Universidad de Costa Rica

Facultad de Ciencias Básicas

Escuela de Biología

Tesis para optar por el grado de

Licenciatura en Biología con énfasis en Zoología

Diversidad y abundancia de mamíferos no voladores en un área urbana con vegetación remanente, Sede Rodrigo Facio de la Universidad de Costa Rica

Juan Diego Salas Solano

Ciudad Universitaria Rodrigo Facio

2018

MIEMBROS DEL TRIBUNAL

Dr. Bernal Rodríguez Herrera
Director de Tesis

M.Sc. Daniel Briceño Lobo
Representante Decanato Facultad de Ciencias Básicas

Dr. Gerardo Ávalos Rodríguez
Miembro del Tribunal

Dr. Gilbert Barrantes Montero
Lector

Dr. Luis Sandoval Vargas
Lector

Juan Diego Salas Solano
Candidato

DEDICATORIA

Esta investigación es dedicada a mis padres y hermano quienes me han ayudado durante toda mi formación. Además, a mi amigo y profesor tutor Bernal Rodríguez Herrera, quien ha motivado y apoyado mi interés y amor por los mamíferos.

AGRADECIMIENTOS

A Bernal Rodríguez Herrera mi principal formador como mastozoólogo. El mismo impulso mi interés y dirigió esta investigación, contribuyendo a lo largo de todo el proceso. Agradezco también a mis lectores Luis Sandoval Vargas y Gilbert Barrantes Montero, por su gran contribución en la sugerencia de ideas y elaboración del trabajo escrito.

Esta investigación fue posible gracias a la colaboración de un grupo de amigos en el trabajo de campo, análisis de datos y elaboración de resultados. Por esta razón le agradezco a: Gilbert Alvarado Barboza, José Daniel Ramírez Fernández, David Villalobos Chaves, Víctor Madrigal, Marco Retana, Gustavo Gutiérrez Espeleta, Jeffrey Sibaja Cordero.

Se agradece a la Escuela de Biología de la Universidad de Costa Rica por el apoyo logístico que ayudo a desarrollar esta investigación.

ÍNDICE GENERAL

Contenido Página

ÍNDICE GENERAL

Contenido Página

LISTA DE FIGURAS

Contenido Página

LISTA DE CUADROS

Contenido Página

CAPÍTULO I

LISTA DE CUADROS

Contenido Página

CAPÍTULO II

RESUMEN DE TESIS

Los espacios verdes urbanos se están convirtiendo en un refugio cada vez más importante para la fauna nativa de Costa Rica. En Costa Rica, la mayor parte de la población humana se concentra en el Valle Central, consecuentemente, la urbanización reduce constantemente la vegetación remanente natural. En mamíferos, el desarrollo urbano generalmente disminuye la diversidad nativa. Describo la riqueza y abundancia de los mamíferos medianos terrestres en el campus de la Universidad de Costa Rica, un área metropolitana con vegetación remanente en el Neotrópico. Realicé un análisis de paisaje utilizando sistemas de información geografica para medir los espacios verdes y la cobertura urbana. El estudio de mamíferos terrestres incluyó trampeo nocturno, conteos diurnos en transeptos, cámaras trampa y reportes ocasionales. Encontré seis especies nativas y tres especies introducidas de mamíferos terrestres, lo que representa menos de un 50% de la diversidad de mamíferos terrestre medianos reportada para el Valle Central hace 40 años. El mapache (*Procyon lotor*) y la ardilla (*Sciurus variegatoides*) común fueron las especies más abundantes, ambas con la capacidad de aprovechar hábitats alterados por el desarrollo urbano. Las especies introducidas, especialmente el gato doméstico, representan un problema por ser importantes depredadores de la fauna nativa y por transmitir enfermedades. Las especies de perezosos (*Bradypus variegatus* y *Choloepus hoffmanni*) en el sitio de estudio se ven afectadas por el típico aislamiento de los fragmentos de vegetación y la falta de conectividad generada por la urbanización. Mantener los fragmentos de vegetación de hábitat natural en las ciudades es primordial para la conservación de la biodiversidad.

El mapache (*Procyon lotor*) es una de varias especies silvestres que prosperan en entornos urbanizados. Estimé el tamaño de la población, la estructura, el ámbito de hogar, las áreas núcleo y los refugios de una población de mapaches urbanos en el campus de la Universidad de Costa Rica. Se capturaron 24 individuos de mapaches (siete machos y 17 hembras) y se marcaron desde agosto del 2014 hasta octubre del 2015. Se estimó una densidad de 40 mapaches/Km^2 para el sitio de estudio. La supervivencia calculada utilizando el modelo de estado único Cormack Jolly Seber sugiere la permanencia de los individuos en los sitios de captura durante el periodo de estudio. Se obtuvieron ubicaciones nocturnas y refugios de un macho y dos hembras utilizando collares con transmisores GPS. Las áreas utilizadas por los tres mapaches monitoreados se localizaron cerca de la vegetación riparia. Los ámbitos de hogar y las áreas núcleo incluyeron una gran proporción de fragmentos de vegetación remanente y cobertura urbana. Identifiqué 11 refugios antropogénicos que corresponden a edificios y 12 sitios naturales que corresponden a vegetación densa de bambú y árboles utilizados como refugios diurnos. Una alta densidad de mapaches encontrados en el sitio fue consistente con otros estudios en áreas urbanas y suburbanas. Mis resultados enfatizan la importancia de los espacios verdes y cuerpos de agua para las poblaciones de mapaches inmersas en las áreas urbanas. Encontré que los árboles y la vegetación remanente representan un hábitat natural importante para la búsqueda de alimento y refugios dentro de los ecosistemas urbanos. Además, recomiendo reducir o eliminar el acceso de los mapaches a los recursos antropogénicos como desperdicios de comida en contenedores de basura y las estructuras humanas como solución para disminuir los problemas asociados a la sobreabundancia de los mapaches.

INTRODUCCIÓN

MARCO TEÓRICO

Durante las últimas décadas, la investigación en los ambientes urbanos ha utilizado un enfoque interdisciplinario que considera a los paisajes urbanos como sistemas socio-ecológicos dentro de los cuales los seres humanos y sus estructuras artificiales están integradas con el ambiente (Alberti et al., 2003; Dearborn & Kark, 2010). Recientemente, los biólogos han comenzado a explorar los mecanismos por los cuales la urbanización afecta la biodiversidad, incluyendo los procesos relacionados con disponibilidad y acceso a recursos, la alteración de interacciones tróficas y la transmisión de enfermedades (Bradley & Altizer, 2007).

El desarrollo urbano fragmenta, aísla, y degrada a los hábitats naturales, simplifica y homogeniza la composición de especies, altera los sistemas hidrológicos, y modifica el flujo de energía y el ciclo de nutrientes (Alberti et al., 2005). Además de los cambios en el clima, el cambio en el uso de la tierra y la acumulación de contaminantes, son los principales factores de alteración de la estructura, función y dinámica de los ecosistemas (Grimm et al., 2008a). La urbanización altera las propiedades de los ecosistemas en el interior, alrededores, e incluso a grandes distancias de las zonas urbanas (Grimm et al., 2008b).

En Costa Rica el crecimiento de la población, la concentración de las zonas urbanas en pequeñas áreas y la falta de desarrollo amigable con la naturaleza ha resultado en la deforestación intensa y en un crecimiento urbanístico desordenado. Cerca de las dos terceras partes de la población del país se concentra en el Valle Central. Como consecuencia, la vegetación que cubría este valle ha sido rápidamente transformada en zonas urbanas (Biamonte et al., 2011). Los fragmentos de bosques, plantaciones y corredores a lo largo de ríos y quebradas que hasta hace poco representaban grandes extensiones alrededor de los centros urbanos, han sido casi completamente eliminados, y los que quedan están muy alterados (Sánchez-Azofeifa et al., 2001).

Hace más de 60 años la actual Sede Rodrigo Facio de la Universidad de Costa Rica estuvo cubierta por grandes extensiones de bosque premontano. Durante el siglo XX esta área, al igual que la mayor parte de las tierras del Valle Central, fue desprovista de su bosque natural y convertida en cafetales. Posteriormente, los cafetales fueron transformados en áreas urbanas debido al crecimiento demográfico produciendo una reducción y aislamiento de la vegetación remanente (Stiles, 1990). Muchos árboles han sido talados y se han sembrado especies nativas, introducidas y ornamentales. Hoy en día la vegetación nativa original es escasa, los espacios naturales se limitan a pequeños fragmentos de vegetación secundaria, árboles aislados y jardines (Biamonte et al., 2011).

En 1955-1957 el campus principal de la Universidad de Costa Rica (31,5 hectáreas) empezó a desarrollarse en lo que era un cafetal abandonado con parches de bosque secundario y matorrales (Stiles, 1990). En los años 70 la Universidad compró la Finca 2 al este (Ciudad de la Investigación) y Finca 3 y 4 (Instalaciones Deportiva) al noreste del campus principal, las cuales estaban cubiertas por cafetales abandonados con una mezcla de bosque secundario, matorrales y zacatales. Desde entonces la tendencia ha sido aumentar el número de construcciones, reduciendo las áreas boscosas a la Reserva Biológica Leonelo Oviedo (0.75 hectáreas) y el Jardín Botánico Orozco (0.25 hectáreas). Actualmente las cuatro fincas de la Sede Rodrigo Facio de la Universidad de Costa Rica comprenden aproximadamente 95 hectáreas, de las cuales más del 50% corresponden a terreno ocupado por edificios, calles y parqueos.

Biamonte et al. (2011) reportan un incremento de la urbanización del 72% entre 1973 y el 2006 en la Sede Rodrigo Facio, con la consecuente destrucción, fragmentación y aislamiento de zonas boscosas y otros hábitats seminaturales, además de la desaparición de 66 especies de aves reportadas en la zona por Stiles (1990). Los remanentes de fragmentos en bosques de áreas urbanas, como por ejemplo en el Valle Central de Costa Rica sirven de hábitat para la sobrevivencia de diferentes especies de anfibios, reptiles, aves y mamíferos medianos (ej. zarigüeyas, ardillas, perezosos y mapaches) (Arias-Aguilar et al., 2015).

Aunque para Costa Rica existen múltiples listados de las especies de mamíferos, aún se desconoce la diversidad de estos en las áreas urbanas y los parches remanentes de vegetación del Valle Central (Janzen, 1983; Wilson, 1983; Rodríguez & Chinchilla, 1996; Carrillo et al., 2000; Mora, 2000; Wilson et al., 2002). Además, poco se conoce sobre la biología de las especies que sobreviven en zonas urbanas del neotrópico, y no se ha evaluado los efectos de la urbanización (ej. aumento, aislamiento de parches naturales, introducción de especies exóticas) sobre las diferentes poblaciones de mamíferos localizadas en zonas urbanizadas (Biamonte et al., 2011; Arias-Aguilar et al., 2015).

Los mapaches (*Procyon lotor*) son al parecer uno de los mamíferos más eficientes en la explotación de los recursos antropogénicos (Prange & Gehrt, 2004). Se distribuyen desde el sureste de Canadá hasta Panamá y por lo general habitan en humedales, llanuras y bosques, con fuentes de agua cercanas (Chow et al., 2005; Reid, 2009). Es una especie omnívora con una dieta amplia que incluye componentes de cadenas tróficas terrestres y acuáticas lo que la hace extremadamente adaptable para utilizar los hábitats humanos alterados también (Lotze & Anderson, 1979; Khan et al., 1995; Chow et al., 2005; Bozek et al., 2007).

El nivel de urbanización afecta cómo los mapaches usan el hábitat. Por ejemplo, en lugares muy urbanizados utilizan alcantarillas y edificios como refugio, y los restos de basura y alimentos de procedencia humana forman parte de su dieta (Prange & Gehrt, 2004; Bozek et al., 2007). Por lo tanto, es de esperar que especies capaces de utilizar los recursos de origen humano presenten a menudo mayores densidades poblacionales en las zonas urbanas, como ha sido reportado en poblaciones de mapaches de zonas templadas (Fedriani et al., 2001; Prange et al., 2003; McKinney, 2002).

A pesar de todo el conocimiento que se ha generado, principalmente en Norteamérica (Khan et al., 1995; Junge et al., 2007; Prange et al., 2003; Prange et al., 2004; Bozek et al., 2007), poco se conoce sobre la biología de esta especie en el Neotrópico. En Costa Rica, los estudios se restringen a los patrones de movimientos (Carrillo & Vaughan, 1988), la variación en el comportamiento por la presencia de turistas en un área silvestre (Carrillo & Vaughan, 1993), y los hábitos alimenticios en el Parque Nacional Manuel Antonio (Carrillo et al., 2001). Aún desconocemos los aspectos de su biología en las poblaciones que ocurren en ambientes urbanos en el país. Sin embargo, de manera anecdótica se han reportado conflictos entre los humanos y los mapaches, principalmente en áreas residenciales y comerciales de Santa Ana y Escazú y edificios como los de la Universidad de Costa Rica, la Universidad Nacional, el Museo de los Niños, Cárcel de Mujeres el Buen Pastor y algunos hoteles.

JUSTIFICACIÓN

Como consecuencia del crecimiento de las poblaciones humanas y la migración de personas a centros urbanos, el fenómeno de urbanización ha ocurrido de manera acelerada en las últimas tres décadas (Harvey et al., 2008; Biamonte et al., 2011). Los ecosistemas terrestres están cada vez más influenciadas por el ritmo y los patrones de crecimiento urbano, y en gran medida, el futuro de los ecosistemas naturales en ambientes urbanos dependerá de nuestra capacidad para incrementar y mantener los ambientes naturales y seminaturales en zonas urbanas manejadas y sostenibles (Alberti, 2010). Con la expansión de las áreas urbanas, las zonas verdes como: fragmentos de bosques, charrales, parques y jardines, se están convirtiendo en un refugio cada vez más importante para la biodiversidad nativa. Aunque la urbanización típicamente resulta en la reducción de la diversidad biológica, podemos destacar la importancia de los espacios con vegetación en la mitigación de los impactos negativos de la urbanización (González & Sal, 2008; González et al., 2009; Goddard et al., 2010).

Los fragmentos de bosques constituyen elementos importantes para la conservación de la vida silvestre (González & Sal, 2008; González et al., 2009; Goddard et al., 2010). La importancia de la conservación de estos parches de vegetación en zonas urbanas ha sido documentada en ciudades de países desarrollados. Se conoce poco acerca de la importancia de los fragmentos urbanos y del efecto de la urbanización en ciudades neotropicales (González & Sal, 2008; McKinney, 2008; González et al., 2009; Goddard et al., 2010; Biamonte et al., 2011; Arias-Aguilar et al., 2015). Por su parte, no se han estudiado las poblaciones de perezosos, ardillas, zarigüeyas, mapaches y otros mamíferos que habitan los parches verdes en las ciudades, ni el efecto del aumento de la urbanización en este grupo de vertebrados. En el caso específico del área de estudio, los mapaches han causado daños representativos en infraestructura, equipo de laboratorio, muebles y tiempo en mantenimiento y reparaciones, por lo que se ha considerado al mapache como una especie conflicto en la zona (Alvarado-Barboza & Gutiérrez-Espeleta, 2013; Alvarado-Barboza, 2014).

