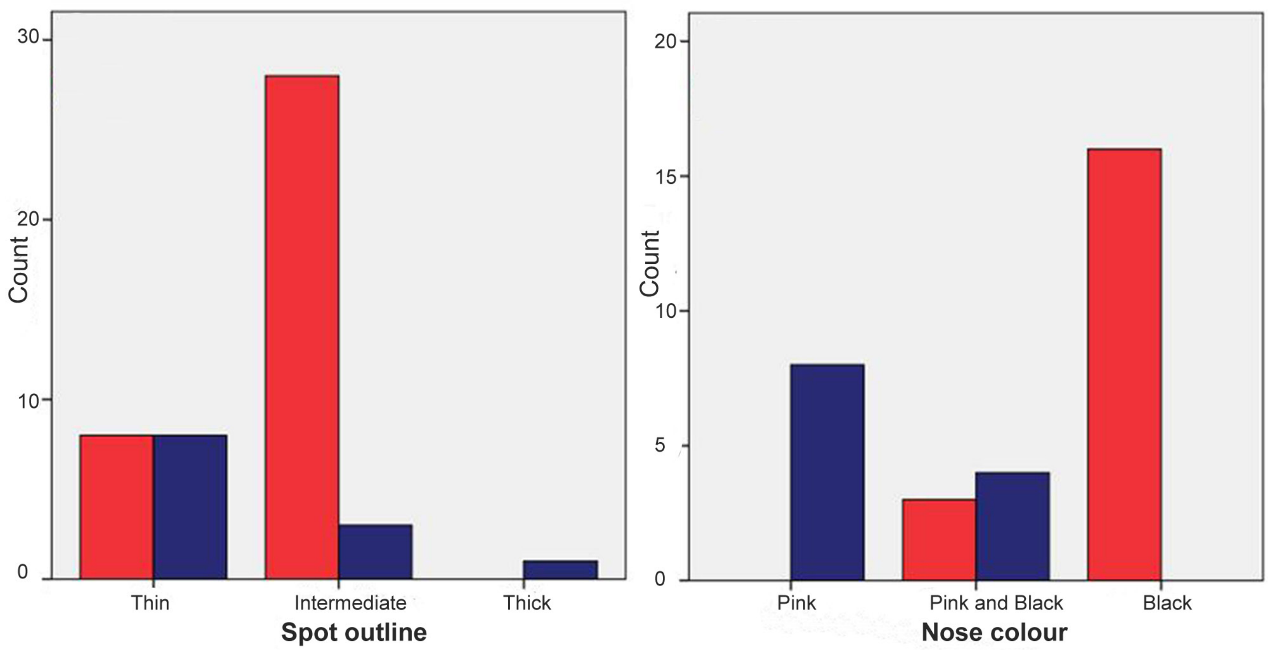

Fig.1. (left) Local ocelots had thin and intermediate spot outlines only, whereas Venezuelan ocelots varied among thin, intermediate and thick spots. (right) Black noses were indicative of individuals from Trinidad (51.6%), and pink noses were typical of Venezuelan ocelots (25.8%). Specimens with mixed coloured noses were rarer (22.6%), and were from either Venezuela or Trinidad.
Key: Red- Trinidad Blue-Venezuela

Fig. 2. A. Venezuelan ocelot with pink nose housed at Serpentarium. B. Venezuelan ocelot with mixed nose colour housed at Serpentarium. C. Trinidadian ocelot with black nose housed at EVZ.

DISCUSSION

Our observations of photographs led to some distinguishing characteristics between the Venezuelan and Trinidadian ocelots. We found that Trinidadian and Venezuelan specimens varied in nose colouration and spot size and shape. Trinidadian ocelots tended towards completely black or to a lesser extent black and pink noses, whereas Venezuelan individuals tended towards completely pink noses. Additionally, the thickness of spot outlines was also interesting, as we found no Trinidadian ocelots with thick outlines.

