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A Balanced Approach to the Adaptive Management of Urban Coyotes

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ABSTRACT: Documented coyote attacks on humans are rare events distributed throughout North America. Geospatial monitoring and categorization of coyote behavior type provides essential information necessary for the focused management of coyotes that pose a risk to human safety. Indices of behavior have been used to measure trends in observed behavior with respect to management effort over time. A method is presented for evaluating coyote behavior density for use in developing a human dimension-based decision model with management implementation thresholds. The proposed model allows for the geo-specific adaptive management of coyotes while considering potential environmental, ecological, and social impacts in the course of protecting human safety.

KEY WORDS: adaptive management, behavior density, behavior index, behavior threshold, *Canis latrans*, coyote, geospecific, Integrated Wildlife Damage Management, Texas, urban coyote

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INTRODUCTION

Documented coyote (*Canis latrans*) attacks on humans are rare events with such incidents dispersed throughout North America (Carbyn 1989, Timm et al. 2004, Timm and Baker 2007, White and Gehrt 2009). Assessing the risk of coyote attacks on humans or their pets is problematic, as variation in coyote behavior is influenced by environmental conditions that are subject to change over space and time. Coyotes that are habituated to environments that provide a food source associated with little perceived risk are more disposed to exhibiting bold or aggressive behavior. Consequently, management strategies for preventing such bold or aggressive behavior have typically focused on education efforts to eliminate human behaviors that lead to coyote food conditioning and habituation (Baker and Timm 1998). Generally, strategies employed initially to alter bold coyote behaviors tend to focus on hazing or harassing coyotes to modify their behavior through a perceived threat, in order to reestablish coyotes' avoidance of humans and human-occupied environments.

Baker and Timm (1998) and Timm et al. (2004) identified a sequence of bold and aggressive coyote behaviors that are typically exhibited before an attack on a human. Timm et al. (2004) and Baker (2007) provide evidence suggesting that aggressive coyote behavior, in the stages immediately preceding human safety incidents, can only be altered by implementing a management strategy involving the lethal removal of coyotes through trapping, snaring, or shooting.

Public support for the lethal management of coyotes in urban areas is generally dependent on: 1) the perceived risk to pet or human safety, 2) the targeted removal of only those coyotes that are exhibiting aggressive behavior, using techniques and methods that consider public and pet safety and avoid other non-target wildlife, and 3) minimizing environmental and ecological effects. These concerns are generally addressed when implementing an adaptive, science-based Integrated Wildlife Damage Management (IWDM) decision-making model for resolving wildlife conflicts (Reidinger and Miller 2013). The IWDM approach encompasses the integration and application of several management methods including cultural practices,

habitat modification, animal behavior management, local population reduction, or a combination of these approaches (USDA 2004). The selection of methods and their application is dependent on the magnitude, geographic extent, duration, frequency, and likelihood of recurring property damage or threat to human safety. Consideration is also given to non-target species, environmental conditions and impacts, social and legal factors, and relative cost and efficacy of the management options.

An adaptive urban coyote management program initiated in the City of Austin and Travis County, Texas in 2005 reflects an IWDM approach, and was proven effective in reducing bold or aggressive coyote behavior and any associated risk to human safety (Farrar 2007). This management strategy focused on: 1) monitoring geo-specific coyote behavior, 2) identifying clusters of reported coyote activity, and 3) using nonquantitative methods, professional judgment, and intuition for identifying areas where either nonlethal management techniques, or nonlethal in conjunction with lethal management techniques, were implemented. Monitoring coyote geo-specific behavior and categorizing the exhibited behavior using Baker's scale as outlined by Timm et al. (2004) provided a basis for establishing indices of coyote behavior (Farrar 2007). These indices facilitated the prioritization of coyote management activity with respect to specific management areas derived from United States Postal Service zip code zones, and they provided a means for measuring coyote behavioral trends for monitoring program effects over time (Farrar 2007). However, indices of coyote behavior with respect to arbitrarily established zip code zones that vary in size across the landscape may not accurately reflect coyote activity within a geo-spatial context when activity occurs on both sides of the boundary of two management zones. In addition, the use of non-quantitative methods for identifying perceived clusters of reported behaviors, and subsequently implementing nonlethal or lethal management action within a management zone may not fully address constituent concerns for minimizing lethal management action nor any perceived ecological or environmental impact resulting from the removal of coyotes. To address these concerns, my two-fold objective was to