En esta investigación generaré información sobre la abundancia y diversidad de mamíferos no voladores en zonas urbanas tropicales. Además, analizaré el uso del espacio y realizaré una estimación de la densidad poblacional de mapaches que habitan en un parche remanente de vegetación en medio de una zona urbana, que funcione de línea base para futuros estudios y de referencias para toma de decisiones con esta especie que actualmente genera conflictos. En zonas tropicales los estudios de mamíferos en ambientes urbanos son escasos (Arias-Aguilar et al., 2015) y las condiciones son muy diferentes a las dadas en climas templados donde se ha generado casi la totalidad de información existente.

Es necesario generar la información de línea base para la correcta toma de decisiones en el manejo de estas poblaciones que se encuentran inmersas en zonas urbanas y en estrecha relación con el humano. Además, es clara la necesidad de idear nuestras propias estrategias de manejo acorde con la ecología de los animales en el trópico, bajo las condiciones de crecimiento urbanístico desordenado, propias de nuestro país. Por tanto, el entendimiento científico de las poblaciones de mamíferos terrestres no voladores en zonas urbanas es esencial para diseñar estrategias de manejo y desarrollo en estos entornos.

OBJETIVOS

Objetivo General

Determinar la riqueza y abundancia de las especies de mamíferos no voladores en una zona urbana con vegetación remanente.

Objetivos específicos

1. Determinar la diversidad y abundancia de los mamíferos no voladores presentes en el campus de la Sede Rodrigo Facio de la Universidad de Costa Rica y alrededores.
2. Determinar la estructura, y el tamaño poblacional de mapaches en el campus de la Sede Rodrigo Facio de la Universidad de Costa Rica.
3. Determinar las áreas de acción, áreas núcleo y refugios de los mapaches en el campus de la Sede Rodrigo Facio de la Universidad de Costa Rica y alrededores.

BIBLIOGRAFÍA

Alberti, M. (2005). The effects of urban patterns on ecosystem function. *International regional science review*, *28*(2), 168-192.

Alberti, M. (2010). Maintaining ecological integrity and sustaining ecosystem function in urban areas. *Current Opinion in Environmental Sustainability*, *2*(3), 178-184.

Alberti, M., Marzluff, J. M., Shulenberger, E., Bradley, G., Ryan, C., & Zumbrunnen, C. (2003). Integrating humans into ecology: opportunities and challenges for studying urban ecosystems. *BioScience*, *53*(12), 1169-1179.

Alvarado-Barboza, G. (2014). Conviviendo con la Fauna: una aproximación a través de los centros de transferencia. *Revistarquis, 2*(6), 1-6.

Alvarado-Barboza, G & Gutiérrez-Espeleta, G. (2013). Conviviendo con los mapaches: del conflicto a la coexistencia. *Biocenosis, 27*, 77-84.

Arias-Aguilar, A., Chacón-Madrigal, E., & Rodríguez-Herrera, B. (2015). El uso de los parques urbanos con vegetación por murciélagos insectívoros en San Jose, Costa Rica. *Mastozoología Neotropical*, *22*(2), 229-237.

Biamonte, E., Sandoval, L., Chacón, E., & Barrantes, G. (2011). Effect of urbanization on the avifauna in a tropical metropolitan area. *Landscape Ecology, 26*(2), 183-194.

Bozek, C. K., Prange, S., & Gehrt, S. D. (2007). The influence of anthropogenic resources on multi-scale habitat selection by raccoons. *Urban Ecosystems*, *10*(4), 413-425.

Bradley, C. A., & Altizer, S. (2007). Urbanization and the ecology of wildlife diseases. *Trends in ecology & evolution*, *22*(2), 95-102.

Carrillo, E., Wong, G., & Rodríguez, M. A. (2001). Hábitos alimentarios del mapachín (*Procyon lotor*)(Carnivora: Procyonidae) en un bosque muy húmedo tropical costero de Costa Rica. *Revista de biología tropical*, *49*, 1193-1197.

Carrillo, E., & Vaughan, C. (1988). Influencia de la lluvia sobre los movimientos de un mapachín en un bosque nuboso de Costa Rica. *Revista de biología tropical*, *36*, 373-376.

Carrillo, E., & Vaughan, C. (1993). Variación en el comportamiento de *Procyon* spp. (Carnivora: Procyonidae) por la presencia de turistas en un área silvestre de Costa Rica. *Revista de biología tropical*. 41: 843-848.

Carrillo E, Wong, G y Sáenz, J. (2000). Mamíferos de Costa Rica. INBIO, Heredia, Costa Rica.

Chow, T. E., Gaines, K. F., Hodgson, M. E., & Wilson, M. D. (2005). Habitat and exposure modelling for ecological risk assessment: A case study for the raccoon on the Savannah River Site. *Ecological Modelling*, *189*(1), 151-167.

Dearborn, D. C., & Kark, S. (2010). Motivations for conserving urban biodiversity. *Conservation biology*, 24(2), 432-440.

Fedriani, J. M., Fuller, T. K., & Sauvajot, R. M. (2001). Does availability of anthropogenic food enhance densities of omnivorous mammals? An example with coyotes in southern California. *Ecography*, *24*(3), 325-331.

Goddard, M. A., Dougill, A. J., & Benton, T. G. (2010). Scaling up from gardens: biodiversity conservation in urban environments. *Trends in Ecology & Evolution*, *25*(2), 90-98.

González-García, A., & Sal, A. G. (2008). Private urban greenspaces or “patios” as a key element in the urban ecology of tropical Central America. *Human Ecology*, *36*(2), 291-300.

González-García, A., Belliure, J., Gómez-Sal, A., & Dávila, P. (2009). The role of urban greenspaces in fauna conservation: the case of the iguana Ctenosaura similis in the 'patios' of León city, Nicaragua. *Biodiversity and conservation*, *18*(7), 1909-1920.

Grau, G.A., Sanderson, G.C. & Rogers, J.P. (1970). Age determination of raccoons. *Journal of Wildlife Management 34*(2): 364-372.

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008a). Global change and the ecology of cities. *Science*, *319*, 756-760.

Grimm, N. B., Foster, D., Groffman, P., Grove, J. M., Hopkinson, C. S., Nadelhoffer, K. J., Pataki, D. E & Peters, D. P. (2008b). The changing landscape: ecosystem responses to urbanization and pollution across climatic and societal gradients. *Frontiers in Ecology and the Environment*, *6*(5), 264-272.

Harvey, C.A., Komar, O., Chazdon, R., Ferguson, B.G., Finegan, B., Griffith, D.M., Martínez-Ramos, M., Morales, H., Nigh, R., Soto-Pinto, L., van Breugel, M., Wishnie, M. (2008). Integrating agricultural landscapes with biodiversity conservation in the Mesoamerican hotspot. *Conservation Biology*, *22*, 8-15.

Janzen, D. H. (1983). Costa Rican Natural History. University of Chicago Press, Chicago.

Junge, R. E., Bauman, K., King, M., & Gompper, M. E. (2007). A serologic assessment of exposure to viral pathogens and Leptospira in an urban raccoon (*Procyon lotor*) population inhabiting a large zoological park. *Journal of Zoo and Wildlife Medicine*, *38*(1), 18-26.

Khan, A. T., Thompson, S. J., & Mielke, H. W. (1995). Lead and mercury levels in raccoons from Macon County, Alabama. *Bulletin of environmental contamination and toxicology*, *54*(6), 812-816.

Lotze, J. H., & Anderson, S. (1979). *Procyon lotor*. *Mammalian species*, 1-8.

Mora, J. M. (2000). Los mamíferos silvestres de Costa Rica. EUNED, San José, Costa Rica.

McKinney, M. L. (2002). Urbanization, Biodiversity, and Conservation. *BioScience*, *52*(10), 883-890.

McKinney, M. L. (2008). Effects of urbanization on species richness a review of plants and animals. *Urban ecosystems*, *11*(2), 161-176.

Petrides, G. A. (1949). Sex and age determination in the opossum. *Journal of Mammalogy*, *30*(4), 364-378.

Prange, S., Gehrt, S. D., & Wiggers, E. P. (2003). Demographic factors contributing to high raccoon densities in urban landscapes. *The Journal of Wildlife Management*, 324-333.

Prange, S., & Gehrt, S. D. (2004). Changes in mesopredator-community structure in response to urbanization. *Canadian Journal of Zoology*, *82*(11), 1804-1817.

Prange, S., Gehrt, S. D., & Wiggers, E. P. (2004). Influences of anthropogenic resources on raccoon (*Procyon lotor*) movements and spatial distribution. *Journal of Mammalogy*, *85*(3), 483-490.

Reid, F. (2009). A field guide to the mammals of Central America & Southeast Mexico. Oxford University Press.

Rodriguez, J. & Chinchilla, F. A. (1996). Lista de mamíferos de Costa Rica. Revista Biología Tropical 44:877-890.

Sánchez-Azofeifa, G. A., Harriss, R. C. & Skole, D. L. (2001) Deforestation in Costa Rica: a quantitative analysis using remote sensing imagery. Biotropica 33:378–384

Stiles, F. G. (1990). La avifauna de la Universidad de Costa Rica y sus alrededores através de veinte años (1968-1989). *Revista de biología tropical*, *38*(2b), 361-381.

Wilson, D. E. (1983). Lista de Mamíferos de Costa Rica. Pp. 457-514, en: Historia natural de Costa Rica (DH Janzen, ed.). Editorial de la Universidad de Costa Rica, San José, Costa Rica.

Wilson, D. E., Timm, R. M. & Cinchilla, F. A. (2002). Mamíferos de Costa Rica. Pp. 227-254, en: Diversidad y conservación de los mamíferos neotropicales (G Ceballos y JA Simonetti, eds.). CONABIO, México.

CAPÍTULO I: Richness and abundance of non-volant terrestrial mammals in an urban environment in the Neotropic.

(Formato para Revista de Biología Tropical)

Richness and abundance of non-volant terrestrial mammals in an urban environment in the Neotropic

Abstract: urban green spaces are becoming an increasingly important refuge for native fauna. In Costa Rica, the bulk of the human population is concentrated in the Central Valley, and consequently, the increasing urbanization has fragmented and reduced the natural landscape. In mammals, urban development generally decreases the native diversity. We describe the richness and abundance of medium sized terrestrial mammals in an green area immerse in an urban matrix. A landscape analysis was conducted to measure the green spaces and urban land covert. Terrestrial mammals were surveyed using night baiting traps, diurnal counts in transects, camera traps, and occasional reports. We found six native and three introduced species of terrestrial mammals, which represents less than 50% the medium sized mammals diversity reported for the Central Valley of Costa Rica 40 years ago. Common raccoon (*Procyon lotor*) and variegated squirrel (*Sciurus variegatoides*) were the most abundant species, both capable of exploiting urban habitats. Introduced species, especially feral cats, represent a problem being predators of native fauna and also contributing to disease transmission. Sloths species (*Bradypus variegatus* and *Choloepus hoffmanni*) in the study site are affected by fragmentation, isolation, and lack of connectivity generated by urbanization. Maintaining vegetation fragments of natural habitat in urban areas is important for biodiversity conservation.

Key words: medium sized mammals, urban green spaces, fragments vegetation, urbanization, mammal diversity, Neotropic.

Area of cities is increasing geographically in response to human population growth, particularly in key biodiversity hotspots such as Tropical Andes, Madagascar, Caribbean and Mesoamerica (Myers et al., 2000; Alberti, 2005; Magura et al., 2010). Urban expansion accelerates habitat loss, introduction of species and threatens biodiversity (Grimm et al., 2008; McKinney, 2008; McDonald, 2008; Seto et al., 2012). Understand the urban species composition is essential to promote conservation efforts and develop sustainable urban planning (Prange & Gehrt, 2004; Luck, 2007; Schneider, 2010; Seto et al., 2012; Aronson et al., 2014).

Urban green spaces such as forest patches, urban and peripheral parks, linear elements (riparian habitats, tree's alignments, and road borders), punctual elements (isolated trees), small green areas (public and private gardens), and other low intensity used spaces (cemeteries and abandoned lots) may increase survivorship of some species which had, until recently, ample distributions, tend to survive in limited green spaces inside urban areas (Melles et al. 2003, González-García 2009, Biamonte et al. 2011). In the majority of Neotropical countries, human population growth resulted in deforestation and uncontrolled expansion of urban areas (Joyce 2006, Biamonte et al. 2011).

Consequently, most natural and semi-natural terrestrial habitats, such as forest fragments, plantations and corridors along rivers and streams have been nearly completely eliminated (Biamonte et al., 2011). In Costa Rica for example, the Central Valley concentrates nearly 2/3 of the Costa Rican population and consequently the rich vegetation that formerly covered this valley has been reduced and transformed in urban landscapes (Fournier, 1991; Joyce, 2006, Biamonte et al., 2011). Remaining of natural habitats in Costa Rican Central Valley are used by amphibians, reptiles, birds and terrestrial mammals to survive inside urban areas (González-García, 2009, Biamonte et al., 2011, Arias-Aguilar et al., 2015). However, those fragments are rapidly disappearing or losing connections as urbanization expands (Joyce, 2006), and how this will affect richness and abundance of terrestrial mammals is yet unpredictable unknown.

Our objective in this investigation is to evaluate the non-volant terrestrial mammal richness and relative abundance inside natural habitats in urban areas that vary in the proportions of urban development and vegetation cover (e.g., natural habitats or gardens). We expect a higher richness and abundance of terrestrial mammals in the areas with more natural vegetation and less urban development and gardens.

MATERIALS AND METHODS

Study site:

We conducted this study on the campus of the Universidad de Costa Rica from August 2014 to March 2017. This is an urban area in the northeastern section of the Costa Rican Central Valley, San José province, Costa Rica (9°54' N, 84°03' W; at 1200m in elevation;). Large tracts of premontane forest covered the study area and connected it formerly continuous forests of the Central Mountain Slope approximately 60–50 years ago (Joyce, 2006). Today the original native vegetation is scarce and restricted to small fragments of remnant riparian vegetation; other vegetation was composed by isolated trees and gardens (Fig. 1 A, B).

The campus includes three major sectors: the central Campus, the Ciudad de la Investigación and the Instalaciones Deportivas. The terrain is undulated and drained to the west by Los Negritos stream that crosses the central Campus and the Ciudad de la Investigación. The Torres River runs along the northern border of the Instalaciones Deportivas (Fig. 1B).