It is well known that ocelots and any captive organism tends to vary in colouration and size in captivity due to diet, habitat enrichment, age and disease, among other factors (Cubas 1996). However, in discussions with zookeepers and private owners, it was noted that the Venezuelan ocelots seemed to be larger than the Trinidadian ocelots, with colour tending towards yellow and grey and Trinidadian specimens tending towards brown and orange (Pers. comm. S. Moonilal and W. Bonyun). However this was not a trait that was evaluated since it is difficult to gauge size and age from camera trap photographs.

Given that Trinidad is such a small landmass compared to the mainland of Central and South America it is possible that there would be a loss of genetic diversity within Trinidadian populations compared to mainland populations which can eventually lead to inbreeding depressions and other genetic disorders. Studies done by Janecka *et al.* (2014) showed that small fragmented populations in Texas had major issues of inbreeding depressions. However this can only be verified through genetic testing. Isolated genetic dynamics could be one factor that possibly leads to Trinidadian ocelot populations becoming genetically different from those of the mainland which could be expressed phenotypically. This might explain the subtle differences between Trinidadian and Venezuelan individuals.

There were various limitations to this study. We were very sceptical about using colour as a major distinguishing factor since visual perception of colour can be subjective. Nonetheless colour variations are possible in felids between populations (Murray and Gardner 1997; Kitchener *et al.* 2006). Therefore all authors independently determined colours and compared afterwards. Additionally, the photographs from most of the camera traps were not of high resolution, and were black and white (infrared). Access to captive ocelots was limited, and thus we could complete only short periods of visual observations, as animals were highly agitated upon the presence of strangers. To reduce the stress on the animals, we kept encounters brief (under 10 minutes). Additionally, there was a relatively small Venezuelan sample size to examine. However, to support our findings, observations were made of two specimens in French Guiana housed at Zoo de Guyane and it was noted that both specimens had completely pink noses. One specimen was observed in Guyana at Guyana Zoological Park (Georgetown) and it also had a pink nose. We also have anecdotal evidence from an observer (M. Rutherford) of another ocelot at Summit Municipal Park, Panama which also had a pink nose. Even closer to Trinidad, the La Guaricha Zoo and Chorros de Milla Zoo in Venezuela both house ocelots with pink noses. This supports our hypothesis that the completely pink nose is mostly a mainland trait.

It is increasingly clear through discussions with several private permitted owners, handlers and wildlife rehabilitation facilities that the illegal wildlife trade of both foreign and local animals is a concern and is increasing. More striking is the number of imported ocelots as well as other wildlife into Trinidad that have been reported to have escaped (pers. comm. Rehabilitation Facilities).

Whilst we can conclude the difference in nose colour and to a lesser degree thickness of spot outline are the distinctive features between Trinidad and Venezuelan ocelots, we are also mindful that scaring on the noses of captive ocelots do not cause the presence of a pink nose. Based on this study, we conclude that ocelots with thin and intermediate spot outlines and black noses are more likely to have originated from Trinidad. However, to increase confidence, further comparisons of the coat colour and pattern variations are required. Comparisons should include more individuals and with images of higher resolution. Ultimately, genetic testing and development of a database would give the greatest resolution regarding the source region for a specimen. With this in mind, we suggest the next step should be genetic testing and comparing morphological features. We also hope this new information can be used to advise regulating authorities on the origins of captive or confiscated specimens.

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REFERENCES

Allen, W.L., Cuthill I.C., Scott-Samuel N.E. and **Baddeley R.** 2011. Why the leopard got its spots: relating pattern development to ecology in felids. *Proceedings of the Royal Society of London B: Biological Sciences*, 278: 1373-1380.

Cubas, Z.S. 1996. Special challenges of maintaining wild animals in captivity in South America. *Revue Scientifique et Technique-Office International des épizooties* 15.1: 267-288.

Eizirik, E., David, V.A., Buckley-Beason, V., Roelke, M.E., Schäffer, A.A. and **Hannah, S.S.** 2013. The Environmentally Sensitive Species (Ocelot) Notice, 2013 1. Legal Supplement Part B–Vol. 52, No. 26–21st February, 2013. Legal Notice No. 31 Republic Of Trinidad And Tobago The Environmental Management Act, Chap. 35:05. Pg 113.