develop a quantitative approach to more precisely and accurately identify and target proposed nonlethal and lethal management action across a management area, and to incorporate public input in the establishment of a quantifiable threshold for initiating lethal management.

MANAGEMENT AREA

The management area encompassed all the unincorporated areas of Travis County, Texas and the City of Austin. The 256,150-ha area ranged in elevation from 122 to 396 m and is represented in Omernik's Level IV ecoregion classifications (Omernik 1987) as the Balcones Canyonlands ecoregion (50%), followed in dominance by the Northern Blackland Prairie (44%), floodplains (4%) and southern post oak (*Quercus stellat*) savannah (2%). Vegetation type transitioned from a live oak (*Quercus virginiana* var. *fusiformis*) - mesquite - ash juniper (*Juniperus ashei*) mix (45%) primarily associated with the Balcones Canyonlands in the western, higher elevations, to grasslands (16%) and croplands (16%) primarily associated with northern blackland prairie in the eastern, lower elevations. The management area is traversed west to east by the Colorado River that forms Lake Travis and Lake Austin in canyon lands before issuing from the Balcones Escarpment and meandering through urban landscape, blackland prairie lands, and finally the lower elevation flood plain. An urban and built-up landscape, including all or parts of 22 incorporated communities comprising 24% of the management area is dominated by the City of Austin. The total human population of Travis County in 2009 was estimated to be 1,026,158 persons, with a population and housing density of 4.0 persons and 1.7 housing units per hectare, respectively.

METHODS

Data Collection, Categorization, Georeferencing and Analysis

The protocol for collecting data on reports of coyote observations, geo-referencing the raw data, and assigning the reported activity to a behavior category remained consistent with methods described in Farrar (2007). Coyote complaints and observation data were collected from constituent reports made to a non-emergency 311 telephone call system. The data collected by city operators included: 1) the location (street address) of the coyote sighting; 2) the number of coyotes sighted; 3) the date of the sighting; 4) the time of the sighting; 5) the observed behavior of the coyote as well as the callers perception of the behavior as either aggressive or non-aggressive; and 6) any coyote contact with a human or pet.

The geographic coordinates of the point locations of coyote observations were calculated using geocoding tools in ArcGIS 9.3. An address locator was created using street address centerline data for the area encompassing Travis county and the City of Austin. Addresses collected from reports were then geocoded for projecting the point location coordinates. Unmatched records were usually related to complainant error or reporting an approximate or non-existent street address number. When possible, I corrected address errors using additional data or comments provided in the original complaint report or by interviewing the

complainant. I removed data records with uncorrectable address locations from the analysis.

Each report was categorized and assigned a coyote behavior score (CBS) of either zero, which reflects nonaggressive human avoidance behavior, or a score of 1 to 7 which reflects the sequence of increasing bold and aggressive coyote behaviors that are typically exhibited before an attack on a human as identified by Baker and Timm (1998) and refined by Timm et al. (2004).