The central Campus occupies a total area of 35 hectares and includes buildings, parking areas, open recreational areas, and two fragments of regenerating forests: the Reserva Ecologica Leonelo Oviedo (RELO) and the Jardín Botánico Orozco (JBO). The Ciudad de la Investigación occupies 24.9 hectares of buildings, parking lots, lawns, riparian vegetation, and pastures along the Los Negritos stream. The Instalaciones Deportivas includes 35.2 hectares of buildings and lawns, secondary forests, sparse bushes and pastures.

Landscape Analysis:

We analyzed the three major sectors of the Universidad de Costa Rica to measure the percentage covered by vegetation and urban areas. We used satellite photos (resolution 1:5000) from Sistema de Información de los Recursos Forestales de Costa Rica (2012). We used ArcGIS version 10.5.3 to classify the landscape in three categories: (1) vegetation cover that correspond to forest fragments, riparian vegetation and other spaces cover by threes (2) open green areas like grasses, gardens and pastures; and (3) urban cover that includes: buildings, streets, sidewalks, and other areas covered by pavement.

Terrestrial mammals survey:

We sampled terrestrial mammals from August 2014 to March 2017 using three methods: (1) night baiting traps, (2) diurnal counts in transects, and (3) camera traps. We also included occasional reports of sightings of terrestrial mammals collected in the campus during the study and deposited in the Zoology Museum of the Universidad de Costa Rica.

We placed baiting traps from August 2014 to December 2015 in three forest fragments at night: (1) the Reserva Ecológica Leonelo Oviedo (RELO), (2) the Jardín Botánico Orozco (JBO), and (3) riparian vegetation (RV) along Los Negritos stream (Fig. 1C). We placed 20 box traps (model

108, 25 x 30 x 81 cm; Tomahawk Live Trap Co., Tomahawk, Wisconsin) per trapping night using commercial cat food as bait (Purina® Felix®). The traps were placed 20 m apart from each other. Traps were open from 1600 to 0700 h, and checked the next day. We conducted 27 trapping nights (15 RELO, 8 JBO, and 4 RV). The maximum numbers of days between trapping nights was 91 and the minimum four (Average = 16 days, SD = 24). We placed traps two consecutive nights in three occasions and three consecutive nights in one occasion. We measured the sampled effort as trap nights (numbers of traps per the numbers of trapping nights).

We did diurnal counts using binoculars by walking at a steady pace along four 1-km long transects from 06:00 to 08:00 am every 2 weeks. We walked each transect 24 occasions from April 2016 to March 2017. Transects were located in three areas with a matrix composed of forest fragments, open green areas and buildings (Fig. 1C). We set transects in the three university sectors on the following way: two transects were set at the Instalaciones Deportivas (ID1 and ID2), one at the Ciudad de la Investigación (CI), and one at the central Campus (CC). During each survey we counted all mammals seen along each transect. The frequency of observations per specie was calculated as the numbers of individual observed per transect.

We used 10 camera traps (Bushnell Trophy Cam HD) in RELO from March to April 2015. The camera-trap method is based on the identification of animal species using photographs and videos taken by automatic cameras. Cameras were placed 50 cm above the ground between 20 m and 40 m from each other. We not take into account photographed small mammal species (less than 1kg) for difficult identification. We repeated this protocol in JBO from June to July 2015. Cameras remained active during 35 consecutive days in RELO and 23 days in JBO. Sampled effort represents the number of trap cameras per the numbers of active days (camera days).

We took pictures of the free-ranging domestics cats during night baiting traps, diurnal counts in transects and occasional observations. We also used the registers in camera trap videos to identify and estimate the number of free-ranging domestics cats in the campus during the study period.

Data analysis:

Frequency of captured was defined as the numbers of individual per specie by trapping night, diurnal count transect and camera trapping day. To estimated relative abundance using two methods we calculated the mean of individuals captured per trapping night and the mean of individuals observed per transect for different species. Based on the mean value of relative abundance, occasional reports and captures in camera traps, we classified the species into three abundance categories: rare (< 1 individual/survey, species occasional report, or rarely capture in camera trap), uncommon (1–3 individuals/survey, or occasional capture in camera trap), and common (> 3 individual/survey).

We used Morisita index of similarity to compare the species composition and abundance across transects. This index has values from 0 to 1, where values close to 0 indicate no similarity between a pair of transects and values close to 1 indicate 100% similarity between a pair of transects. We evaluated species richness and species abundances similarity between transects using one-way analysis of similarities (ANOSIM; Clarke 1993; Hammer 2012), using Morisita index of similarity as the distance measurement. We used PAST (version 2.17; Øyvind Hammer, Natural History Museum, University of Oslo, Norway) for Morisita and ANOSIM analysis. Values are reported as means ± SE.

RESULTS

Land use

The study area is mainly covered by urban areas in the CC and CI. The forest fragments are restricted mainly to the riparian vegetation along Los Negritos stream, and the natural remnant vegetation corresponding to the RELO and JBO. In ID the land use correspond predominantly to natural spaces whit a forest fragment, pastures and riparian vegetation along Torres River and recreational spaces cover by trees (Table 1, Fig. 1).

Richness and relative abundances of terrestrial mammals

A total of nine species of terrestrial mammals from five orders, nine families, and nine genera were registered in the study area (Table 2). Mammals included six native species and three introduced.

We conducted a total capture effort of 524 (281 RELO, 165 JBO, and 78 RV) trap nights. We captured in 141 occasions mammals of three species. The average catch per night trap was 5.2 (SD = 2.6). The common raccoon (*Procyon lotor*) was the species with the highest average catch per night, followed by the common opossum (*Didelphis marsupialis*) and the free-ranging domestic cat (*Felis catus*) (Table 3).

We recorded six mammal species during diurnal counts. The average number of individuals observed per transects per day was 9.1(SD = 4.7). Variegated squirrels (*Sciurus variegatodes*) were the most common species in the four transects. Three-toed sloth (*Bradypus variegatus*) and two-toed sloth (*Choloepus hoffmanni*) were observed only in CC. The higher frequencies of sloths observed during a diurnal count suggest a minimum of seven individuals of three-toed sloth and three individuals of two-toed sloth on the CC during the study period. Free-ranging domestic cats were observed in the CC, CI and ID1. Northern raccoon and free-ranging dogs (*Canis familiaris*) were observed with low frequency and only in CC (Table 4). The urban gradient and the proximity between transects explains the similarity in the richness and abundance of mammal species (ANOSIM: $R = 0.24$, $p < 0.001$). The two closest transects had the highest similarity (Fig. 2).

We obtained a total of 653 videos of mammals (580 camera days). We identified a total of six species of terrestrial mammals. The most commonly recorded specie was the common raccoon, followed by common opossum (recorded only in the RELO) and cats. Norway rat (*Rattus norvegicus*) variegated squirrels, and dogs were rarely recorded (Table 5).

We identify 24 free-ranging domestic cats on night baiting traps, diurnal counts in transects, camera trap videos and occasional observations. We reported the occasional collection of the Central American least shrew *Cryptotis orophilus* captured on April 7, 2016, by a domestic cat near the Los Negritos stream (9 ° 56'16.7 "N, 84 ° 02'43.9" W, 1232m altitude). We deposited the specimen in the Museum of Zoology University of Costa Rica (Catalog UCR-4694).

DISCUSSION

Wild mammal populations are subject to extreme pressures from habitat reduction (Janzen, 1983) and rapid urban expansion (He et al., 2014). The accelerated expansion of the urban landscape in Costa Rica eliminated a large proportion of natural and semi-natural habitats (e.g., coffee plantations and open green areas), increased the isolation of the native vegetation. Mapping and quantifying natural habitat loss following urban expansion is important for understanding the impacts on biodiversity (Grimm et al., 2008; McDonald et al., 2013; Sushinsky et al., 2013; He et al., 2014). An important percentage of the vegetation in the study area is included in protected forest fragments. However, a little more than fifty percent of habitat was occupied by buildings, pavement and others urban structures. The constant increasing urbanization has a negative impact on animal diversity, because diversity tends to correlate positively with vegetative complexity and plant species-richness (Savard et al., 2000; McKinney, 2002). In Costa Rica's Central Valley, urbanization increased 72% from 1973 to 2006 (Biamonte et al., 2011) and in the specific case of the Universidad de Costa Rica, buildings constructions related to the increase of student enrollment still occurs, increasing the risk for the remaining urban biodiversity.

The loss of natural habitat is one of the main causes of biodiversity decline (Pimm & Raven, 2000; Brooks et al., 2002; Fahrig, 2003; He et al., 2014); and for mammals, species richness decrease strongly in areas with extreme urbanization (e.g., central urban core areas) (McKinney, 2008). Wilson report in the 80´s from the urban areas of the Central Valley more than 25 species of medium sized terrestrial mammals (Janzen, 1983). However, we found less than ten species. Although small rodent species were not included in the study, various medium-size mammals registered years ago like monkeys, anteaters, rabbits, porcupines, agoutis, weasels, and skunks were not found in this study. Therefore, the isolated fragments sampled in this study are able to sustain only a small fraction of the original fauna (Biomonte et al., 2011; Aronson, 2014).

The variegated squirrels were the most abundant species in our study site. This species as other squirrels in the genus *Sciurus* are well known for the ability to approach urban habitats in different world regions (McCleery et al., 2008; McCleery, 2009; Parker et al., 2014; Rézouki et al., 2014, Jokimäki et al., 2017; La Morgia et al., 2017). The capability of the squirrels to use native and introduced trees as roosting and feeding resources, and other resources such as food provided by human, pet food, buildings, poles and electrical wiring, allows this species to adapt well to urban areas. Possibly, the high diversity of native and nonnative plants in the study site (Di Stefano et al. 1996), and the capacity of the squirrels to exploit that diversity, explains the high abundance. Variegated squirrels are extremely opportunistic were observed feeding on a great variety of vegetable resources including seeds, flowers, fruits, leaves and branches from native and nonnative trees and vines.

Urbanization also alters ecosystem processes through human activities, which can degrade habitats but can also increase other resource types such as anthropogenic food resources available in refuse containers and urban structures used as den sites (Prange & Gerht, 2004). Species capable of efficiently exploiting those new resources may occur at higher densities in cities than in comparable rural or natural areas (Harris & Rayner, 1986; Fedriani et al., 2001; McKinney, 2002; Prange et al., 2003; Prange & Gerht, 2004). Thus, the abundance of anthropogenic resource use by members of a community could result in the dominance of a few or even a single species in urbanized areas (Prange & Gerht, 2004). Species that respond positively to anthropogenic resources are typically generalists, with broad dietary and habitat requirements (McKinney, 2002). This is the case of common raccoons and common opossums, and even the squirrels which in the study site used similar habitats, foods, and roosting sites (Shirer & Fitch, 1970; Kissell & Kennedy, 1992; Ladine, 1997; Prange & Gerht, 2004). Additionally, these species are also tolerant to fragmentation and human presence, facilitating their survival in urban habitats (Prange & Gerht, 2004).

Like in others studies, the population of raccoons found in the study site appear to be highly efficient at exploiting anthropogenic resources (Prange et al., 2003; Prange & Gehrt, 2004), due to the highest abundance of raccoons in the study site. Common opossum is widespread in the Neotropics where it adapts well to different conditions (Prange & Gehrt, 2004), It is common in forests and urban environments, and has generalist diet, consuming fruits, small animals, and discarded human food in urban environments (Barros & de Aguiar Azevedo, 2014). Although, compare to opossums, larger body size and greater dexterity may allow raccoons better access to trash cans and dumpsters (Prange & Gehrt, 2004) and common opossum were rarely observed making use of these resources in the site. In addition, we suggest that differential human response to specific mammal species presence may also have an effect in mammal community structure. We do not have comparable data for cause-specific mortality, however, for many people the repulse response commonly observed to common opossum presence is kill the animal, different to the observed for squirrels and raccoons for example.

Three of the nine species found in the study site were introduced mammals, agreeing with the patterns observed in other taxonomic groups such as reptiles, amphibians, invertebrates and plants (Mackin-Rogalska et al., 1988; Gibbon et al., 2000; Tait et al., 2005; Duguay et al., 2007; McKinney, 2008) where increase the proportion of nonnative species toward the urban core. Detrimental impacts of non-native species on native biota have occurred through competition, predation, herbivory, habitat alteration, disease and genetic effects (Manchester & Bullock, 2000;

McKinney, 2008); but, free-ranging domestic cats and rats are particularly harmful (Longcore et al., 2009). For example, free-ranging domestic cats are the major predator of birds, small mammals, reptiles, amphibians, and fish in cities (Loss & Marra, 2013). Cat abundance has been shown to be negatively correlated with the densities of some small mammals (Baker et al., 2003; McCleery, 2010), and in one study, 69% of the prey items brought home by house cats were mammals (Woods et al., 2003; McCleery, 2010). Furthermore, free-ranging domestic cats and rats are also potential public nuisance because may spread disease to other species (Easterbrook et al., 2007; Robertson, 2008; Costa et al., 2015).

Differences were found in the terrestrial mammal composition among sectors in the campus of the university. Fragmentation creates patches that isolate populations and hinder movements among patches (Markovchick- Nicholls et al., 2008). Terrestrial fragments on urban lands are less hostile to faunal movements (Watling & Donnelly, 2006). Small and distant patches support few species because distance or isolation limits migration and small patches provide fewer resources, thus supporting smaller, and more extinct-prone, local populations (Brooks et al., 2002; Marzluff, 2005; Faeth et al., 2011). We report two species of sloths, both native species that is now to be present in the Central Valley before urbanization occurs. The lack of connectivity between the fragments maintains sloths populations isolated in the campus of the Universidad de Costa Rica. Young and juveniles sloths were observed in the study for both species indicating reproduction. However, roads and buildings can act as physical barriers, limiting movement and possibly increasing endogamy for the sloth populations (Baker & Harris, 2007; Markovchick- Nicholls et al., 2008; McCleery, 2010). Direct causes of mortality were reported during the study when sloths fall and impacts to the street or by electrocution in electrical wiring. Decreased patch size, increased isolation, increased edge effects, and higher levels of human disturbance can serve to reduce or eliminate populations of fragmentation-sensitive species (Crooks, 2002; Fernández-Juricic, 2002; Patten & Bolger, 2003).

Preserving patches of natural habitat within urbanized landscapes is often advocated as a method of conserving natural communities (Fernández-Juricic & Jokimäki, 2001; Marzluff & Ewing, 2001; Rudd et al., 2002; Prange & Gerht, 2004). A better integration of nature in urban environments not only preserves the biodiversity, but a favor human wellness. Contact whit natural settings hasten recovery from stress, enhancing observational skills and the ability to reason (Horwitz, 2001; Alvey, 2006; Tzoulas, 2007; Dearborn & Kark, 2010). Maintaining high local diversity in urban environments increases the contact with elements of the natural world that contribute to the well-being and quality of life (Horwitz, 2001; Brown & Grant, 2005; Tzoulas, 2007). The study represent the first work with medium sized mammals in the metropolitan area in Costa Rica and one of the first whit mammals in cities in the neotropics (Arias-Aguilar et al., 2015). We expect contribute to promote the conservation of natural environments in cities.

