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Estimating relative distribution of raccoons, opossums, skunks, and foxes using animal control data

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Abstract: We used indices of animal control reports per capita and areas of land covers to assess the relative habitat-use of raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), skunks (*Spilogale putorius* and *Mephitis mephitis*), and foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*). We used confirmed (hereafter, verified) calls made to Brevard Animal Services, Florida, and assessed potential human demographic influences associated with unconfirmed (hereafter, unverified) reports where it was uncertain whether or not an animal was present. To estimate habitat use, we performed quadrat sampling using a geographic information system (GIS) and obtained areas of land cover within each quadrat. We evaluated numbers of confirmed animals per capita against areas of land cover in a quadrat using Forward Logistic Regression and Stepwise Multiple Linear Regression analyses. Our results indicate that raccoons were positively associated with a mixture of populated areas near streams and negatively associated with wetland forests, shrub and brushland, and tree crops. Opossums were positively associated with a mixture of row crops, bays and estuaries, high-density residential areas, and streams, while negatively associated with golf courses and low-density residential areas. Skunks were associated with a mixture of residential, institutional, and recreational areas, roads, pastures, and wetlands with some forest cover near water. Foxes were positively associated with open agricultural- and industrial-use areas often located near bays and estuaries, and negatively associated with golf courses, extraction sites, and shrub and brushland areas. On a landscape level, animal groups selected certain land cover categories and did not use land covers based on availability. If care is taken to remove potential biases, verified animal control reports can be used as a low-cost, opportunistic method to determine where raccoons, opossums, skunks, and foxes are located in urban areas. Using verified animal control reports appears promising for identifying areas where raccoons, opossums, skunks, and foxes are located in urban areas.

Key words: animal control, *Didelphis virginiana*, GIS, human–wildlife conflicts, *Mephitis mephitis*, *Procyon lotor*, sampling, *Spilogale putorius*, wildlife hotline, *Urocyon cinereoargenteus*, *Vulpes vulpes*

Although the presence of wildlife in urban areas offers many benefits, encounters between humans and wildlife also can be negative. Raccoons (*Procyon lotor*), Virginia opossums (*Didelphis virginiana*), eastern spotted skunks (*Spilogale putorius*), striped skunks (*Mephitis mephitis*), red foxes (*Vulpes vulpes*), and gray foxes (*Urocyon cinereoargenteus*) are often found near populated areas in Brevard County, Florida. In addition to causing property damage (Conover et al. 1995, Messmer 2000), these animals are potential vectors for a number of zoonotic diseases, including rabies (Rosatte et al. 1991, Riley et al. 1998, Broadfoot et al. 2001) and raccoon roundworm (*Baylisascaris procyonis*) (Roussere et al. 2003, Page et al. 2005).

It is especially important to identify quickly where animals encounter humans, domestic animals, and other wildlife in cases where spread of disease is a concern (Riley et al. 1998,

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Broadfoot et al. 2001). Locating these areas may both show where disease transmission is likely to occur and improve management or control techniques (Hadidian et al. 1989, Riley et al. 1998, Broadfoot et al. 2001, Gehrt 2002). A rapid, low-cost and opportunistic technique that enables large areas to be sampled quickly is necessary to identify areas where wildlife, domestic animals, and humans interact so that spread of disease can be reduced (Bruggers et al. 2000, Fall and Jackson 2002).

Several excellent methods for estimating habitat-use or abundance of wildlife in urban areas exist (e.g., scent stations, track plates, trapping, etc.). However, there are problems with using these techniques in urban areas. Most techniques require permission to gain access to private lands and appropriate permits, both of which take time. In addition, setting up an effective sampling system with scent stations (Prange and Gehrt 2004) and track plates (Zielinski and Truex 1995) often requires equipment, funding, and time to collect the data.

Telephone call reports from the public to animal control agencies (hereafter, reports or animal control reports) can offer another source of data to quickly assess relative habitat-use in urban areas (Quinn 1995). Members of the public often call local animal control agencies to report the location of an animal. In many instances, these reports are confirmed because an officer is dispatched to the location, encounters live or deceased animals, and records information. One advantage of using animal control reports is that they are already recorded by most agencies dealing with wildlife and, therefore, are readily available. Using these reports also provides a quick source of data for sampling that does not require obtaining additional permission from landowners. Other studies have used animal control reports to assess the effectiveness of rabies-baiting in Pinellas County, Florida (Olson et al. 2000) and to identify changes in a raccoon population after a rabies outbreak (Anthony 1990). With the addition of GIS software and landscape information, a rapid and low-cost assessment of wildlife in urban areas may be possible (Broadfoot et al. 2001).

