

Behavioral Changes to Anthropogenic Environments in Two Species of Macaque

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Abstract

Primatology is often conducted in the wild, focusing on elucidating how species live in the ecology of their native habitat. As human development has increased across the globe, more attention should be paid to how primates adapt to the anthropogenic environment. This study reviewed the published literature on *Macaca fascicularis* and *sylvanus*, comparing quantitative aspects of the species' behavior in differing degrees of anthropogenic environments. Anthropogenic habitation was expected to lead to greater consumption of human foods, smaller home ranges, longer resting times, and larger social groups. In *M. fascicularis*, a statistically significant relation was found between group size and habitat, but no relation was found for the other counts in either species. A call for more research into these populations' ecology and behavior is presented.

Keywords: *urbanization, Anthropocene, urban ecology*

1 Introduction

The sciences of ecology and wildlife biology were born of a sense of exoticism, a Romanticist question of how the natural world came to be that in its climax allowed thinkers like Darwin to explore the world in pursuit of ever more novel findings and ideas (Nichols, 2005). Today biologists continue to focus on the pristine, basing their models of species and ecological change on the “natural” world unmolested by human encroachment. Today, however, humans have changed the face of the planet in many cases beyond recognition from the “natural” order. Despite its frequent dismissal in ecological study, the human environment has its own ecology and unique resources that it itself should be considered from an ecological lens. An analysis of the primatology fieldwork that has heretofore been conducted in such environments is needed to understand the state of the field.

1.1 The Anthropogenic World

Human society has had a profound impact on the ecosystems of the Earth, radically changing in only a few centuries how wide swaths of the planet, terrestrial and marine, Accordingly, geologists and climate scientists have donned the current epoch the “Anthropocene” (Crutzen & Stoermer, 2000; Lewis & Maslin, 2015). While scholars debate the exact onset of this geologic era, whether 8,000 years before present (Kirch, 2005; Ruddiman, 2003) or as recent as the Industrial Revolution (Crutzen, 2002), it is indisputable that the majority of terrestrial life on the planet has been impacted in some way by human expansion.

Conservation of the natural environment is a laudable goal, as there is no better way to protect biodiversity and endangered species than to set aside undisturbed land (Hatfield et al., 2019; Newmark, 1995). However, it cannot be denied that human settlement has drastically reduced the total land area possible for such undisturbed conservation. The anthropogenic environment is as much a part of the ecological landscape as is a coral reef, and its study can provide insight into the evolution and development of populations in an increasingly human-dominated world.

Despite this pressing need to consider anthropogenic environments, ecology research – and primatology in particular – has persistently remained far from human environments. Only between 0.4% and 6% of ecology research has been conducted in the 75% of Earth's ice-free terrestrial surface that harbors human settlement (Collins et al., 2000; Miller & Hobbs, 2002). Conservation biologists' and ecologists' focus on the idea of a "wilderness" leaves the flora and fauna of cities little understood (Niemelä, 1999), although when population censuses are taken in cities as developed as Phoenix, Arizona and Baltimore, Maryland, researchers have been surprised by the diversity present (Kloor, 1999).

1.2 Anthropogenic Environments as Primate Habitats

Primatologists in particular prefer to conduct research at a small array of permanent, long-term field sites, which fails to account for the primates who are not represented (Bezanson & McNamara, 2019). This model of research has of course benefits, mainly its desire to maintain relations with the local community and in its producing comparative and consistent results. Certainly the exotic field-site model has served conservationists and researchers well in the past half-century. However, understanding how the subjects of primatology research fit into the rest of the world is just as – if not more – important in the current global environment.

Most of the prevailing research of the human-nonhuman divide falls into one of two camps: that of ethnoprimateology or that of interspecies conflict management. The former primarily looks at the species divide through an ethnographic lens, in which humans and nonhuman primates together shape a social space each with shared and distinct roles (Fuentes, 2012; Riley, 2013). The latter consists of a diverse array of ecological scholarship aimed at reducing primate endangerment in human environments such as roadways (Lindshield, 2016), analyzing primate effects on cultivated crops (Hill, 2017; Hockings, Yamakoshi, & Matsuzawa, 2017; McKinney, Westin, & Serio-Silva, 2015), and physical conflict (Hoffman & O'Riain, 2012). Recently, researchers have begun to apply focal-animal sampling techniques to primates in troops that have made their home ranges either wholly or partially inside heavily developed areas. Specifically, there is now a wealth of *Macaca* spp. diet and range information which can be directly compared to research on those same species in less anthropogenic environments. Urban primate populations that have undergone recent study include those of *M. sylvanus* in Gibraltar (Klegarth et al., 2017; Kwiatt, 2017) and Béjaïa (Maibeche, Moali, Yahi, & Menard, 2015) and of *M. fascicularis* in Singapore (Klegarth et al., 2017).