ACKNOWLEDGMENTS

We thank Victor Madrigal and the Red de Áreas Protegidas (RAP) of the Universidad de Costa Rica for the contribution to generate the maps. The Universidad de Costa Rica provided financial support, materials and equipment.

RESUMEN

Los espacios verdes urbanos se están convirtiendo en un refugio cada vez más importante para la fauna nativa de Costa Rica. En Costa Rica, la mayor parte de la población humana se concentra en el Valle Central, consecuentemente, la urbanización reduce constantemente la vegetación remanente natural. En mamíferos, el desarrollo urbano generalmente disminuye la diversidad nativa. Describimos la riqueza y abundancia de los mamíferos medianos terrestres en el campus de la Universidad de Costa Rica, un área metropolitana con vegetación remanente en el Neotrópico. Realizamos un análisis de paisaje utilizando sistemas de información geografica para medir los espacios verdes y la cobertura urbana. El estudio de mamíferos terrestres incluyó trampeo nocturno, conteos diurnos en transeptos, cámaras trampa y reportes ocasionales. Encontramos seis especies nativas y tres especies introducidas de mamíferos terrestres, lo que representa menos de un 50% de la diversidad de mamíferos terrestre medianos reportada para el Valle Central hace 40 años. El mapache (*Procyon lotor*) y la ardilla (*Sciurus variegatoides*) común fueron las especies más abundantes, ambas con la capacidad de aprovechar hábitats alterados por el desarrollo urbano. Las especies introducidas, especialmente el gato doméstico, representan un problema por ser importantes depredadores de la fauna nativa y por transmitir enfermedades. Las especies de perezosos (*Bradypus variegatus* y *Choloepus hoffmanni*) en el sitio de estudio se ven afectadas por el típico aislamiento de los fragmentos de vegetación y la falta de conectividad generada por la urbanización. Mantener los fragmentos de vegetación de hábitat natural en las ciudades es primordial para la conservación de la biodiversidad.

REFERENCES

Adams, L. W. (2005). Urban wildlife ecology and conservation: a brief history of the discipline. *Urban ecosystems*, *8*(2), 139-156.

Alvey, A. A. (2006). Promoting and preserving biodiversity in the urban forest. *Urban Forestry & Urban Greening*, *5*(4), 195-201.

Arias-Aguilar, A., Chacón-Madrigal, E., & Rodríguez-Herrera, B. (2015). El uso de los parques urbanos con vegetación por murciélagos insectívoros en San José, Costa Rica. *Mastozoología neotropical*, *22*(2), 229-237.

Alberti, M. (2005). The effects of urban patterns on ecosystem function. *International regional science review*, *28*(2), 168-192.

Aronson, M.F.J., La Sorte, F.A., Nilon, C.H., Katti, M., Goddard, M.A., Lepczyk, C.A., Warren, P.S., et al. (2014). A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. *Proc. R. Soc. Lond. B*, 281, 20133330.

Baker, P. J., Ansell, R. J., Dodds, P. A., Webber, C. E., & Harris, S. (2003). Factors affecting the distribution of small mammals in an urban area. *Mammal review*, *33*(1), 95-100.

Baker, P. J., & Harris, S. (2007). Urban mammals: what does the future hold? An analysis of the factors affecting patterns of use of residential gardens in Great Britain. *Mammal Review*, *37*(4), 297-315.

Barros, F. B., & de Aguiar Azevedo, P. (2014). Common opossum (Didelphis marsupialis Linnaeus, 1758): food and medicine for people in the Amazon. *Journal of ethnobiology and ethnomedicine*, *10*(1), 65.

Biamonte, E., Sandoval, L., Chacón, E., & Barrantes, G. (2011). Effect of urbanization on the avifauna in a tropical metropolitan area. *Landscape Ecology*, *26*(2), 183-194.

Bonnington, C., Gaston, K. J., & Evans, K. L. (2014). Squirrels in suburbia: influence of urbanisation on the occurrence and distribution of a common exotic mammal. *Urban ecosystems*, *17*(2), 533-546.

Brooks, T. M., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., Rylands, A. B., Konstant, W. R., ... & Hilton‐ Taylor, C. (2002). Habitat loss and extinction in the hotspots of biodiversity. *Conservation biology*, *16*(4), 909-923.

Brown, C., & Grant, M. (2005). Biodiversity and human health: What role for nature in healthy urban planning?. *Built Environment*, *31*(4), 326-338.

Chalker-Scott, L. (2015). Nonnative, noninvasive woody species can enhance urban landscape biodiversity. *Arboric. Urban For*, *41*(4), 173-186.

Costa, F., Wunder Jr, E. A., De Oliveira, D., Bisht, V., Rodrigues, G., Reis, M. G., ... & Childs, J. E. (2015). Patterns in Leptospira shedding in Norway rats (Rattus norvegicus) from Brazilian slum communities at high risk of disease transmission. *PLoS neglected tropical diseases*, *9*(6), e0003819.

Crooks, J. A. (2002). Characterizing ecosystem‐ level consequences of biological invasions: the role of ecosystem engineers. *Oikos*, *97*(2), 153-166.

Dearborn, D. C., & Kark, S. (2010). Motivations for conserving urban biodiversity. *Conservation biology*, *24*(2), 432-440.

Di Stéfano, J. F., Nielsen, V., Hoomans, J., & Fournier, L. A. (1996). Regeneración de la vegetación arbórea en una pequeña reserva forestal urbana del nivel premontano húmedo, Costa Rica. *Revista de Biología Tropical*, *44*(2 A), 575-580.

Ditchkoff, S. S., Saalfeld, S. T., & Gibson, C. J. (2006). Animal behavior in urban ecosystems: modifications due to human-induced stress. *Urban ecosystems*, *9*(1), 5-12.

Donnelly, R., & Marzluff, J. M. (2004). Importance of reserve size and landscape context to urban bird conservation. *Conservation Biology*, *18*(3), 733-745.

Dowding, J. E., & Murphy, E. C. (2001). The impact of predation by introduced mammals on endemic shorebirds in New Zealand: a conservation perspective. *Biological Conservation*, *99*(1), 47-64.

Duguay, S., Eigenbrod, F., & Fahrig, L. (2007). Effects of surrounding urbanization on non-native flora in small forest patches. *Landscape Ecology*, *22*(4), 589-599.

Easterbrook, J. D., Kaplan, J. B., Vanasco, N. B., Reeves, W. K., Purcell, R. H., Kosoy, M. Y., ... & Klein, S. L. (2007). A survey of zoonotic pathogens carried by Norway rats in Baltimore, Maryland, USA. *Epidemiology & Infection*, *135*(7), 1192-1199.

Faeth, S. H., Bang, C., & Saari, S. (2011). Urban biodiversity: patterns and mechanisms. *Annals of the New York Academy of Sciences*, *1223*(1), 69-81.

Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. *Annual review of ecology, evolution, and systematics*, *34*(1), 487-515.

Fedriani, J. M., Fuller, T. K., & Sauvajot, R. M. (2001). Does availability of anthropogenic food enhance densities of omnivorous mammals? An example with coyotes in southern California. *Ecography*, *24*(3), 325-331.

Fernández-Juricic, E. (2002). Can human disturbance promote nestedness? A case study with breeding birds in urban habitat fragments. *Oecologia*, *131*(2), 269-278.

Fernández-Juricic, E., & Jokimäki, J. (2001). A habitat island approach to conserving birds in urban landscapes: case studies from southern and northern Europe. *Biodiversity and conservation*, *10*(12), 2023-2043.

Fournier, L.A. (1991) Desarrollo y perspectiva del movimiento conservacionista costarricense. Editorial Universidad de Costa Rica, San Jose´, Costa Rica.

Gibbon, J. W., Scott, D. E., Ryan, T. J., Buhlmann, K. A., Tuberville, T. D., Metts, B. S., ... & Winne, C. T. (2000). The Global Decline of Reptiles, Déjà Vu Amphibians: Reptile species are declining on a global scale. Six significant threats to reptile populations are habitat loss and degradation, introduced invasive species, environmental pollution, disease, unsustainable use, and global climate change. *BioScience, 50*(8), 653-666.

González-García, A., Belliure, J., Gómez-Sal, A., & Dávila, P. (2009). The role of urban greenspaces in fauna conservation: the case of the iguana Ctenosaura similis in the 'patios' of León city, Nicaragua. *Biodiversity and conservation*, *18*(7), 1909.

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global change and the ecology of cities. *Science*, 319(5864), 756-760.

Harris, S., & Rayner, J. M. V. (1986). Urban fox (Vulpes vulpes) population estimates and habitat requirements in several British cities. *The Journal of Animal Ecology*, 575-591.

He, C., Liu, Z., Tian, J., & Ma, Q. (2014). Urban expansion dynamics and natural habitat loss in China: a multiscale landscape perspective. *Global change biology*, *20*(9), 2886-2902.

Horwitz, P., Lindsay, M., & O'Connor, M. (2001). Biodiversity, Endemism, Sense of Place, and Public Health: Inter- relationships for Australian Inland Aquatic Systems. *Ecosystem Health*, *7*(4), 253-265.

Janzen, D. H. (1983). *Costa Rican natural history* (No. 508.7286 J269c Ej. 1 02502842.05). University of Chicago Press,.

Jessup, D. A. (2004). The welfare of feral cats and wildlife. *Journal of the American Veterinary Medical Association*, *225*(9), 1377-1383.

Jokimäki, J., Selonen, V., Lehikoinen, A., & Kaisanlahti-Jokimäki, M. L. (2017). The role of urban habitats in the abundance of red squirrels (Sciurus vulgaris, L.) in Finland. *Urban Forestry & Urban Greening*, *27*, 100-108.

Joyce, AT. (2006). Land use change in Costa Rica: 1996–2006, as influenced by social, economic, political, and environmental factors. Litografía e imprenta LIL, S.A., San

José, Costa Rica.

Junior, V. C., & Leite, Y. L. R. (2007). Uso de habitats por pequenos mamíferos no Parque Estadual da Fonte Grande, Vitória, Espírito Santo, Brasil. *Boletim do Museu de Biologia Mello Leitão (n. s)*, *21*, 57-77.

Kissell Jr, R. E., & Kennedy, M. L. (1992). Ecologic relationships of co-occurring populations of opossums (Didelphis virginiana) and raccoons (Procyon lotor) in Tennessee. *Journal of Mammalogy*, *73*(4), 808-813.

La Morgia, V., Paoloni, D., & Genovesi, P. (2017). Eradicating the grey squirrel Sciurus carolinensis from urban areas: an innovative decision- making approach based on lessons learnt in Italy. *Pest management science*, *73*(2), 354-363.

Ladine, T. A. (1997). Activity patterns of co-occurring populations of Virginia opossums (Didelphis virginiana) and raccoons (Procyon lotor). *Mammalia*, *61*(3), 345-354.

Laurance, W. F. (2008). Theory meets reality: how habitat fragmentation research has transcended island biogeographic theory. *Biological conservation*, *141*(7), 1731-1744.

Longcore, T., Rich, C., & Sullivan, L. M. (2009). Critical assessment of claims regarding management of feral cats by trap–neuter–return. *Conservation biology*, *23*(4), 887-894.

Loss, S. R., Will, T., & Marra, P. P. (2013). The impact of free-ranging domestic cats on wildlife of the United States. *Nature communications*, *4*, 1396.

Luck, G. W. (2007). A review of the relationships between human population density and biodiversity. *Biological Reviews*, *82*(4), 607-645.

Mackin-Rogalska, R., Pinowski, J., Solon, J., & Wojcik, Z. (1988). Changes in vegetation, avifauna, and small mammals in a suburban habitat. *Polish Ecological Studies*, *14*, 293-330.

Magura, T., Lövei, G. L., & Tóthmérész, B. (2010). Does urbanization decrease diversity in ground beetle (Carabidae) assemblages?. *Global Ecology and Biogeography*, *19*(1), 16-26.

Manchester, S. J., & Bullock, J. M. (2000). The impacts of non- native species on UK biodiversity and the effectiveness of control. *Journal of Applied Ecology*, *37*(5), 845-864.

Markovchick- Nicholls, L., Regan, H. M., Deutschman, D. H., Widyanata, A., Martin, B., Noreke, L., & Ann Hunt, T. (2008). Relationships between human disturbance and wildlife land use in urban habitat fragments. *Conservation Biology*, *22*(1), 99-109.

Marzluff, J. M. (2005). Island biogeography for an urbanizing world: how extinction and colonization may determine biological diversity in human-dominated landscapes. *Urban Ecosystems*, *8*(2), 157-177.

Marzluff, J. M., & Ewing, K. (2001). Restoration of fragmented landscapes for the conservation of birds: a general framework and specific recommendations for urbanizing landscapes. *Restoration Ecology*, *9*(3), 280-292.

McCleery, R. A. (2009). Changes in fox squirrel anti-predator behaviors across the urban–rural gradient. *Landscape Ecology*, *24*(4), 483.

McCleery, R. A. (2010). Urban mammals. *Urban ecosystem ecology*, 87-102.

McCleery, R. A., Lopez, R. R., Silvy, N. J., & Gallant, D. L. (2008). Fox squirrel survival in urban and rural environments. *The Journal of wildlife management*, *72*(1), 133-137.

McDonald, R. I., Kareiva, P., & Forman, R. T. (2008). The implications of current and future urbanization for global protected areas and biodiversity conservation. *Biological conservation*, *141*(6), 1695-1703.

McDonald, B. C., Gentner, D. R., Goldstein, A. H., & Harley, R. A. (2013). Long-term trends in motor vehicle emissions in US urban areas. *Environmental science & technology*, *47*(17), 10022-10031.

McKinney, M. L. (2002). Urbanization, biodiversity, and conservation: the impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems. *BioScience*, *52*(10), 883-890.

McKinney, M. L. (2006). Urbanization as a major cause of biotic homogenization. *Biological conservation*, *127*(3), 247-260.

McKinney, M. L. (2008). Effects of urbanization on species richness: a review of plants and animals. *Urban ecosystems*, *11*(2), 161-176.

Medina, F. M., Bonnaud, E., Vidal, E., Tershy, B. R., Zavaleta, E. S., Josh Donlan, C., ... & Nogales, M. (2011). A global review of the impacts of invasive cats on island endangered vertebrates. *Global Change Biology*, *17*(11), 3503-3510.

Melles, S., Glenn, S., & Martin, K. (2003). Urban bird diversity and landscape complexity: species–environment associations along a multiscale habitat gradient. *Conservation Ecology*, *7*(1).

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403*(6772), 853.

Parker, T. S., Gonzales, S. K., & Nilon, C. H. (2014). Seasonal comparisons of daily activity budgets of gray squirrels (Sciurus carolinensis) in urban areas. *Urban ecosystems*, *17*(4), 969-978.

Patten, M. A., & Bolger, D. T. (2003). Variation in top- down control of avian reproductive success across a fragmentation gradient. *Oikos*, *101*(3), 479-488.