Relative Behavior Density

To establish a quantitative method for identifying perceived clusters of reported coyote activity, I geospatially quantified categorically weighted coyote observations collected from April 2008-May 2012 using the kernel density function included in the ArcGIS 9.3 Spatial Analyst toolbox. The quadratic kernel function described by Silverman (1986) calculates a density of point locations within a predefined circular neighborhood, and is reflected as the summation of values of all kernel surfaces where they overlay the center of each raster cell. Neighborhood space is dependent on the selection of the bandwidth, or search radius, of a kernel density estimator. Whereas coyote management objectives focused on managing coyote behavior and activity in residential areas, I defined the model neighborhood as a circular area of 7.3 km² with radius of 1.524 km, which approximates an average of resident coyote home range sizes reported in studies conducted in seven different urban landscapes (Gehrt 2007). I defined the model analysis grid as cells of area approximating the average size of residential lots which was calculated using Travis Central Appraisal District property records of parcels legally zoned as single-family residential (2332.21 m²), and used the square root of the result to define the dimension of the model cell as 48×48 m. To visually evaluate the differences between nonquantitative and quantitative methods for identifying areas for implementing lethal management, I compared map outlines of perceived clusters of coyote activity designated as high priority areas for lethal management in April 2008 by overlaying the management area map with a geospatially quantified raster representing the density of categorically weighted coyote observation data points which I define as the relative behavior density (RBD).

Frequency Distributions, Behavior Indices, and Trend Analysis

I used chi-square tests for homogeneity of proportions to test for any change in the monthly and overall proportional distributions of coyote behavior score (CBS) observation data collected, prior to and after RBD and a lethal management implementation threshold was implemented in May 2008. When a behavioral category exhibited an expected value of less than 5, the data in the category was pooled with the next lower behavioral score category for the analysis. I also omitted data from the initial management year (2005) to remove any effect of coyote behavior in absence of any prior year management activity. Likewise, I omitted May-December 2008 data to eliminate the influence of using nonquantitative methods for implementing lethal management within the year (2008) when

the RBD parameter was integrated into a decision model. I also excluded behavioral score data collected after April 2011 so frequency distributions reflected behavioral scores collected over consistent monthly time periods within a year (January 2006-April 2008 and January 2009-April 2011, respectively).

To access coyote behavior trends and monitor program effects over time, I used the categorized behavior score (CBS) data to establish an index of coyote behavior (ICB) defined as the monthly average of all CBS data collected within the analysis period. I used a multiplicative model comprising log transformation of the behavior indices and linear regression to detect and monitor trends in behavior which was observed as a percent change in behavior reflected through the back transformation of the slope of the regression (Bradu and Munklak 1970, Sauer and Geissler 1990, Farrar 2007). The analysis of the monthly trends of the ICB was determined for the periods January 2006-April 2008, when nonquantitative methods for focusing and implementing lethal management were utilized; and for January 2009-April 2011, when RBD was integrated into a decision model for focusing and implementing management efforts. Similar to the analysis of frequency distributions, I omitted data from the initial management year (2005), May-December 2008 data, and behavioral score data collected after April 2011.

Establishing Lethal Management Implementation Threshold

Citizen input from public meetings hosted by the City of Austin/Travis County Animal Services Office and homeowners and civic associations throughout the City of Austin and Travis County from 2004 through 2008 was used to estimate a lethal management implementation threshold. Citizens were provided information on the biology and ecology of coyotes, and also information on both lethal and nonlethal techniques used to prevent and alleviate bold and aggressive coyote behavior. Constituents were subsequently queried for informal input on what management methods were deemed appropriate for alleviating bold or aggressive coyote behavior according to the frequency of behavior and behavioral stages as defined by Timm et al. (2004). Subsequent to constituent input, the behavior modification implementation threshold for using lethal management was established in April 2008 by calculating a RBD value that reflected public intolerance for behaviors associated with the CBS values 0-7.

RESULTS

Public input on the tolerance for the different categories of coyote behavior and the number of incidents tolerated before lethal methods were considered appropriate for managing bold and aggressive coyotes indicate: 1) no tolerance for coyotes acting aggressively toward adults during mid-day; 2) no tolerance for coyotes seen in and around children's play areas, school grounds, and parks in mid-day; 3) no tolerance for coyotes attacking and taking pets on leash or in close proximity to their owners; coyotes chasing joggers, bicyclists, and other adults; 4) no tolerance for coyotes chasing or taking pets during daylight hours; 5) tolerance for no more than a couple of incidents

