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Managing the Small Indian Mongoose (*Herpestes javanicus*) in the Midst of Human Recreation: What is the Optimal Approach?

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ABSTRACT: In natural recreation areas, habituated wildlife can pose a threat to visitor health and safety by transmitting disease or causing physical injury. Although removal of problem wildlife can help to alleviate these problems, it can also be a labor-intensive, costly practice. To improve the efficiency of a removal program, trapping efforts should be directed towards the spatial and temporal peaks of the target species' activity patterns. An animal's activity is often dictated by environmental conditions such as season or lunar phase; however, in a recreation area, it can also be affected by anthropogenic factors such as human presence and provisioning of food sources (i.e. trash cans or picnic areas). A species can 1) be attracted to anthropogenic food sources when human presence is highest, or 2) be attracted to anthropogenic food sources, but only when humans are not present, or 3) avoid anthropogenic food sources and human presence entirely. Each of these scenarios would necessitate a different management strategy to achieve the highest level of trapping efficiency. In the Caribbean National Forest, Puerto Rico, small Indian mongooses are currently controlled by removal trapping to reduce the threat of rabies transmission. Although trapping usually occurs diurnally near areas of high human use, it is unknown whether or not this strategy targets the highest number of animals. Using radiotelemetry, we investigated the movement behavior of 7 mongooses trapped in the picnic areas. We determined animals' hourly travel distances, activity levels (moving or stationary), and distance of animal locations from human structures (trails, trash cans, and picnic cabanas); and compared these measures between days of high and low visitorship. The distance mongooses were found from human structures was not affected by the day of the week. Activity levels and movements varied by day, but it was unclear how this variation was affected by forest visitor levels. This paper will discuss how these results can be used to develop the most efficient trapping strategy.

KEY WORDS: activity, anthropogenic food, exotic species, *Herpestes javanicus*, invasive species, mongoose, predator control, Puerto Rico, recreation, trapping

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INTRODUCTION

The ability of humans to view and interact with wildlife is usually considered a valuable component of recreating in natural areas. However, in some cases, the close proximity of wild animals to humans results in unwanted consequences. For example, both black and grizzly bears in national parks can cause injury to humans and extensive damage to property (Gniadek and Kendall 1998, Matthews and Lackey 2003). Raccoons and squirrels in urban parks and neighborhoods have been implicated in injury and disease transmission (Daniels *et al*. 1997, Roussere *et al*. 2003). Several bird species, particularly corvids and geese, can harass humans (Jones and Nealson 2003), foul recreation areas, and potentially spread disease (Welsh *et al*. 1992, Gorenzel and Salmon 1992, Ankney 1996). Active management either through exclusion or population reduction must often be initiated when human-wildlife conflict reaches unacceptable levels (Treves and Naughton-Treves 2005).

Many human-wildlife conflicts occur even though species actively attempt to avoid people either spatially or temporally. However, in many cases, human presence itself draws animals to recreation areas. Recreational developments in natural areas such garbage bins, picnic areas, and trails can serve as a significant supplemental food source to wildlife (see Fedriani *et al*. 2001). Animals either can feed on human foods directly (Gilchrist and Otali 2002) or can benefit from the habitat created by human use; for example, an increase in prey populations or the creation of "edge" habitat (Yahner 1988).

Species using human recreation areas as a resource can respond to humans directly in several ways. First, they may attempt to use the area only at times of reduced human presence. For example, foxes, wolves, and bears using human use areas have all been observed to have more nocturnal activity patterns than remote-living conspecifics (Vila *et al*. 1992, Harrison 1997, Beckmann and Berger 2003). In other instances, species exhibit a more proximate response, abandoning an area when humans arrive (Smith and Johnson 2004). Alternatively, other species seem to use the presence of humans as a cue for food resources. These species actively follow or habituate to human activity (Gutzwiller *et al*. 2002).