Godfrey, D., **Lythgoe J.N**. and **Rumball D.A**. 1987. Zebra stripes and tiger stripes: the spatial frequency distribution of the pattern compared to that of the background is significant in display and crypsis. *Biological Journal of the Linnean Society*, 32: 427-433.

González, C.A.L., Brown D.E and **Gallo-Reynoso J.P.** 2003. The ocelot *Leopardus pardalis* in north-western Mexico: ecology, distribution and conservation status. *Oryx*, 37: 358-364.

Gonzalez-Maya, J.F., Navarro-Arquez, E. and **Schipper J**. 2010. Ocelots as prey items of jaguars: a case from Talamanca, Costa Rica. *The Revista de Biología Tropical*, 45: 1223-1229.

Janecka, J.E., Tewes, M.E., Laack, L., Caso, A., Grassman, L.I. and **Honeycutt, R.L.** 2014. Loss of genetic diversity among ocelots in the United States during the 20th century linked to human induced population reductions. *PloS one*, 9: e89384.

Kitchener, A. 2006. *The natural history of the wild cats*. Comstock Pub. Associates, 1991.

Kitchener, A.C., Beaumont MA., and **Richardson D**. 2006. Geographical variation in the clouded leopard, Neofelis nebulosa, reveals two species. *Current Biology*, 16: 2377-2383.

Khan, K. 2008. Human-Wildlife Conflicts: A review of large felid carnivore. M.Sc. major paper. York University, Toronto, Ontario, Canada.

Khan, K. and **R.S. Mohammed.** 2015. Captive Ocelots at Trinidad's Emperor Valley Zoo: Retrospective and Suggested Management. *Living World, Journal of the Trinidad and Tobago Field Naturalists' Club*, 2015: 52-56.

Miththapala, S., Seidensticker J., Phillips L.J., Fernando S.B.U., and **Smallwood J.A.** 1989. Identification of individual leopards (*Panthera pardus kotiya*) using spot pattern variation. *Journal of Zoology*, 218: 527-536.

Murray, J.L. and **Gardner, G.L.** 1997. *Leopardus pardalis*. *Mammalian species*, 548: 1-10.

Nelson, H.P. 2004. Tropical forest ecosystems of Trinidad: Ecological Patterns and public perceptions. PhD thesis, University of Wisconsin, Madison (2004).

Nowell, K. and **Jackson, P**. (eds.)1996. Wild cats: status survey and conservation action plan International Union for Conservation of Nature and Natural Resources. Gland, Switzerland.

Ortolani, A.1999. Spots, stripes, tail tips and dark eyes: predicting the function of carnivore colour patterns using the comparative method. *Biological Journal of the Linnean Society*, 67: 433-476.

Ortolani, A. and **Caro, T.M.** 1996. The adaptive significance of color patterns in carnivores: phylogenetic tests of classic hypotheses. *Carnivore behavior, ecology, and evolution*, 2: 132-188.

Paviolo, A., Crawshaw, P., Caso, A., de Oliveira, T., Lopez-Gonzalez, C.A., Kelly, M., De Angelo, C. and **Payan, E.** 2015. *Leopardus pardalis*. (errata version published in 2016) The IUCN Red List of Threatened Species 2015: e.T11509A97212355. [Online] Available at http://dx.doi.org/10.2305/IUCN.UK.2015-4.RLTS.T11509A50653476.en (Accessed 9 February 2017)

Reid B.A. (ed) 2012. **Courtenay Rooks** and **Gregor Barclay**. Chapter 15, Natural History of Trinidad and Tobago. Caribbean Heritage. *The University of the West Indies Press. Kingston.*

Wilting, A., Buckley-Beason, V.A., Feldhaar, H., Gadau, J., O'brien, S.J. and **Linsenmair, K.E.**, 2007. Clouded leopard phylogeny revisited: support for species recognition and population division between Borneo and Sumatra. *Frontiers in Zoology*, 4: 15.