1.3 Hypotheses

The null hypothesis is the prediction that in all surveyed characteristics, *M. sylvanus* and *M. fascicularis* individuals do not differ when in anthropogenic versus wild environments. Four alternative hypotheses are presented:

1. *Anthropogenic-dwelling macaques exhibit a dietary shift with a bias toward human foods.* The higher relative availability of human foods in such environments provides an ample source of nutrition when the foods that make up the animals' natural diets are not obtainable.
2. *Anthropogenic-dwelling macaques exhibit smaller ranges and shorter daily path lengths.* Urban and rural human-inhabited areas present a higher density of environmental hazards, including vehicular traffic and physical conflict with people. It is predicted that in such environments, animals would travel less to avoid danger.
3. *Time spent resting is directly correlated with consumption of human foods, while time spent feeding is indirectly correlated.* The energy density of human foods is often much higher than that of foods growing in the wild, as a result of both processing and domestication. Macaques that can access such foods regularly may be able to decrease the amount of time spent feeding to reach their needed caloric intake.

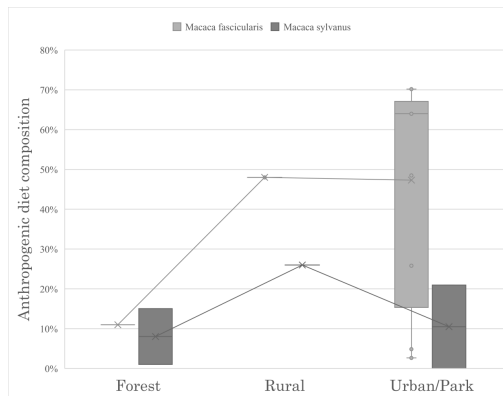


Figure 1: Dietary Composition of Macaques by Habitat

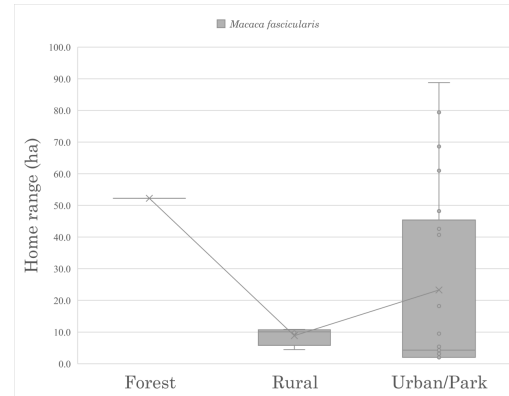


Figure 2: Home Range Size of Macaque Groups by Habitat

4. *Anthropogenic-dwelling macaques live in larger social groups.* A lack of predation and more reliable access to food are expected to reduce a pressure toward small group sizes, allowing macaque groups in such environments to grow to larger sizes than would be expected in the wild.

1.4 Review of Literature

1.4.1 Collection of Data

Due to the frequency with which researchers survey urban populations of the two species, *M. sylvanus* and *M. fascicularis* were chosen as the target species for comparison. 13 studies were found to cover at least one of the two species' behavioral patterns in anthropogenic or "wild" habitat. Data collected from each study, where present, included the environment (as urban/park, peri-urban, rural, or forest), the percentage of the group's home range that was anthropogenic, the number (minimum, maximum, and mean) of individuals, survey method, home range (either MCP or KDE), daily path length, movement rate, diet (natural: yes, no; refuse: no, minor, extensive; sanctioned provisioned: no, yes; illicit provisioned: no, minor, extensive; and raided: no, minor, extensive, also as percentages when available), and activity budget (percent of time spent resting or feeding).

2 Results

2.1 Data Analysis

Data were entered into a spreadsheet and analyzed using Microsoft Excel version 1911. A list of all macaque groups identified is available in Table 1.

2.1.1 Hypothesis 1

On the question of anthropogenic foods in macaque diets, very little information was found in studies of forest- or rural-dwelling animals of either species. Furthermore, there were multiple groups of urban-dwelling macaques whose anthropogenic food consumption was far lower than expected, and even lower than some forest groups (*M. fascicularis* min. 3%, *M. sylvanus* min. 0%; see Figure 1). The first hypothesis, that anthropogenic foods are correlated with anthropogenic habitation, is not accepted.