For problem wildlife that must be managed, their behavioral response to humans in recreation areas should determine the most efficient strategy. When targeting species that use human-use areas but avoid human presence, exclusion, trapping, or hazing near human-use areas should occur at night or on days when there are few human visitors. Conversely, for species that are attracted to the presence of humans, management in recreation areas should occur on the days/seasons of highest visitorship (i.e., weekends or summertime) to target the highest number of animals. In management practices, the ability to take advantage of these variations in behavior becomes especially crucial when time, money, or personnel dedicated to the control program are limited.

The small Indian mongoose (*Herpestes javanicus*) is an opportunistic omnivore introduced to islands of the world to control rat populations in sugarcane fields in the late 19th Century (Espuet 1882, Baldwin *et al*. 1952, Gorman 1979, Hoagland *et al*. 1989). However, due to its eventual inefficacy in depressing rat populations and its adverse impacts on native species (Seaman 1952, Nellis and Everard 1983), attempts at reducing the populations were soon initiated. Despite these efforts, the mongoose continues to maintain stable populations in most of the islands to which it was introduced.

In the Caribbean National Forest, Puerto Rico, the mongoose population is of high management concern (Velez 1998). Mongooses quickly habituate to anthropogenic food sources (Nellis and Everard 1983, Coblentz and Coblentz 1985), and the high levels of human recreation in the Caribbean National Forest are thought to attract the animals. Not only are mongooses documented predators of native species (Engeman *et al*. 2006), but they also accounted for 75% of reported rabies cases in 2004 and are the primary vectors and reservoirs of the disease in Puerto Rico (Krebs *et al*. 2005). Frequent sightings of rabid mongooses, mongoose attacks on visitors, and the high seroprevalence of rabies (19.3% seropositive; Velez 1998) cause significant management concerns in the Caribbean National Forest.

Mongooses are managed in the Caribbean National Forest primarily through removal trapping, which occurs on the relatively small scale of setting up to 15 traps per day for between 1 and 5 days per month, on average. One employee is dedicated to the task, but this individual also is responsible for control of numerous other species in the forest such as bees, feral dogs, feral cats, non-native iguanas, etc. Thus, maximizing the efficiency of his time spent targeting each species is crucial.

In 2002, we initiated research investigating mongoose space use behavior in the Caribbean National Forest. Specifically, we were interested in the effects of anthropogenic food associated with human recreation on mongoose space use and social behavior across two seasons. Our goals were to assess the risk of rabies transmission in these two types of areas and also to inform current management strategies related to trap or bait spacing and seasonal timing. Results from our study indicated that mongooses responded to the presence of human activity: they had smaller home ranges in areas of high human use (Quinn and Whisson 2005). In this paper, we investigated whether or not mongooses also responded to the day-to-day variation in visitor levels. It had been generally accepted that mongooses descended on recreation areas on days when human presence was at its highest levels, and that they stayed relatively close to those areas while humans were there. Thus, we predicted that mongooses would 1) move smaller distances, 2) be less active, and 3) be found closer to human-used areas on days of higher visitor use.

METHODS

Study Area

The Caribbean National Forest (CNF), Puerto Rico is located in the Sierra de Luquillo Mountains, about 40 km east of the city of San Juan (Figure 1). The CNF encompasses approximately 11,500 ha of virgin forest over extremely rugged terrain. Four forest types are classified in the CNF, delineated by elevation and structure: Tabonuco (occurring in the foothills at elevations below 610 m), Dwarf or Elfin woodlands (cloud forest occurring on ridge tops above 850 m), Palo Colorado, and Sierra Palma (both occurring in the middle elevations between 600-850 m). Rainfall averages 300 cm annually throughout the CNF. Seasons are generally classified as wet (May-October) or dry (November-April), but frequent rain can obscure these seasonal patterns. Temperatures range between 17 and 21°C, with the warmer temperatures occurring in June-August. The CNF attracts about 1 million visitors per year. Most visitor activity occurs in the developed visitor areas; the Palo Colorado, Quebrada Grande, Caimitillo, and Sierra Palma picnic areas; the trails radiating out from the picnic areas; and at the El Portal Visitor Center. These developed areas represent only 4.6 % of the total forest area, and the remainder sees very little human use (USFS 1997).