Pimm, S. L., & Raven, P. (2000). Biodiversity: extinction by numbers. *Nature*, *403*(6772), 843-845.

Prange, S., Gehrt, S. D., & Wiggers, E. P. (2003). Demographic factors contributing to high raccoon densities in urban landscapes. *The Journal of wildlife management*, 324-333.

Prange, S., & Gehrt, S. D. (2004). Changes in mesopredator-community structure in response to urbanization. *Canadian Journal of Zoology*, 82(11), 1804-1817.

Reichard, S. H., & White, P. (2001). Horticulture as a pathway of invasive plant introductions in the United States: most invasive plants have been introduced for horticultural use by nurseries, botanical gardens, and individuals. *BioScience*, *51*(2), 103-113.

Rézouki, C., Dozières, A., Le Cœur, C., Thibault, S., Pisanu, B., Chapuis, J. L., & Baudry, E. (2014). A viable population of the European red squirrel in an urban park. *PloS one*, *9*(8), e105111.

Robertson, S. A. (2008). A review of feral cat control. *Journal of feline medicine and surgery*, *10*(4), 366-375.

Rudd, H., Vala, J., & Schaefer, V. (2002). Importance of backyard habitat in a comprehensive biodiversity conservation strategy: a connectivity analysis of urban green spaces. *Restoration ecology*, *10*(2), 368-375.

Savard, J. P. L., Clergeau, P., & Mennechez, G. (2000). Biodiversity concepts and urban ecosystems. *Landscape and urban planning*, *48*(3-4), 131-142.

Schneider, A., Friedl, M. A., & Potere, D. (2010). Mapping global urban areas using MODIS 500-m data: New methods and datasets based on 'urban ecoregions'. *Remote Sensing of Environment*, *114*(8), 1733-1746.

Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences*, *109*(40), 16083-16088.

Shirer, H. W., & Fitch, H. S. (1970). Comparison from radiotracking of movements and denning habits of the raccoon, striped skunk, and opossum in northeastern Kansas. *Journal of Mammalogy*, *51*(3), 491-503.

Steele, M. A. (2008). Evolutionary interactions between tree squirrels and trees: a review and synthesis. *Current Science*, 871-876.

Sushinsky, J. R., Rhodes, J. R., Possingham, H. P., Gill, T. K., & Fuller, R. A. (2013). How should we grow cities to minimize their biodiversity impacts?. *Global change biology*, *19*(2), 401-410.

Tait, C. J., Daniels, C. B., & Hill, R. S. (2005). Changes in species assemblages within the Adelaide metropolitan area, Australia, 1836–2002. *Ecological Applications*, *15*(1), 346-359.

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., & James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and urban planning*, *81*(3), 167-178.

van Heezik, Y., Smyth, A., Adams, A., & Gordon, J. (2010). Do domestic cats impose an unsustainable harvest on urban bird populations?. *Biological Conservation*, *143*(1), 121-130.

Watling, J. I., & Donnelly, M. A. (2006). Fragments as islands: a synthesis of faunal responses to habitat patchiness. *Conservation Biology*, *20*(4), 1016-1025.

Woods, M., McDonald, R. A., & Harris, S. (2003). Predation of wildlife by domestic cats Felis catus in Great Britain. *Mammal review*, *33*(2), 174-188.

Yahner, R. H. (1998). Butterfly and skipper use of nectar sources in forested and agricultural landscapes of Pennsylvania. *Journal of the Pennsylvania Academy of Science*, 104-108.

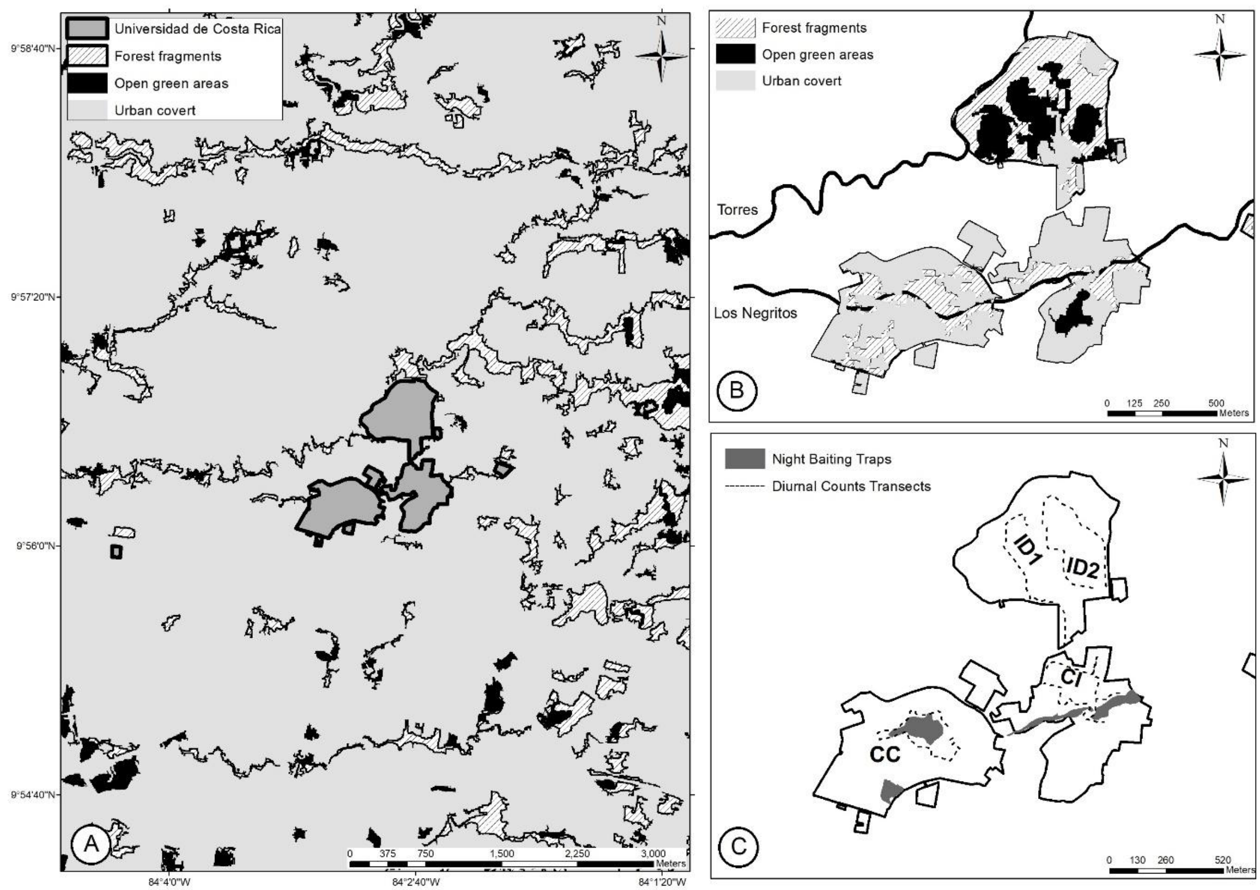

Figure 1. Urban zone cover by three land uses (A and B). Diurnal transects and capture night traps sites (Jardín Botánico Orozco, Reserva Ecológica Leonelo Oviedo, and Riparian Vegetation from left to right) in the three major sectors of Universidad de Costa Rica, San José, Costa Rica (C).

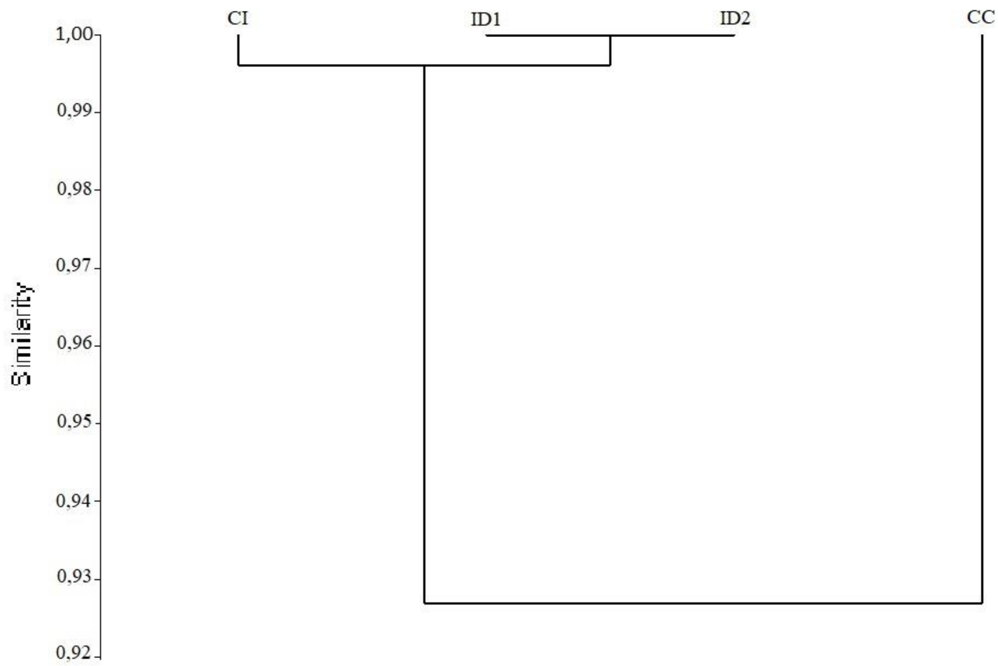

Figure 2. Comparison of terrestrial mammal composition among transects (CC: Central Campus, CI: Ciudad de la Investigación, ID1 and ID2: Instalaciones Deportivas 1 and 2 respectively) sampled during diurnal counts in the campus of Universidad de Costa Rica, San José, Costa Rica using Morisita index of similarity, April 2016-March 2017.

Table 1. Size (ha) and percent occupied by the different habitats in the three major sectors of the Universidad de Costa Rica, San José, Costa Rica.

Land cover	Campus Central	Ciudad de la Investigación	Instalaciones Deportivas	Total
Urban	25.1 (71.5%)	18.6 (75%)	5.6 (16%)	49.3 (51.8%)
Forest	10 (28.5)	4.5 (18%)	17.7 (50%)	32.2 (33.8%)
Open green areas		1.7 (7%)	12 (34%)	13.7 (14.4%)
Total	35,1	24.8	35.3	95.2

Table 2. Terrestrial mammals found in the campus of Universidad de Costa Rica, San José, Costa Rica, August 2014-March 2017. Type of record includes: night trap (NT), diurnal counts (DC), camera trap (CT) and occasional report (OR).

Taxa	Common name	Type of record	Abundance category
ORDER DIDELPHIMORPHIA Family Didelphidae *Didelphis marsupialis* Linnaeus, 1758	Common Opossum	NT, CT	Uncommon
ORDER PILOSA Family Megalonychidae *Choloepus hoffmanni* Peters, 1858	Two-toed sloth	DC	Rare
Family Bradypodidae *Bradypus variegatus* Schinz, 1825	Three-toed sloth	DC	Uncommon
ORDER EULIPOTYPHLA Family Soricidae *Cryptotis orophilus* Allen, 1895	Central American least shrew	OR	Rare
ORDER RODENTIA Family Sciuridae *Sciurus variegatoides* Ogilby, 1839	Variegated squirrel	DC, CT	Common
Family Muridae *Rattus norvegicus* Berkenhout, 1769	Norway rat	CT	Rare
ORDER CARNIVORA Family Felidae *Felis catus* Schreber, 1775	Domestic cat	NT, DC, CT, OR	Uncommon
Family Canidae *Canis familiaris* Linnaeus 1758	Domestic dog	DC, CT, OR	Rare
Family Procyonidae *Procyon lotor* Linnaeus, 1758	Common raccoon	NT, DC, CT, OR	Common

Table 3. Terrestrial mammal captures (mean ± SD per capture night) during night trap sessions in the Reserva Ecológica Leonelo Oviedo (RELO), Jardín Botánico Orozco (JBO), and the Riparian vegetation (RP) on the campus of Universidad de Costa Rica, San José, Costa Rica, August 2014-December 2015.

	RELO	JBO	RV	Total
Traps nights	281	165	78	524
Nigths of capture	15	8	4	27
Numbers of mammals captures	86 (5.7 ± 2.3)	38 (4.8 ± 3.4)	17 (4 ± 1.8)	141 (5.2 ± 2.6)
Numbers of *Didelphis marsupialis* captures	29 (1.9 ± 1.4)	0	11 (2.5 ± 1.3)	40 (1.4 ± 1.5)
Numbers of *Procyon lotor* captures	54 (3.6 ± 2.8)	28 (3.5 ± 2.8)	2 (0.5 ± 0.6)	84 (3.1 ± 2.7)
Numbers of *Felis catus* captures	3 (0.2 ± 0.4)	10 (1.3 ± 1.2)	4 (1 ± 0.8)	17 (0.6 ± 0.9)

Table 4. Mean and standard deviation of terrestrial mammals observed per diurnal counts in four transects (CC: Central Campus, CI: Ciudad de la Investigación, ID1 and ID2: Instalaciones Deportivas 1 and 2 respectively) in the campus of Universidad de Costa Rica, San José, Costa Rica, April 2016-March 2017.

Specie	CC	CI	ID1	ID2	Total
Sciurus variegatoides	6.83 ± 3.07	6.46 ± 3.15	8.46 ± 4.88	10.79 ± 5.69	8.14 ± 4.61
Bradypus variegatus	1.79 ± 1.28	0	0	0	0.45 ± 1.00
Choloepus hoffmanni	0.79 ± 0.72	0	0	0	0.20 ± 0.49
Felis catus	0.54 ± 0.59	0.21 ± 0.51	0.08 ± 0.28	0	0.21 ± 0.46
Procyon lotor	0.08 ± 0.41	0	0	0	0.02 ± 0.20
Canis familiaris	0	0.33 ± 1.13	0	0	0.08 ± 0.57

Table 5. Numbers of terrestrial mammal videos obtained using camera traps in two forest fragments in the campus of Universidad de Costa Rica, San José, Costa Rica, March-July 2015.

	RELO	JBO	Total
Camera days	350	230	580
Active days	35	23	58
Mammals	391	262	653
Didelphis marsupialis	122	0	122
Procyon lotor	182	252	434
Felis catus	77	9	86
Rattus norvegicus	8	0	8
Sciurus variegatoides	1	1	2
Canis familiaris	1	0	1

CAPÍTULO II: Raccoon density, habitat use, and establishment of refuges in neotropical urban environment, Costa Rica.