of daylight observance of coyotes on streets and in parks and yards; 6) tolerance for no more than a couple of incidents of coyotes approaching adults and/or taking pets at night; 7) tolerance for occasional incidents of coyotes on neighborhood streets and in yards at night; 8) complete tolerance for observing or hearing coyotes in greenbelts or other undeveloped habitat day or night, or coyotes observed exhibiting human avoidance behavior (Table 1). These results indicate more tolerance for observing nighttime coyote activity versus observing daylight coyote activity. In general, the public tolerance of reported incidents of coyotes on neighborhood streets and in yards at night varied greatly, with some respondents having little tolerance and others considering the behavior natural with little chance for negative interaction. Coyotes approaching adults and/or taking pets at night was tolerated to the extent that the public viewed night-time coyote activity as normal, but they were unable to accept a pattern of greater than two incidents of the behavior within a neighborhood. The tolerance for the daylight observance of coyotes on streets and in parks and yards was limited to one incident, with general concurrence that a pattern of two or more incidents warranted the local removal of the offending coyote(s). Consequently, the scale of public tolerance resulted in a calculated threshold value of 6.0 RBD units for differentiating the target areas for implementing lethal management.

Table 1. Public tolerance for coyote behaviors used in the establishment of a Relative Behavior Density (RBD) threshold level for implementing lethal management of urban coyote in the City of Austin and unincorporated areas of Travis County, Texas, from May 2008 through May 2012.

Coyote Behavior Score Categories (CBS)	Public Tolerance of Behavior (incidents)	Relative Behavior Density (RBD) Threshold
0	unlimited	none
1	occasional	unknown
2	2	4-6
3	2	6
4	0	0
5	0	0
6	0	0
7	0	0

Spatial analysis of georeferenced CBS data provided an unbiased, quantitative distribution of the relative density of coyote behavior across the landscape, as reflected in the RBD unit value for each 48×48-m grid cell for rural, suburban, and urban environments within the management area (Figure 1). In this figure, the high priority areas shown (defined in April 2008) surpass the threshold defined in May 2008 by the quantitative method. However, one area located in zip code 78734 that was not designated as a high priority management area actually exceeded the RBD threshold established for implementing lethal management action.

Summary statistics of CBS generated from 311 call data collected over consistent monthly time intervals before and after integration of CBD (January 2006-April

Figure 1. Management area map with outlines of perceived clusters of coyote activity, designated as high priority areas for lethal management, overlain with the geospatially quantified RBD raster of categorically weighted coyote observation data, as reported in April 2008, in various zip codes in the City of Austin and unincorporated areas of Travis County, Texas.

2008 vs. January 2009-April 2011) indicate a 33% increase in reported coyote observations after April 2008. However, chi-square tests for homogeneity of proportions indicate both the monthly and overall proportional distributions of CBS observation data reported after April 2008 were not homogenous to the monthly and overall proportional frequency distributions generated from CBS observation data collected before May 2008, when RBD was implemented ($p < 0.00001$ and $p < 0.03660$, respectively;

Figures 2 and 3). A summary of coyote reports collected from January 2005 through April 2012 suggest a cyclic trend beginning in September 2008 (Figure 4).

Trend analysis using linear regression of the log transformed monthly ICB values indicates a decreasing trend of 1.5 percent per month ($p < 0.00601$; -2.5% to -0.5%, 95% CI) before, and an increasing monthly trend of 1.6 percent ($p < 0.00128$; 0.25% to 3.0%, 95% CI) after the integration of the RBD threshold model in May 2008 (Figure 5).

Figure 2. Frequency distribution of coyote behavior score (CBS) observation data by month before and after the implementation of the coyote relative behavior density (RBD) statistic and lethal management behavior density threshold decision model.

Figure 3. Frequency distribution of coyote behavior score (CBS) observation data before and after the implementation of the coyote relative behavior density (RBD) statistic and lethal management behavior density threshold decision model.