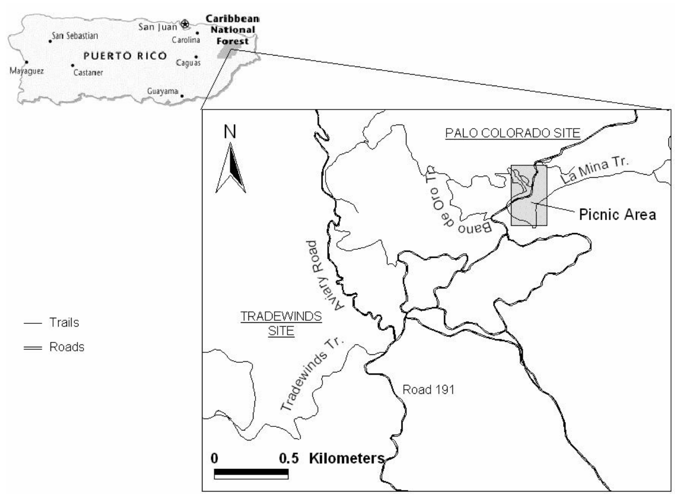

Figure 1. Map of study area, Caribbean National Forest, Puerto Rico.

We conducted our study from 2 October to 18 December 2002 (dry season) around the Palo Colorado visitor center and recreation area along La Mina Trail. Palo Colorado is the most heavily used area of the forest, with about 30 cabanas, cook pits, trash cans, and cobbled trails that have been developed for picnics and tours. Although the area is opened to the public from 7:30 a.m. to 6 p.m., most visitation occurs between the hours of 10 a.m. and 4 p.m. Recreation activities include hiking, swimming in the river, picnicking, and barbequing. Hiking groups range in size from single individuals to large groups of up to 20 people with a guide. Picnicking group size is also variable, from 1 or 2 people to groups of 20 or more.

Vegetation throughout the site is classified as Palo Colorado (*Cyrilla raciflora*) forest, although Sierra Palm (*Prestoea montana*) is dominant on gentle slopes and in drainages. The area is also interspersed with patches of dense native vegetation dominated by coral plant (*Hamelia patens*) and non-native ornamental vegetation dominated by bamboo (*Bambusa vulgaris*), firecracker plant (*Sanchezia speciosa*), and impatiens (*Impatiens* sp.).

Trapping and Animal Handling

Mongooses were trapped during October 2002 using Tomahawk (Tomahawk Live Trap Co., Tomahawk, WI) and Havahart (Woodstream Corp., Lititz, PA) live traps baited with canned tuna packed in water. We placed 30 traps at 50-m intervals along 2 of the trails in 2 of the picnic areas, hiding traps in vegetation 1 to 5 m off-trail, and approximately 50 m into the forest behind the picnic area. We set the traps in the morning between 0700h and 0900h and checked them once in the afternoon between 1500h and 1700h. Traps were closed overnight.

Animals greater than 400 g were immobilized with a 0.2 cc to 0.4 cc intramuscular injection of ketamine chloride (Ketaset®). Eye lubricant applied to both eyes prevented drying. We recorded the weight, reproductive status, and general physical condition of each animal. Mongooses were classed as mature when the testicles were descended (males) and if nipples seemed dark or worn (females), otherwise they were classed as juveniles. We then ear-tagged each animal and fitted them with 2-stage radio-transmitters (40 pulses per minute, frequency range of 150.100-150.400 mHz) mounted on nylon radio collars (Sirtrack Ltd., New Zealand) weighing approximately 21 g. Animals were returned to traps for at least 6 hrs after anaesthesia to ensure complete recovery before release. Animals not collared were immediately released at their site of capture.