(Formato para Mastozoología Neotropical)

Raccoon density, habitat use, and establishment of refuges in neotropical urban environment, Costa Rica

Abstract: The raccoon (*Procyon lotor*) is one of several wildlife species thriving in urban environments. We estimated the population size, structure, home range, core areas and refuges of an urban raccoon population in the campus of the Universidad the Costa Rica, an isolated forest fragment in the metropolitan area of San José, Costa Rica. Twenty-four raccoon individuals (seven males and 17 females) were captured and marked from August 2014 through October 2015, with a density of 40.3 raccoons/Km^2 on the study site. Survival calculated using Cormack Jolly Seber single-state modeling suggest the permanency of the individuals captured in the study area. Nocturnal location and refuges of one male and two females were obtained using GPS collars transmitters. Areas used by the three monitored raccoons are located close to the riparian vegetation. Home ranges and core areas include a large proportion of both remnant vegetation fragments and urban cover. We identify 11 anthropogenic refuges corresponding to buildings and 12 natural sites corresponding to dense bamboo vegetation and tree refuges used during the day. A high density of raccoons found at the site was consistent with other studies in urban and suburban areas. Our findings emphasizing the importance of green spaces close to water for raccoon populations immersed in urban areas. We found that remnant vegetation represent important natural habitat for foraging and found refuges within urban ecosystems. We recommend reducing or eliminating access to anthropogenic resources such as food waste in dumpster and identified human structures used by raccoons can decrease the nuisance problems associate to raccoons overabundance.

Key words: raccoon, urbanization, GPS collar, remnant vegetation, forest fragment, refuges, Costa Rica.

Rapid urbanization has caused many environmental impacts associated with the reduction of green spaces (Aronson 2017). City growth typically involves the conversion of natural habitat into buildings, impervious surfaces, and road construction (McKinney 2002), resulting in habitat loss, fragmentation, and pollution (Uno et al. 2010). Urbanization also alters ecosystem processes through human activities, which may degrade habitats or increase resources (Prange & Gehrt 2004). The disturbances created by urbanization not only destroy the habitat of native species, but also create better conditions for species that adapt to urban and suburban environments (McKinney 2006).

Species that respond positively to anthropogenic changes are typically generalists on diet and with broad habitat requirements (McKinney 2002); such as the common raccoons (*Procyon lotor*) (Bozek et al. 2007; Wehtje & Gompper 2011). Species capable of efficiently exploiting human waste as food and man-made structures as burrow or roost sites often occur at higher densities in urban areas than in rural habitats and forest (Henner et al. 2004; Prange & Gehrt 2004; Prange et al. 2004; Beasley et al. 2007b). Raccoons are very efficient in exploiting anthropogenic resources (Prange et al. 2004; Prange & Gehrt 2004; Bozek et al. 2007).

Abundant wildlife near human developments commonly results in human–wildlife interactions (VanDruff et al. 1994; O'Donnell & DeNicola 2006). Artificial feeding, provision of cover for nesting and refuge, and poorly designed or deteriorating structures that provide access to wildlife may conflicts in human-wildlife interactions (VanDruff et al. 1994; O'Donnell & DeNicola 2006). Raccoon overabundance in urbanized areas often leads to nuisance problems and concerns such as disease outbreaks, nest depredation, and conflicts in urban settings where animals destroy property and pose the threat of disease and parasites transmission to humans, pets, and wild birds and other mammals (Wilson et al. 1997; Page et al. 1998; Prange et al. 2003; Henner et al. 2004; Davidson 2006; O'Donnell & DeNicola 2006).

The objective of this study is to estimate the population size, population structure (sex and age), home range, location of core areas and refuges of an urban raccoon population in the campus of the Universidad de Costa Rica. Given that forest fragments present in urban areas were scarce and isolated, and the Universidad de Costa Rica preserve one of the few natural vegetation patches inside the San José metropolitan area, we predict that the remnants of forest fragments of the University campus maintain a high density of raccoons and that this population exhibit high site fidelity. In the last decade, reports about the presence of these mammals in Costa Rican urban environments are increasing. Although it is well known that raccoons are able to exist in urban-suburban areas along its distribution (Prange et al. 2003; Prange et al. 2004; Prange & Gehrt 2004; Bozek et al. 2007; Wehtje & Gompper 2011), urban populations in the Neotropic have not yet been investigated to date. Information of city residents, preliminary field studies and anecdotic observations indicate that raccoons are numerous and generate conflicts in various areas of the Costa Rican Central Valley, including the campus of the Universidad de Costa Rica (Alvarado & Gutiérrez 2013; Alvarado 2014). We expect that the urban areas in the campus and surroundings represent an important habitat used by raccoons to forage and refuges.

MATERIALS AND METHODS

Study site:

We conducted this study at the campus of the Universidad de Costa Rica, an urban area in the northeastern section of the Central Valley, San José province, Costa Rica (9°54' N, 84°03' W; at 1200m in elevation; Fig. 1). This region includes the metropolitan area and nearly 2/3 of the population and consequently the vegetation that recently covered this valley has been rapidly converted in urban landscapes (Joyce 2006). Today the original native vegetation is scarce and restricted to small fragments of natural remnant vegetation, isolated trees, and gardens (Biamonte et al. 2011).

The terrain of the university campus is undulated and drained to the west by Los Negritos stream, which crosses the campus, and by the Torres River in the northern border. The campus occupies buildings, parking areas, lawns, riparian vegetation, and pastures along the Los Negritos stream and the Torres River. The University campus also includes the Leonelo Oviedo Ecological Reserve (RELO) and the Orozco Botanical Garden (JBO), two protected areas occupied by forest fragments of 1.7 and 0.45ha, respectively.

Capture/Recapture:

We sampled raccoons from August 2014 to December 2015 using night baiting traps in three forest fragments: RELO, JBO, and riparian vegetation (RV) along Los Negritos stream. We placed 20 box traps (model 108, 25 x 30 x 81 cm; Tomahawk Live Trap Co., Tomahawk, Wisconsin) per trapping night and baited with commercial cat food (Purina® Felix®). The traps were placed 20 m apart from each other. We open box traps from 1600 to 0700 h, when we checked the next day. We conducted 27 trapping nights (15 RELO, 8 JBO, and 4 RV). The numbers of days between trapping nights were four to 91 (Mean = 16, SD = 24). We placed traps two consecutive nights in three occasions and three consecutive nights in one occasion. We measured the sampled effort as trap nights (numbers of traps per the numbers of trapping nights).

Captured were immobilized with an intramuscular injection of ketamine hydrochloride and xylazine (5:1 ratio, dosage = 0.1 ml/kg of estimated body mass) (Gehrt et al. 2001) while still inside the box-traps, and were classified as adults (≥12 months), and juveniles (< 12 months) by reproductive characteristics (Sanderson 1961) and tooth wear (Grau et al. 1970). Weight and body measurements were recorded for all individuals, and then marked with ear tags (Monel #4, National Band and Tag Company, Newport, Kentucky, USA). Additionally, we tattooed each individual in the internal part of the posterior leg to accommodate for ear tag loses and aid in future identification.

Frequency of captured was defined as the numbers of individuals captured for trapping night. We estimated density (D = N/A) as the proportion of individuals marked during trapping sessions (N) relative to the total area of the Universidad de Costa Rica campus(A).

We used the Cormack Jolly Seber single-state modeling (Hestbeck et al. 1991; Brownie et al. 1993) to estimate weekly survival (ϕ) and recapture likelihood (ρ) using the program MARK (White & Burnham 1999; Cooch & White 2016). Due to the time period of the study and the biology of the species (average life and reproductive rate), we considered “survival” as the permanency of the individuals in the study area. MARK uses encounter histories to compute maximum likelihood estimates of survival and recapture. Each model is compared against other models and ranked according to fit using the 2nd-order variant of the Akaike Information Criterion (AICc—Sugiura 1978; Burnham & Anderson 2002, Wagenmakers & Farrell 2004). The model or models with the lowest AICc value were considered the best models (Burnham & Anderson 2002).

Estimation of home ranges, core areas and refuges:

We fitted two female (F1, F2) and one male (M1) adult raccoons captured in the RELO with VHF and GPS collars transmitters (model TGB-325/311CB, Telenax, Playa del Carmen, México). We program the GPS transmitter to track locations at intervals of 30 min during the night and one location during the day at 1300h to determine resting sites. Locations were taken every day up to battery discharge; however, the number of locations collected depended on the GPS signal (affecting by atmospheric conditions, forest cover and available satellites), battery life (varies between transmitters and depends of the time finding signal and the numbers of locations taken), and damages in the GPS transmitter (caused by raccoons), so not all possible locations were taken.

We used adaptative local convex hull (a-LoCoH) nonparametric kernel method to generate 95% (home range) and 50% (core area) use distributions for each individual. Analyses were done using the package "adehabitatHR" (Calenge, 2006) from R (R Core Team, 2013). Minimum-convex-polygon estimates also were calculated.

Landscape Analysis:

We used satellite images (resolution 1:5000) from Sistema de Información de los Recursos Forestales de Costa Rica (2012) to measure the percentage area covered by green and urban areas and classify the landscape in three categories: (1) plant cover corresponding to forest fragments, riparian vegetation, and other spaces covered by trees; (2) Open green areas like lawns and pastures; and (3) Urban cover including buildings, streets, sidewalks, and other areas impervious surfaces. We estimated the proportions of each habitat type within each home range or core area. We identify the GPS locations taken during the day to determine the types of refuges used for the raccoons: artificial and natural refuges. We used ArcGIS version 10.5.3 to conduct this land cover analysis.

RESULTS

We captured raccoons in 84 occasions during 524 trap nights (in 27 trapping nights) from August 2014 through October 2015: 24 raccoon individuals (five adult males, 11 adult females, two juvenile males and six juvenile females), with a sex radio of 2.4 females/male. Frequency of captured raccoons ranged between zero to nine individuals per trapping night (Mean = 3.1, SD = 2.7) individual per trapping night. Based on the 24 marked individuals in the campus of the Universidad de Costa Rica (0.595 Km^2) we estimate a density of 40.3 raccoons/Km^2.

The best-fit model contained a constant weekly survival and recapture probability (Table 1). Models whit effect of time in survival and recapture had higher AICc values, making them poorer fits. Model including not effect of time on survival and recapture had lower AICc scores. Survival probability estimated from the best-fitting model was high ($\phi \pm SE = 0.929 \pm 0.075$), suggesting that the permanence in the site of the individuals captured was high throughout the study. Weekly recapture probability was low for the best-fitting model ($\rho \pm SE = 0.119 \pm 0.085$).

Home-range, core-area and refuges

During a period of six months we recorded 1061 locations, including 793 nocturnal (139 F1, 487 F2, and 167 M1) and 268 diurnal (27 F1, 206 F2, and 35 M1). Male raccoon M1 home range (52.6ha) and core area (11.2ha) was largest in comparison to females F1 (home range = 3.7ha, core area = 0.8ha) and F2 (home range = 5.6ha, core area = 0.6) (Table 2, Fig. 1, 2 and 3). Females show overlap in their home rages, specifically in the area that is locate the RELO. Male home range overlapped, and included part of the female's home range. Areas used by the three monitored raccoons were located along riparian vegetation of Los Negritos stream (Fig. 1, 2 and 3). The protected areas RELO include home ranges and core areas of the three monitored raccoons and JBO include activity areas for two raccoons (F2 and M1). Home ranges and core areas of the three monitored raccoons include a large proportion of both remnant vegetation fragments and urban cover (Table 3, Fig. 1, 2 and 3).

We identify 11 anthropogenic (2 F1, 7 F2 and 3 M1) and 12 natural (5 F1, 4 F2 and 8 M1) sites used as diurnal refuges (Fig. 1, 2 and 3). One anthropogenic rest site was used by two individuals (F2 and M1), three natural rest sites were used by two individuals (one for F1 and F2, two for F1 and M1), and one natural rest site was used by the three monitored raccoons. Seventeen refuges were located inside or next to green spaces (seven anthropogenic and ten natural), and nine of these refuges (two anthropogenic and seven natural) were located along Los Negritos stream. Anthropogenic refuges correspond to buildings within the university campus and some commercial buildings. Natural resting sites correspond principally to dense vegetation of bamboo and refuges in trees.

DISCUSSION

Our findings are consistent with studies that have documented high densities of raccoons in urban and suburban areas (Gehrt & Fritzell 1997; Prange et al. 2003; Bozek et al. 2007; Prange & Gerht 2004; Prange et al. 2004; Prange et al. 2011). However, density estimated for the study site fell within the lower range of densities reported from other urban/suburban areas (41-333 raccoons/km2) (Gehrt & Fritzell 1997; Prange et al. 2003; Prange et al. 2004; Prange & Gerht 2004; Prange et al. 2011). Given that we did not find information available on populations of raccoons in cities in the Neotropics, we cannot make direct comparisons with other populations of urban or rural raccoons. According to other raccoons populations, adult females outnumbered adult males, and sex ratio in the study area was similar to data reported (Gehrt & Fritzell 1997; Gehrt & Fritzell 1998a; Gehrt & Fritzell 1998b).

Multiple demographic factors for raccoons contributed to high densities at the urban sites, including increased survival, higher annual recruitment, and increased site fidelity (Prange et al. 2003; Prange et al. 2004). The capture of older individuals at the urban sites suggests a higher survival. Juveniles captured throughout the study also may indicate an annual reproduction and recruitment in the study site. In addition, permanency of individuals marked in the site suggests high site fidelity. As in other studies, the urban and suburban populations exhibiting greater site fidelity than the rural population (Gerht & Fox 2004; Bozek et al. 2007). Limited dispersal or reciprocal site fidelity in urban mammals has been hypothesized to be a function of the harsh environment surrounding urban habitat patches and the high quality food and resources consistently available in the urban environment (Lurz et al. 1997; Virgl & Messier 2000; Lin & Batzli 2001; Etter et al. 2002; Prange et al. 2003; McCleery, 2010). For raccoons ability to learn how to take advantage of abundant anthropogenic resources, and high level of intraspecific tolerance contributes for high site fidelity (Gerht et al. 1999; Gerht & Fox 2004; Bozek et al. 2007).

For raccoons, water is a resource that might be expected to control the use of individual space (Lotze & Anderson 1979; Kaufmann 1982). Raccoons are most abundant, and concentrate their activities, near water source and much of their diet is associated with aquatic habitats (Lotze & Anderson 1979; Sanderson 1987; Gerht & Fritzell 1998n). The density of raccoons in the protected forest fragment (RELO) that is crossed by Los Negritos stream, and the localization of the home ranges and core areas of the monitored raccoons along the stream, indicate the importance of this stream and the forest fragment and river side vegetation associated for the raccoon population.

The natural habitats immersed in the urban matrix may also serve to increase the raccoons density and reduce home range size (Prange et al. 2004; Prange & Gehrt 2004; Beasley et al. 2007b; Prange et al. 2011). Additionally, the critical environmental factor allowing for increased densities, as well as reduction in sizes of home ranges, was the abundance of artificial food resource (Prange et al. 2004; Beasley et al. 2007b; Bozek et al. 2007; Wehtje & Gompper 2011). Corresponding whit the high density in the study area and consistently whit our results, urban raccoons typically use smaller home ranges than rural animals: 5-79 ha compared to 50-300 ha, often focusing their activities around sources of anthropogenic food (Gehrt & Fritzell 1997; Kamler & Gipson2003; Gehrt & Fox 2004; Bozek et al. 2007).