2.1.2 Hypothesis 2

M. Sylvanus studies were excluded from home range size comparisons as they lacked enough data for the three habitat types. In *M. fascicularis*, while rural home ranges were overwhelmingly smaller than forest ranges, there was an extremely wide range of urban home ranges (min. 2.0 ha, mean 4.3 ha, max. 88.8 ha;

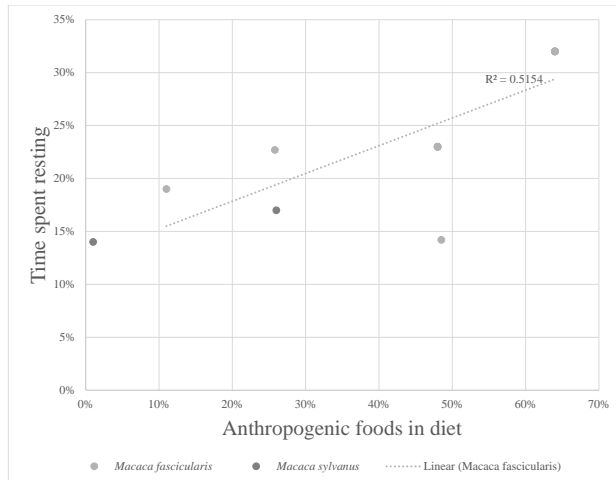


Figure 3: Resting Time as a Function of Anthropogenic Food Consumption

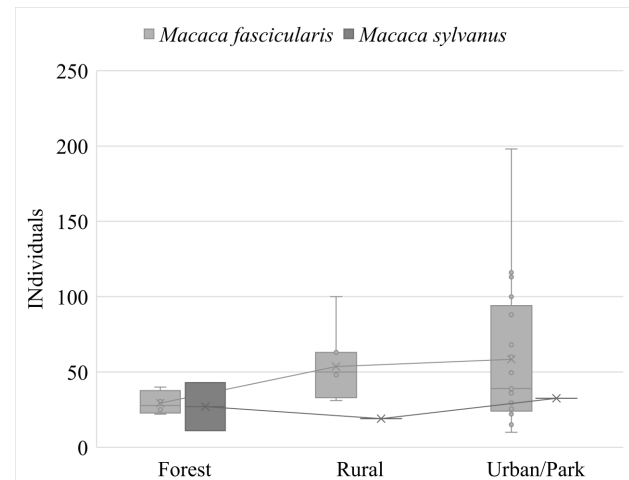


Figure 4: Individuals per Macaque Group by Habitat

see Figure 2) that overlaps the ranges for both forest and rural macaques' home ranges. On this count there is not enough information to accept the second hypothesis.

2.1.3 Hypothesis 3

Few studies included both the time spent resting and the proportion of animals' diet deriving from anthropogenic sources, with two and five in *M. sylvanus* and *fascicularis*, respectively. Making a linear model is of no use in the two-datapoint set, so only *M. fascicularis* was analyzed. With a positive trendline and R^2 of 0.52, there is tentative evidence of a correlation between diet and energy expenditure. Without more data, however, hypothesis 3 cannot be reliably accepted.

2.1.4 Hypothesis 4

Of the 53 *Macaca* groups identified from the literature, 19 lacked censuses of group size. There is not enough data for a conclusive picture of *M. sylvanus*, but some conclusions may be drawn from the data on *M. fascicularis*. While forest-inhabiting groups ranged from 22 to 40 individuals in size, urban-dwelling populations existed in a much larger range of group sizes from 10 to 198 individuals, with most occurring in the 24-94 range. Albeit with large margins of error (see Figure 4), there is a statistically significant ($p < 0.05$) result for group size. At least for *M. fascicularis*, the fourth hypothesis – that anthropogenic-dwelling macaques live in larger social groups – can be tentatively accepted.

3 Discussion

It was difficult to find enough primatology studies that had been conducted in anthropogenic environments, a finding reflective of Collins et al.'s 2000 finding of 0.4% of ecology research having an urban focus. A more thorough investigation of which species are most heavily focused on in such research may allow for a more comprehensive comparison. More importantly, however, it is necessary to grow the state of the primary literature so that a more comprehensive understanding of the ecologies of both cities and these species.

Overall, there is not enough published data to confirm or reject the null hypothesis, let alone any of the four alternative hypotheses proposed. There was tentative evidence for hypotheses three and four: a connection between diet and activity budget and between group size and habitat. On the former, it is necessary to perform more studies that include both anthropogenic diets and activity budget, which can allow for a larger sample size in comparisons. Furthermore, a correlation does not fully explain such a phenomenon.

The energy densities of those specific foods which are eaten by the studied populations should be evaluated to ensure that the hypothesis is backed with biological significance. Few studies, even those which described anthropogenic food consumption, explained which foods the animals were eating, be they fruits or processed foods. In pursuit of the latter hypothesis, group size data on *M. sylvanus* would help to allow a cross-species comparison, but it remains interesting that the group sizes observed have such a wide range. It is likely that the hypothesis of lower predation allowing larger group sizes is too simple a model to explain the phenomenon of anthropogenic-dwelling macaques.

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Table 1: Collected literature on *Macaca* spp. behavior.