Telemetry

Mongooses were tracked using hand-held 3-element Yagi antennas (Sirtrack Ltd., New Zealand) and receivers (TR4 model, Telonics, Mesa, AZ). Each mongoose was located from 4 to 15 times per week, between 0700h and 1800h, when mongooses are most active (Pimentel 1955, Vilella 1998). Each individual was located ≤3 times per day, at intervals of <2 hrs, either by homing or by triangulating from 2 locations at least 50 m apart. This resulted in between 20 and 50 locations per animal for the sampling period. Locations were recorded using a Trimble Global Positioning System (GPS) unit (Trimble Navigation Ltd, Sunnyvale, CA). For each location, we recorded whether or not the animal was moving, as determined by signal modulation. We also visually estimated the animal's distance from cabanas, trash cans, and trails using 4 distance classes: physically on or in the structure (class 0), 1-10 meters (class 1), 10-50 meters (class 2), and more than 50 meters (class 3). Human activity levels were determined by using data collected by USFS personnel, who conduct visual counts of all vehicles that enter the forest on a daily basis. Visitor numbers are estimated by classifying vehicles by the number of people they can carry (i.e., one automobile = 4 people, one bus = 20 people).

Data Analysis

Visual investigation of a graph of daily visitor use levels over time in the Palo Colorado recreation area indicated that there was a significant difference in the number of visitors depending on the day of the week. Because of this, and also because we wanted to analyze and present the data in a way that would be relevant to management (i.e., to be used in planning a weekly schedule), we summarized the visitorship data based on the day of the week. To determine whether or not this decision was statistically valid, we analyzed the mean number of visitors for each day of the week using ANOVA. We also performed a Tukey-Kramer means comparison to compare all possible pairs of days.

Movement was classified as 1 (moving) or 0 (not moving) for each location. We also calculated the linear distance moved between successive locations taken within a single day. Distances were summarized as the average distance moved (m) per hr (the sum of distances moved between successive locations within the day, divided by the number of hours between first and last locations taken). Visual observation of a histogram of distances moved per hour revealed that there were 13 observations of animals moving very large distances in a short amount of time (260 meters/hr or more), while the rest of the observed movement distances moved per hour were less than 193 meters. Because such movements appeared to be rare events (13 observations out of 290), we analyzed these data both with and without those observations excluded.

We used a Chi-squared analysis to test the effects of the day of the week on 1) the frequency of locations in which the animal was moving, and 2) the number of locations at each distance class from each type of human-use structure. We used a Wilcoxon rank sum test to determine the effect of day of the week on the mean distance moved per hour, and a Tukey-Kramer means comparison to compare the means of all possible pairs of days. These analyses were performed twice: once considering movements of greater than 260 meters/hr, and once without considering them.

Where necessary, data were log transformed to achieve normality of distribution and homogeneity of variances. All data analysis was conducted using the JMP statistical software package (SAS Institute, Cary, NC).

RESULTS

There was a significant effect of day of the week on number of visitors to the forest ($F = 12.93$, df = 6, $P < 0.001$). Tukey-Kramer means comparison indicated that the number of visitors on Sundays and Saturdays was higher than the rest of the days of the week. Thursday had the lowest number of visitors, but this was not significantly different from other weekdays (Figure 2).

Mongooses were more frequently found moving on Saturdays, Sundays, Mondays, and Thursdays than on other days ($\chi^2 = 29.05$, df = 6, $P < 0.001$) (Figure 3). However, we detected only a slight effect of day on the average distance moved per hour ($\chi^2 = 11.95$, df = 6, $P = 0.06$) (Figure 4); mongooses moved slightly longer distances on Tuesdays and Sundays, and slightly smaller