Females raccoons appear to space themselves out according to the available food and water resources (Beasley et al. 2007a; Bozek et al. 2007). Where food is more abundant, and many individuals share space without food sources, related females may overlap more in home range and occasionally interact during nocturnal foraging or in diurnal resting burrows (Kamler &

Gipson2003, Gehrt & Fox 2004, Prange et al. 2011). We observed overlap in the home range and core areas of monitored females, and the captures of adults females in a small effective trapping area used to capture raccoons suggest overlaps of the female raccoon population in the study site. Consistently whit other studies in sites whit high density raccoons (Gehrt & Fritzell 1997; Gehrt & Fritzell 1998b; Gehrt & Fritzell 1999; Kamler & Gipson 2003; Chamberlain et al. 2003; Bozek et al. 2007; Prange et al. 2011), male show larger home range and core area than females, and also male overlap females home ranges. Males adopt that allow then to maximize their individual fitness, given this distribution of females (Gehrt & Fritzell 1997; Gehrt & Fritzell 1999; Kamler & Gipson2003; Chamberlain et al. 2003; Prange et al. 2011). In areas with intermediate densities of females, males share space whit other males (Gehrt & Fritzell 1999; Chamberlain et al. 2003; Kamler & Gipson 2003, Prange et al. 2011). These male groups frequently travelled and roost together, overlapping many different females, but no other males (Gehrt & Fritzell 1999; Kamler & Gipson 2003; Prange et al. 2011).

Habitat use was similar between monitored individual; male typically occupied larger home ranges than females, but raccoons selected habitat in their home ranges and core areas with similar preferences. Urban habitat appears to be equal or more utilized than green spaces in the university campus. The study area, with the presence of remnant vegetation creates a high quality habitat, potency by the presence of anthropogenic resources. This urban area receive intensive public use because university campus remains active during most of the year, which result in the formation of well defined, superrich foraging patches in the form of refuse containers. In urbanized environments, artificial food resources are relatively reliable and frequently spatially fixed (e.g., refuse containers), so that raccoons likely remain around these resources and reduces movements to search food (Prange et al. 2004; Bozek et al. 2007; Wehtje & Gompper 2011).

Raccoons are ecological generalists and have adapted to modern landscapes by using burrows in trees, ground, and abandoned buildings (Henner et al. 2004; O'Donnell & DeNicola 2006). In relation whit the activity areas, we observed that refuges selected by raccoons are close to food and water resources and close to green spaces. Availability of free water likely influence raccoon distribution across landscapes (Gehrt & Fritzell 1998b; Beasley et al. 2007b). Reported refuge sites on the university campus are inside or very close to remnant vegetation, and many of these along los Negritos stream. Furthermore, studies suggest that raccoons consistently select refuges with greater availability of free water than was available within their home range (Henner et al. 2004; Beasley et al. 2007b).

Studies suggest that raccoons in high-density populations, such as those in urbanized areas, are at greater risk of disease transmission because will further facilitate transmission of diseases (Page et al. 1998; Prange et al. 2003; Prange et al. 2004). Furthermore, raccoons in urbanized areas represent reservoirs of diseases and parasites that may affect humans and domestic animals, as well as other native species (Wilson et al. 1997; Page et al. 1998; Prange et al. 2004). Overabundance population as we found in the study area and the related increase in interactions with other species intensify the risk to pathogens transmission (McCleery 2010).

Our findings illustrate the importance of green spaces for raccoons populations immersed in urban areas. We found that trees and vegetation represent important natural refuges for raccoons, these burrows sites are mainly restricted and more abundant in forest fragments, emphasizing the importance of natural habitats. However, we suggest a positive relationship between urban habitat use by raccoon population and availability of anthropogenic refuges and food resources. We recommended reduce or eliminate access to anthropogenic food sources (e.g., covering refuse containers, removing refuse before dusk, better treatment and classification for the waste) and identified human structures used by raccoons provide a nonlethal means of managing these populations. Limit propensity for raccoons to frequent urban habitat can decrease the nuisance problems and associate risk to human health. Furthermore, protect and conserve free water and green spaces, including riparian vegetation, isolate forest fragments and areas covered by trees and vegetation in general, provides productive areas for foraging and found refuges within urban ecosystems.

ACKNOWLEDGMENTS

We thank Victor Madrigal and the Red de Áreas Protegidas (RAP) of the Universidad de Costa Rica for the contribution to generate the maps. The Universidad de Costa Rica provided financial support, materials and equipment.

RESUMEN

El mapache (*Procyon lotor*) es una de varias especies silvestres que prosperan en ambientes urbanos. Estimamos el tamaño de la población, la estructura, el ámbito de hogar, las áreas núcleo y los refugios de una población de mapaches urbanos en el campus de la Universidad de Costa Rica, un fragmento de bosque aislado en el área metropolitana de San José, Costa Rica. Se capturaron 24 individuos de mapaches (7 machos y 17 hembras) y se marcaron desde agosto del 2014 hasta octubre del 2015, y se estimó una densidad de 40,3 mapaches/Km^2 para el sitio de estudio. La supervivencia calculada utilizando el modelo Cormack Jolly Seber de estado único sugiere la permanencia de los individuos capturados en el área de estudio. Obtuvimos ubicaciones nocturnas y refugios de un macho y dos hembras utilizando collares con transmisores GPS. Las áreas utilizadas por los tres mapaches monitoreados se localizaron cerca de la vegetación riparia. Los ámbitos de hogar y las áreas núcleo incluyeron una gran proporción de fragmentos de vegetación remanente y cobertura urbana. Identificamos 11 refugios antropogénicos que corresponden a edificios y 12 sitios naturales que corresponden a vegetación densa de bambú y árboles utilizados como refugios diurnos. Una alta densidad de mapaches encontrados en el sitio fue consistente con otros estudios en áreas urbanas y suburbanas. Nuestros resultados enfatizan la importancia de los espacios verdes y cuerpos de agua para las poblaciones de mapaches inmersas en las áreas urbanas. Encontramos que los árboles y la vegetación remanente representan un hábitat natural importante para la búsqueda de alimento y refugios dentro de los ecosistemas urbanos. Además, recomendamos reducir o eliminar el acceso de los mapaches a los recursos antropogénicos como desperdicios de comida en contenedores de basura y las estructuras humanas como solución para disminuir los problemas asociados a la sobreabundancia de los mapaches.

REFERENCES

Alvarado-Barboza, G., & Gutiérrez-Espeleta, G. (2013). Conviviendo con los mapaches: del conflicto a la coexistencia. *Biocenosis*, *27*(1-2), 77-84.

Alvarado-Barboza, G. (2014). Conviviendo con la Fauna: una aproximación a través de los centros de transferencia. *RevistArquis 2*(6), *1-6*.

Aronson, M. F., Lepczyk, C. A., Evans, K. L., Goddard, M. A., Lerman, S. B., MacIvor, J. S., ... & Vargo, T. (2017). Biodiversity in the city: key challenges for urban green space management. *Frontiers in Ecology and the Environment*, *15*(4), 189-196.

Beasley, J. C., Devault, T. L., & Rhodes Jr, O. E. (2007). Home-range attributes of raccoons in a fragmented agricultural region of northern Indiana. *Journal of Wildlife Management*, *71*(3), 844-850.

Biamonte, E., Sandoval, L., Chacón, E., & Barrantes, G. (2011). Effect of urbanization on the avifauna in a tropical metropolitan area. *Landscape Ecology*, *26*(2), 183-194.

Bozek, C. K., Prange, S., & Gehrt, S. D. (2007). The influence of anthropogenic resources on multi-scale habitat selection by raccoons. *Urban Ecosystems*, *10*(4), 413-425.

Brownie, C., Hines, J. E., Nichols, J. D., Pollock, K. H., & Hestbeck, J. B. (1993). Capture-recapture studies for multiple strata including non-Markovian transitions. *Biometrics*, 1173-1187.

Burnham, K. P., & Anderson, D. R. (2002). Model selection and multimodel inference New York. *NY: Springer*.

Calenge, C. (2006). The package “adehabitat” for the R software: a tool for the analysis of space and habitat use by animals. *Ecological modelling*, *197*(3-4), 516-519.

Cooch, E. G., & White, G. C. (2016). Program MARK: Ba gentle introduction^.

Chamberlain, M. J., Conner, L. M., Leopold, B. D., & Hodges, K. M. (2003). Space use and multi-scale habitat selection of adult raccoons in central Mississippi. *The Journal of Wildlife Management*, 334-340.

Crooks, K. R. (2002). Relative sensitivities of mammalian carnivores to habitat fragmentation. *Conservation biology*, *16*(2), 488-502.

Davidson, W. R. (2006). Field manual of wildlife diseases in the southeastern United States. *Field manual of wildlife diseases in the Southeastern United States.*, (Ed. 3).

Etter, D. R., Hollis, K. M., Van Deelen, T. R., Ludwig, D. R., Chelsvig, J. E., Anchor, C. L., & Warner, R. E. (2002). Survival and movements of white-tailed deer in suburban Chicago, Illinois. *The Journal of Wildlife Management*, 500-510.

Gehrt, S. D., & Frttzell, E. K. (1997). Sexual differences in home ranges of raccoons. *Journal of Mammalogy*, *78*(3), 921-931.

Gehrt, S. D., & Fritzell, E. K. (1998a). Duration of familial bonds and dispersal patterns for raccoons in south Texas. *Journal of Mammalogy*, *79*(3), 859-872.

Gehrt, S. D., & Fritzell, E. K. (1998b). Resource distribution, female home range dispersion and male spatial interactions: group structure in a solitary carnivore. *Animal behaviour*, *55*(5), 1211-1227.

Gehrt, S. D., & Fritzell, E. K. (1999). Behavioural aspects of the raccoon mating system: determinants of consortship success. *Animal Behaviour*, *57*(3), 593-601.

Gehrt, S. D., Hungerford, L. L., & Hatten, S. (2001). Drug effects on recaptures of raccoons. *Wildlife Society Bulletin*, 833-837.

Gehrt, S. D., & Fox, L. B. (2004). Spatial patterns and dynamic interactions among raccoons in eastern Kansas. *The Southwestern Naturalist*, *49*(1), 116-121.

Grau, G. A., Sanderson, G. C., & Rogers, J. P. (1970). Age determination of raccoons. *The Journal of Wildlife Management*, 364-372.

Henner, C. M., Chamberlain, M. J., Leopold, B. D., & Burger Jr, L. W. (2004). A multi-resolution assessment of raccoon den selection. *Journal of Wildlife Management*, *68*(1), 179-187.

Hestbeck, J. B., Nichols, J. D., & Malecki, R. A. (1991). Estimates of movement and site fidelity using mark- resight data of wintering Canada geese. *Ecology*, *72*(2), 523-533.

Joyce, AT. (2006). Land use change in Costa Rica: 1996–2006, as influenced by social, economic, political, and environmental factors. Litografía e imprenta LIL, S.A., San José, Costa Rica.

Kamler, J. F., & Gipson, P. S. (2003). Space and habitat use by male and female raccoons, Procyon lotor, in Kansas. *The Canadian Field-Naturalist*, *117*(2), 218-223.

Kaufmann, J. H. (1982). Raccoon and allies. *Wild Mammals of North America*.

Lin, Y. T. K., & Batzli, G. O. (2001). The influence of habitat quality on dispersal, demography, and population dynamics of voles. *Ecological Monographs*, *71*(2), 245-275.

Lotze, J. H., & Anderson, S. (1979). Procyon lotor. *Mammalian species*, (119), 1-8.

Lurz, P. W. W., Garson, P. J., & Wauters, L. A. (1997). Effects of temporal and spatial variation in habitat quality on red squirrel dispersal behaviour. *Animal Behaviour*, *54*(2), 427-435.

McCleery, R. (2010). Urban mammals. *Urban ecosystem ecology*, 87-102.

McKinney, M. L. (2002). Urbanization, biodiversity, and conservation: the impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems. *BioScience*, *52*(10), 883-890.

McKinney, M. L. (2006). Urbanization as a major cause of biotic homogenization. *Biological conservation*, *127*(3), 247-260.

O'Donnell, M., & DeNicola, A. (2006). Den site selection of lactating female raccoons following removal and exclusion from suburban residences. *Wildlife Society Bulletin*, *34*(2), 366-370.

Page, L. K., Swihart, R. K., & Kazacos, K. R. (1998). Raccoon latrine structure and its potential role in transmission of Baylisascaris procyonis to vertebrates. *The American Midland Naturalist*, *140*(1), 180-185.

Prange, S., Gehrt, S. D., & Wiggers, E. P. (2003). Demographic factors contributing to high raccoon densities in urban landscapes. *The Journal of wildlife management*, 324-333.

Prange, S., & Gehrt, S. D. (2004). Changes in mesopredator-community structure in response to urbanization. *Canadian Journal of Zoology*, *82*(11), 1804-1817.

Prange, S., Gehrt, S. D., & Wiggers, E. P. (2004). Influences of anthropogenic resources on raccoon (Procyon lotor) movements and spatial distribution. *Journal of Mammalogy*, *85*(3), 483-490.

Prange, S., Gehrt, S. D., & Hauver, S. (2011). Frequency and duration of contacts between free-ranging raccoons: uncovering a hidden social system. *Journal of Mammalogy*, *92*(6), 1331-1342.

Sanderson, G. C. (1987). Raccoon. *Wild furbearer management and conservation in North America*, 487-499.

Sugiura, N. (1978). Further analysts of the data by akaike's information criterion and the finite corrections: Further analysts of the data by akaike's. *Communications in Statistics-Theory and Methods*, *7*(1), 13-26.

Uno, S., Cotton, J., & Philpott, S. M. (2010). Diversity, abundance, and species composition of ants in urban green spaces. *Urban Ecosystems*, *13*(4), 425-441.

VanDruff, L. W., Bolen, E. G., & San Julian, G. J. (1994). Management of urban wildlife. *Research and management techniques for wildlife and habitats*, 507-30.

Virgl, J. A., & Messier, F. (2000). Assessment of source-sink theory for predicting demographic rates among habitats that exhibit temporal changes in quality. *Canadian Journal of Zoology*, *78*(8), 1483-1493.

Wagenmakers, E. J., & Farrell, S. (2004). AIC model selection using Akaike weights. *Psychonomic bulletin & review*, *11*(1), 192-196.Wehtje, M., & Gompper, M. E. (2011). Effects of an experimentally clumped food resource on raccoon Procyon lotor home-range use. *Wildlife Biology*, *17*(1), 25-32.

White, G. C., & Burnham, K. P. (1999). Program MARK: survival estimation from populations of marked animals. *Bird study*, *46*(sup1), S120-S139.