DISCUSSION

Quantifying relative geo-specific coyote behavior density across the landscape is consistent with an IWDM approach by providing an objective, quantitative means of assessing the magnitude, geographic extent, and relative likelihood of recurring bold or aggressive coyote incidents involving property damage or threat to human safety across the landscape. The results suggest that the decision model integrating RBD reduced incidents of CBS categories greater than 3.0 by focusing and limiting lethal management efforts to only those areas exhibiting relatively

high RBD values. However, the integration of geo-specific behavior density with human dimensions may have indirectly influenced urban coyote activity within the management area, as reflected in the 33% increase in the total number of coyote reports submitted by the public and the associated 1.6% monthly increasing trend in ICB from January 2009-April 2011. The change in the monthly and overall frequency distribution of CBS, and the 36%, 55%, 29%, and 16% increases in reports of CBS categories 0, 1, 2, and 3, respectively, suggest an increasing trend in the coyote population abundance across the management area.

Figure 4. Coyote observations and associated mean behavioral scores by month, from January 2005 through April 2011.

Figure 5. Monthly trend of the index of coyote behavior (ICB) before and after the implementation of the coyote relative behavior density (RBD) statistic and lethal management behavior density threshold decision model.

The cyclic nature of the increased observations tended to occur during months of coyote pup dispersal, typically beginning in earnest in September and lasting through fall and early winter months (Figure 4). This cyclic pattern is largely absent after the initial year of urban coyote management in 2005 and prior to the integration of RBD in 2008, suggesting there was no associated compensatory or density-dependent response to the lethal removal of 43 coyotes across the management area from 2005 through

April 2008. An alternative explanation is that any compensatory or density-dependent response was delayed a minimum of three years.

After the integration of RBD, only 14 coyotes were lethally removed (from 2009 through April 2011), but reports of coyote observations during dispersal months September through December increased 76%. A plausible explanation for this increase is that the revised management implementation threshold (that may have effectively

reduced the target area size for implementing lethal management) may have led to an increase in reproductive female survival. A decrease in reproductive female mortality and the associated increase in overall coyote pup recruitment and survival would be reflected through juvenile dispersal into the urban and suburban landscape, resulting in an increase in human interaction.

While using the adaptive management strategy that relied on nonquantitative methods and intuition for identifying sites for implementing lethal management, there was no concomitant increase in reported observations or interactions with coyotes. Consequently, urban coyote project managers using a coyote behavior density model for establishing lethal management implementation thresholds should consider a protocol for balancing public perception and values with science-based knowledge, in order to achieve a relatively stable coyote behavior density level that effectively minimizes relative risk to human safety while also minimizing negative impacts. In this regard, more information is needed on the sensitivity to variation in urban coyote home range area estimation of the kernel density model search radius parameter. Density calculations could affect which areas are targeted for lethal control.

Input on the public's tolerance for the different categories of coyote behavior, and the number of incidents tolerated, also affects which areas are targeted for nonlethal or lethal coyote management. Over time, the public tolerance for the different behavior categories may change with respect to constituent's perception of risk to pets or humans. Any change in public perception toward greater risk to pet or human safety may effectively reduce tolerance and therefore lower the RBD threshold for implementing lethal management. This would effectively increase the area managed as well as the probability of removing adult female coyotes, effectively eliminating coyote recruitment and dispersal that appears directly correlated with coyote-human interaction and conflict.

Quantifying geo-specific RBD allows for the continuous monitoring of coyote behavior across the landscape. It provides a nonbiased alternative method for identifying and targeting areas for the dissemination of information to constituents in localities where RBD is increasing but remains below a predefined threshold for implementing lethal management. Constituent participation in identifying local tolerance for different behavior categories provides an avenue for establishing a socially-acceptable protocol, as well as justification for the lethal removal of problem coyotes. Constituent participation also promotes support of the urban coyote management program by compelling the public to recognize the complexity of minimizing the program's social, environmental, and ecological effects, while minimizing urban coyote risk to pet and human safety.

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