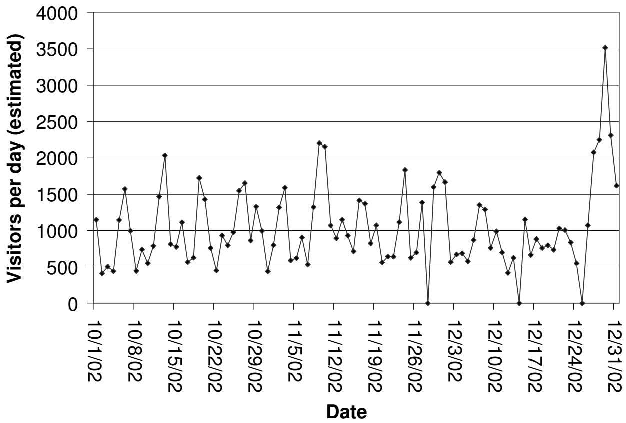

Figure 2. Comparison of mean number of visitors per day (log transformed) at the Palo Colorado recreation area, Caribbean National Forest, Puerto Rico, 1 October - 30 December 2002.

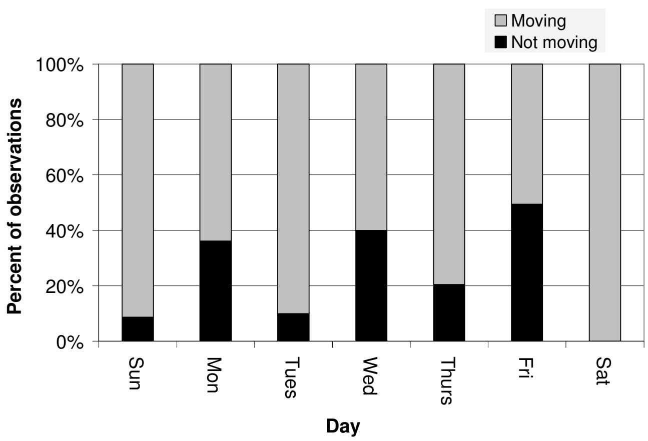

Figure 3. Contingency plot of the percentage of moving fixes observed in mongooses by day of the week, Caribbean National Forest, Puerto Rico.

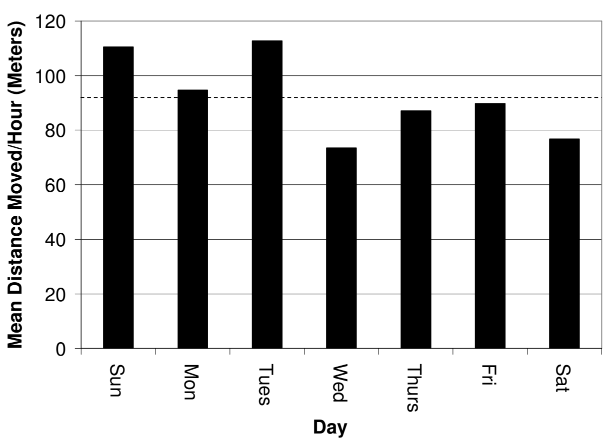

Figure 4. Comparison of the mean travel speed of mongooses (meters moved per hour) by day of the week (long-distance movements excluded), Caribbean National Forest, Puerto Rico.

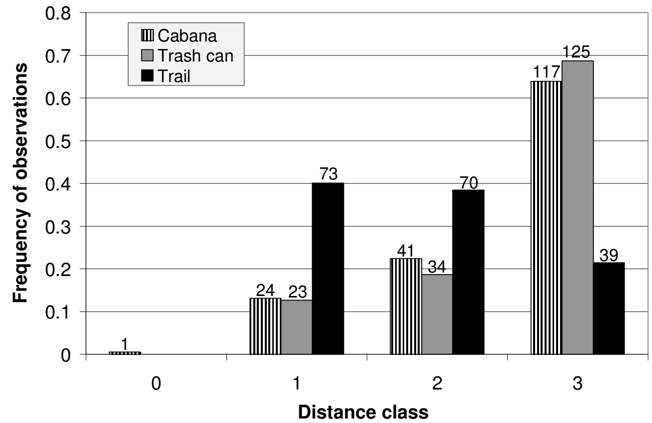

Figure 5. Frequency of observations of mongooses at 4 distance classes from cabanas, trash cans, and trails; Caribbean National Forest, Puerto Rico. Distance classes = 0: physically in or on the structure, 1: 1-10 meters, 2: 10-50 meters, 3: more than 50 meters. Histogram bars are labeled with counts of observations.