Wilson, M. L., Bretsky, P. M., Cooper Jr, G. H., Egbertson, S. H., Van Kruiningen, H. J., & Cartter, M. L. (1997). Emergence of raccoon rabies in Connecticut, 1991–1994: spatial and temporal characteristics of animal infection and human contact. *The American journal of tropical medicine and hygiene, 57*(4), 457-463.

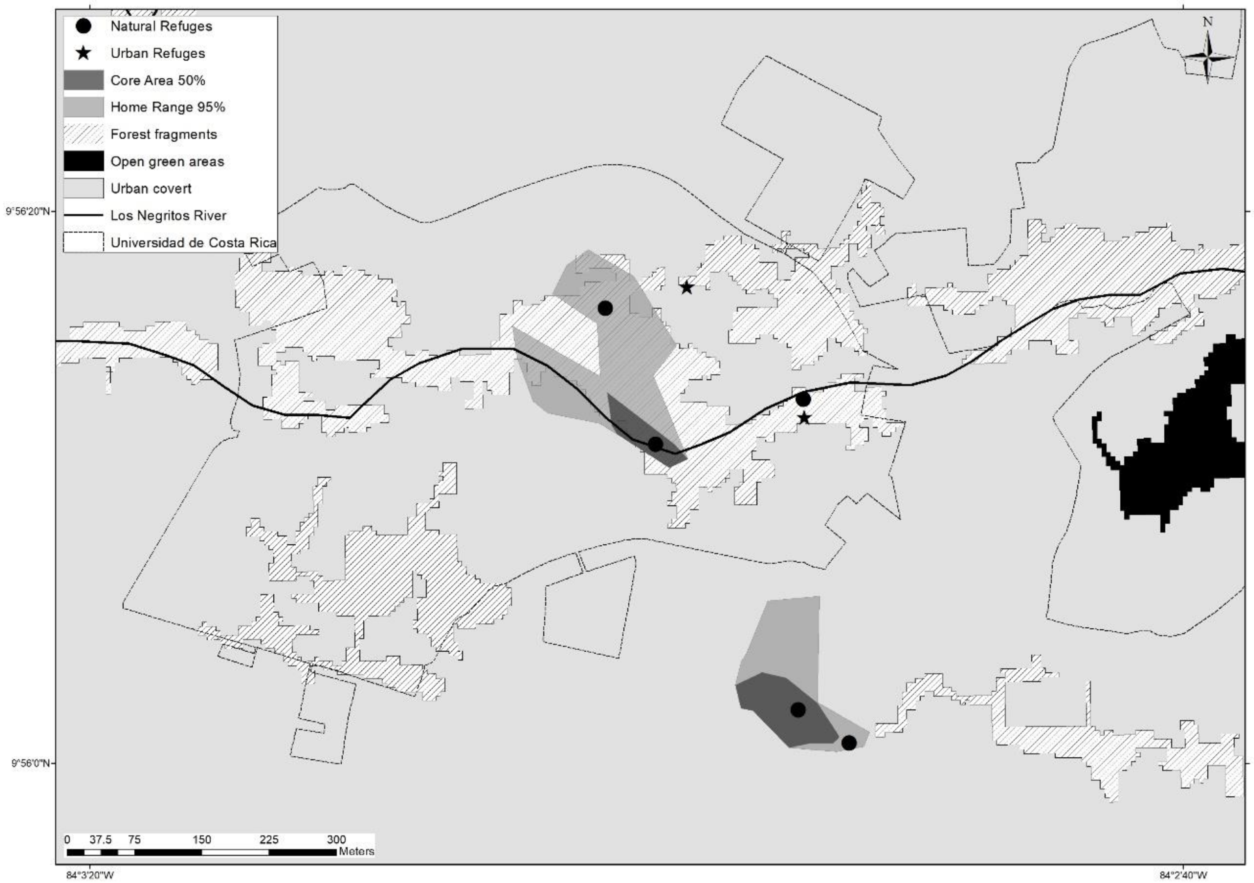

Figure 1. Home range 95% and core area 50% using adaptative local convex hull (a-LoCoH) nonparametric kernel and refuges of the female raccoon F1 within the three landscape covers in the study site, June-September 2015.

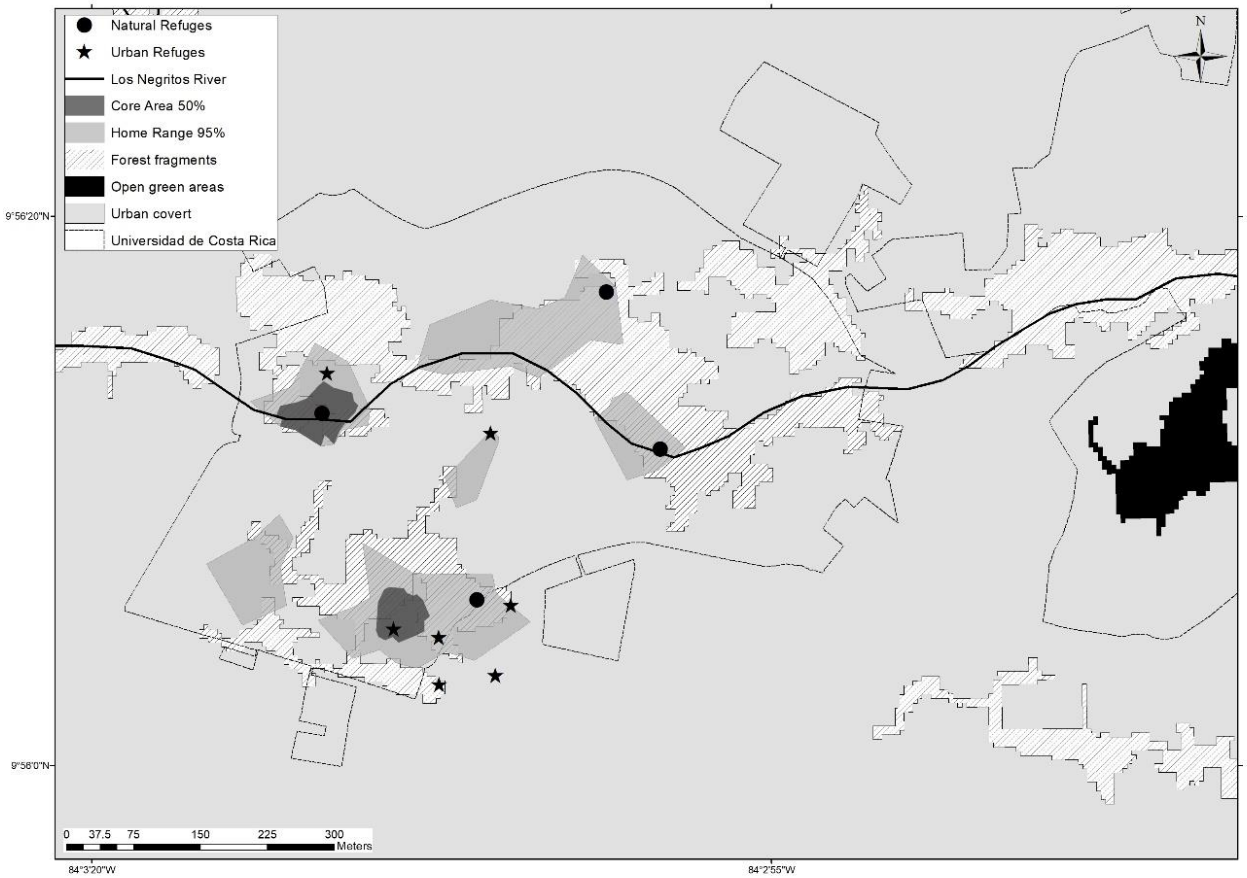

Figure 2. Home range 95% and core area 50% using adaptative local convex hull (a-LoCoH) nonparametric kernel and refuges of the female raccoon F2 within the three landscape covers in the study site, October-December 2015.

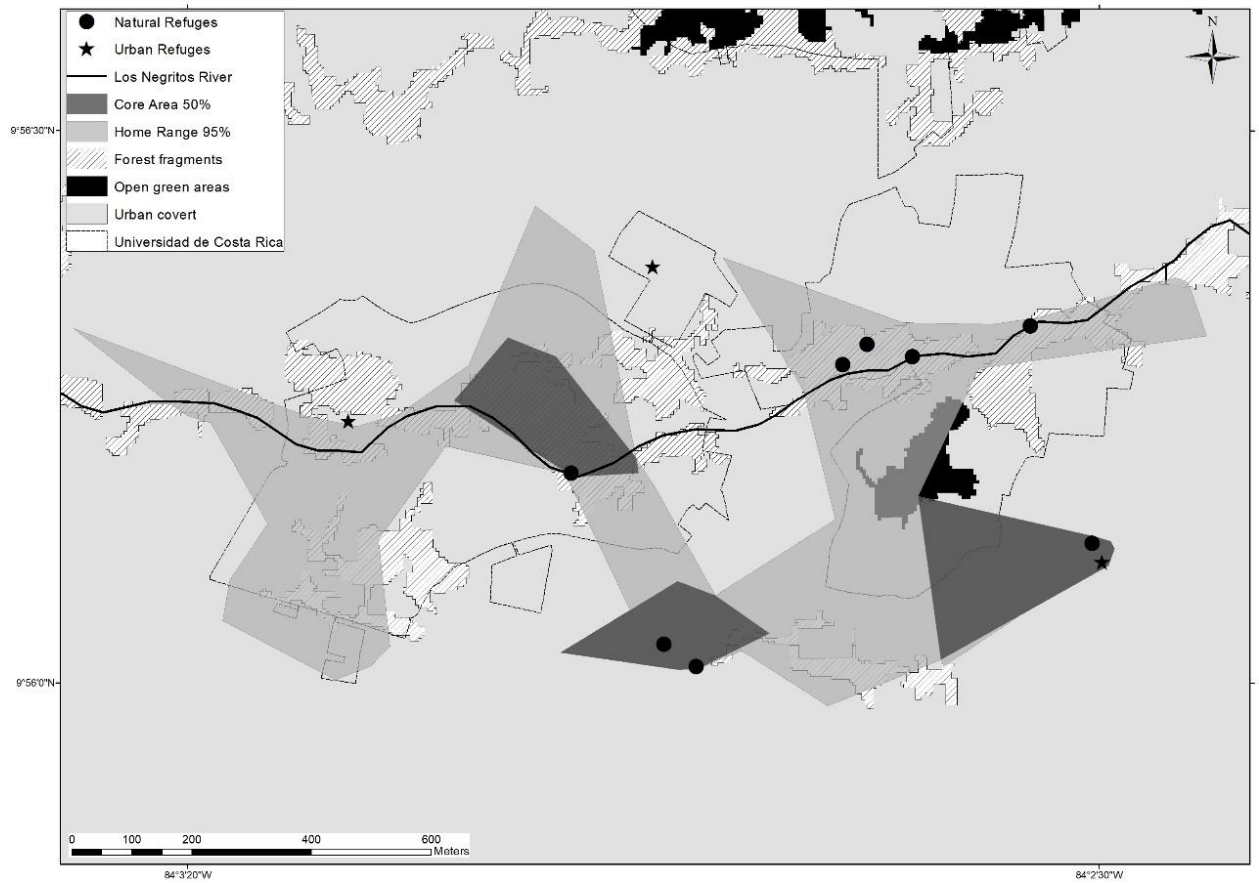

Figure 3. Home range 95% and core area 50% using adaptative local convex hull (a-LoCoH) nonparametric kernel and refuges of the male raccoon M1 within the three landscape covers in the study site, October 2015.

Table 1. Representative single-state models to assess the effect of time on weekly survival (ϕ) and recapture (*ρ*) probabilities in 24 raccoons (*Procyon lotor*) individuals, captured in the campus of the Universidad de Costa Rica, August 2014-October 2015 (k = number of estimable parameters; ω = Akaike model weight).

Model	AICc	ΔAICc	K	ω
ϕ(.)*ρ*(.)	24110.75	0.00	2	0.99968
ϕ(.)*ρ*(t)	24126.86	16.11	13	0.00032
ϕ(t)*ρ*(.)	24150.30	39.55	22	0.00000
ϕ(t)*ρ*(t)	24247.57	136.82	41	0.00000

Table 2. Home ranges and core areas of adult raccoons in the campus of the Universidad de Costa Rica, San José, Costa Rica, August 2014-December 2015.

Monitored Individuals	Interval	Nights	Numbers of locations	Minimum Convex Polygon (MPC) 100% (ha)	Adaptative local convex hull (a-LoCoH) nonparametric kernel		
					100% home range (ha)	95% home range (ha)	50% core area (ha)
F1	06/19/2015 to 09/06/2015	42	166	12.7	5.5	3.7	0.8
F2	10/8/2015 to 12/11/2015	62	693	20.3	9.5	5.6	0.6
M1	10/9/2015 to 10/28/2015	19	202	124.4	67.7	52.6	11.2

Table 3. Size and percentage of habitat types within each home ranges and core areas of monitored raccoons in the campus of the Universidad de Costa Rica, September-December 2016.

Monitored Individuals	Adaptative local convex hull (a-LoCoH) nonparametric kernel	Habitat types		
		Vegetation cover	Open green areas	Urban cover
F1	Home range 95%	1.72 (47%)	0	1.94 (53%)
	Core area 50%	0.23 (28.4%)	0	0.58 (71.6%)
F2	Home range 95%	2.98 (53.1%)	0	2.63 (46.9%)
	Core area 50%	0.32 (50%)	0	0.32 (50%)
M1	Home range 95%	11.60 (22%)	1.20 (2.3%)	39.84 (75.7%)
	Core area 50%	2.99 (26.7%)	0.01 (0.1%)	8.21 (73.2%)

APÉNDICES

Anexo 1. Refugios naturales y artificiales utilizados por los tres mapaches monitoreados entre Junio y Diciembre del 2015 en el campus de la Universidad de Costa Rica y alrededores, San José, Costa Rica.

Mapache	Natural	Artificial
F1	• Bambú Puente Química-Generales • Vegetación detrás del LEBI • Bambú Música-Bellas Artes • Vegetación Colegio Vargas Calvo 1 • Vegetación Colegio Vargas Calvo 2	• Edificio Microbiologia • Edificio Bellas Artes
F2	• Bambú Comedor • Bambú Puente Química-Generales • Vegetación detrás del LEBI • Bambú Jardín Botánico Orozco	• Edificio Comedor Estudiantil • Edificio Física-Matemáticas • Edificio Arquitectura • Edificio Radio U • Local Amargura 1 • Local Amargura 2 • Local Amargura 3
M1	• Bambú Puente Química-Generales • Vegetación Colegio Vargas Calvo 1 • Vegetación Colegio Vargas Calvo 2 • Vegetación Ciudad de la Investigación 1 cercana a casas • Vegetación Ciudad de la Investigación 2 detrás INISA • Vegetación Ciudad de la Investigación 3 • Vegetación Ciudad de la Investigación 4 edificio de parqueo • Vegetación Lourdes	• Edificio Comedor Estudiantil • Edificio CIGRAS • Edificio Lourdes