Source	Species	Location	Name	Habitat	Urban ¹	Individuals	KDE (ha) ²	DPL (km) ³	Food			Time spent		
									Garbage	Provisioned	Raided	Total	Resting	Feeding
Maibèche et al. (2015)	<i>sybanus</i>	Béjaïa	Les Oliviers	Urban		33			No	Moderate	No	0.21		
			Cap Car-bon	Forest		43			No	Minor	No	0.15		
Klegarth et al. (2017)	<i>fascicularis</i>	Singapore	SG-BB	Urban	0.58		35	1.37	Moderate	Minor				
			SG-BNTR ⁰¹	Urban	0.05		34.70	1.56	Minor	No				
			SG-BNTR ⁰²	Urban	0.19		23.8	0.72	Moderate	Minor				
			SG-BTRR	Urban	0		42.7	0.95	Minor	No				
			SG-MNCF	Urban	0.11		40.80	2.16	Moderate	Minor				
			SG-RR	Urban	0		54.7	1.11	No	Minor				
			SG-WW	Urban	0		25.9	1.53	Minor	Moderate				
			GIB-AD	Urban	0.36		12.4	1.48	Moderate	Extensive				
			GIB-CC	Urban	0		9.5	1.4	Minor	Extensive				
			GIB-LBI	Urban	0		10.8	1.09	Moderate	No				
			GIB-MH	Urban	0.27		83.3	3.46	Moderate	Moderate				
			GIB-PPA	Urban	0		13.7	1.21	Minor	Extensive				
			GIB-RAW	Urban	0		20.10	1.6	Moderate	Extensive				
Sha and Hanya (2013)	<i>fascicularis</i>	Singapore	High	Urban		26	9.5	1.48	Moderate	Moderate		0.49	0.14	
			Low	Urban		22	18.2	1.8	Minor	Moderate		0.26	0.23	
Ilham et al. (2017)	<i>fascicularis</i>	West Sumatra	A	Urban		36	2		Moderate	Moderate		0.7		
			B	Urban		28	2		Moderate	Moderate		0.7		
			C	Urban		68	2		Moderate	Moderate		0.7		
			X	Urban		15	2		Minor	Minor		0.05		
			G	Urban		10	2		Minor	Minor		0.03		
			P	Urban		15	2		Minor	Minor		0.03		
			E	Urban			34							
Wong (1994) el Alami et al. (2012)	<i>sybanus</i>	Kowloon Ozoud Falls	E	Urban										
			Semi-provisioned Wild-feeding	Rural		19						0.26	0.17	0.28
Fuentes et al. (2011)	<i>fascicularis</i>	Bali	1	Forest		11						0.01	0.14	0.26
Md-Zain et al. (2011)	<i>fascicularis</i>	Universiti Ke-bangsaan Malaysia	1	Rural		31	7.2		No	Extensive			0.23	
			2	Rural		100	11		No	Extensive			0.23	
			3	Rural		63	17		No	Extensive			0.23	
	<i>fascicularis</i>	Universiti Ke-bangsaan Malaysia	LF	Urban		60			Moderate	Minor				
			KBH KIY	Urban		39			Moderate	Minor				
				Urban		37			Moderate	Minor				

¹Percent of home range occupied by anthropogenic structures²Home range using KDE³Daily path length⁴Combined managed provisioning and illicit provisions (e.g. tourists)

Schurr et al. (2012)	<i>syllanus</i>	Gibraltar	KAB	Urban	23			Moderate	Minor		
			KRK	Urban	52			Moderate	Minor		
			KIZ	Urban	30			Moderate	Minor		
			KKM	Urban	50			Moderate	Minor		
			PBP	Urban	100			Moderate	Minor		
Brotcorne (2014)	<i>fascicularis</i>	Bali	AD	Urban						0.77	
			PPA	Urban						0.76	
			MH	Urban						0.5	
			TNBBg	Forest	25	0.14	32.5	Moderate	No	Minor	0.11
			Nez	Rural	48	0.52	6.6	Minor	No	Moderate	0.48
			Tear	Rural	33	0.52	5.9	Minor	No	Moderate	0.48
			Temple2	Rural	50	0.52	2	Minor	No	Moderate	0.48
			Scarface	Rural	50	0.52	9.5	Minor	No	Moderate	0.48
			Cemetery	Urban	88	0.74	1.7	Minor	No	Extensive	0.64
			East	Urban	113	0.74	4.10	Minor	No	Extensive	0.64
			Michelin	Urban	116	0.74	2.9	Minor	No	Extensive	0.64
			Central	Urban	102	0.74	4.40	Minor	No	Extensive	0.64
			Temple	Urban	198	0.74	3.4	Minor	No	Extensive	0.64
			A	Forest	22	0					0.32
van Noordwijk and van Schaik (1999)	<i>fascicularis</i>	North Sumatra									0.34
											0.27
											0.27