distances on Wednesdays. This effect was weaker when the 13 long-distance movement events were included in analysis (χ^2 = 11.10, df = 6, P = 0.09). In general, mongooses were observed at greater distances from cabanas and trash cans than from trails (Figure 5). We detected no effect of day on the frequency of locations at each distance class from each type of human-use structure (cabanas: χ^2 = 10.36, df = 18, P = 0.92; trails: χ^2 = 5.90, df = 12, P = 0.92; trash cans: χ^2 = 10.18, df = 12, P = 0.60). Results of these Chi-squared analyses, however, should be interpreted with caution, as 20% of the cells in the contingency table contained fewer than 5 observations. Specifically, Saturdays and Tuesdays had very few observations.

DISCUSSION

Our data did not support our predictions that mongooses would be drawn to human recreation areas on days with the highest number of visitors. Although we did find a slight effect of day on mongoose movement, the effect was the opposite of what we predicted. Mongooses seemed to move more frequently and at greater speeds on Sundays, one of the days of highest visitor levels. They also were found moving more frequently on Saturdays, the other day of highest visitor levels. Because we did not classify the specific behavior of mongooses while they were moving, it is difficult to determine the cause of the movement. Mongooses were not necessarily found nearer to human structures on days of high visitorship, and thus may not be attracted to human presence. Therefore, it is possible that the increased amount of movement observed on these days was a result of mongooses constantly attempting to *avoid* human presence. However, if the animals were primarily foraging while moving, it is also possible that food resources (such as insects, lizards, or rodents) were moving more when humans were present. Thus, mongooses would be moving more while capturing these prey items.

Mongooses were also moving more frequently on Mondays and Thursdays, and at greater speeds on Tuesdays. These three days of the week had lower visitor levels. The reason for this pattern is unclear, although it may be that different factors on weekdays cause similar movement behaviors observed on weekends. For example, mongooses may be able to more fully utilize their home range on days of low visitor levels since they do not have to avoid humans. Thus, the amount of movement would be the same as on days of high visitor levels, but it would occur in different parts of the home range. However, because mongooses were equally likely to be found near human structures on any day of the week, this scenario is unlikely. It is possible that the increased movement on any day of the week may be due to some other factor– either related to human activity levels or not– that we did not measure.

Without a clearer understanding of the mechanism underlying the relationship between day of the week and mongoose activity, management based on visitor levels may not be the most efficient approach. However, our results do indicate that a control program can be based on spatial and seasonal patterns of human activity (see also Quinn and Whisson 2005). Mongooses were generally found further from cabanas and trash cans but closer to trails, so focusing trapping efforts along trails (rather than near cabanas) may target more animals. As trails also provide the easiest foot access through the Caribbean National Forest, this modification of current management activities can be achieved with ease. Additionally, since mongooses were not necessarily closer to human structures on days of high human activity, control can continue to occur on days of lower visitor levels without compromising efficiency– thus reducing the chance that a forest visitor might come into contact with an active trap set, or worse, one containing a mongoose.

Finally, the animals in our study occupied fairly stable home ranges. It is likely, however, that there are also nomadic animals in the population (Coblentz and Coblentz 1985). These animals may be more responsive to human activity, and they may be attracted to the presence of humans or the odor of their food. If this is the case, then a trapping program targeting human structures on days of high visitor levels may indeed by the optimal approach. However, tracking these transient animals' behavior via telemetry to determine their response to human activity levels may be problematic. Instead, continued monitoring through mark and release or removal trapping on days of varying visitor levels may reveal a numerical response of these populations to human activity. If such a response exists, then it too can be taken advantage of to develop efficient control practices.

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