However, there are potential problems with using confirmed sightings of trapped or deceased animals to derive estimates of the distribution and habitat-use of wildlife if potential inherent biases are not addressed. Animal presence also is questionable if an independent observer (e.g., animal control officer) cannot identify or confirm a reported animal was actually present at a location. In areas with a mixture of urban- and rural-use, sampling rural areas with fewer people could lead to an underestimate of wildlife populations, as there may be fewer people present to report an animal. Also, differences in public attitudes toward wildlife damage (Conover 2001) may cause call bias, i.e., some people may call to report an animal or request a trap while others may not (Anthony et al. 1990).

The purpose of this study was to determine whether animal control data and quadrat (2.0-km^2 grid cell) sampling in a GIS can be used to assess the relative use of different land cover categories by raccoons, opossums, skunks, and foxes. We assessed whether animals preferentially selected land covers or used certain areas based on availability in the landscape. Next, we evaluated unconfirmed reports to see whether they resulted in different predictions than confirmed reports. We examined potential demographic influences on unconfirmed animal control reports to determine if bias could explain any differences observed in the models.

Methods

To assess wildlife land-use in Brevard County, Florida, we examined 17,053 animal control reports over 4 years of available reports from Brevard County Animal Services and Enforcement (BAS) for years 2000, 2003, 2004, and 2005. Data for 2001 and 2002 were not available. BAS reports specify locations of dead, sick, injured, confined, roaming, or nuisance wildlife throughout the county. We selected 4 groups of animals from BAS records for analyses: raccoons, opossums, skunks, and foxes. Both striped and spotted skunks were present in the study area, but the distinction was not made as to which species in the records were present; therefore, we did not distinguish between the 2 species in the analyses. A similar situation occurred with gray and red foxes.

We separated the data into 2 groups for our analyses: verified sightings and unverified sightings. The verified sightings consisted of

6,797 cases in which a BAS officer encountered an animal and recorded whether it was dead, trapped, rehabilitated, impounded, or euthanized. The remaining 10,256 unverified reports included incomplete, ambiguous, anonymous, and repeated reports (>1 call per address per animal group per year), and reports without a recorded result. To eliminate the impact of repeated reports from the same address, we used 1 call per address per animal type per year to determine a point location for each verified call.

To obtain the precise locations of the reports, we used address geocoding in ArcGIS® version 9.1 (Environmental Research Institute, 2006, Redlands, Calif.). Address geocoding locates street addresses and plots the point locations in the GIS. We standardized street addresses and obtained zip codes for reports lacking zip codes from the U.S. Postal Service to increase the likelihood of a correct match. To minimize error, we included only reports that were matched with a precision of 80% to minimize the likelihood that an incorrect address with a similar street name would be mapped.

Because the number of reports an agency receives may be related to human population size, we obtained data for only those areas with people and telephones present to allow the potential for a telephone call (report) from each quadrat. We obtained human demographic data from the U.S. Census Bureau (2004), which provides demographic information about people throughout the country at an aggregated level to ensure confidentiality (Rindfuss et al. 2004). We assumed that changes in demographics would not differ greatly over the period of data collection for the animal control reports. To control for human population in the area, we used the number of reports per capita for each animal group per quadrat, defined as the number of officer-verified animals per quadrat divided by mean human population in that quadrat.

We obtained habitat characteristics associated with the point locations where verified sightings occurred from a land cover layer from St. Johns River Water Management District for the year 2000. While Anthony et al. (1990) and Olson et al. (2000) examined land-use associations with animal control data, we selected land cover (physical characteristics) over land-use (human uses) as a more specific descriptor of characteristics on the land (Rindfuss et al. 2004). Prior to analyses, we examined the independence of land cover categories using Pearson Correlation Analysis (Zar 1996). We grouped the remaining subcategories based on appropriate habitat descriptions defined by metadata and photographs for each land cover.

We developed sample quadrats consisting of quadrats from a raster layer created in ArcGIS. This quadrat size provided enough individuals per quadrat for analysis, allowed for random sampling of non-adjacent quadrats, and ensured at least 1 report per quadrat. When any quadrats contained inappropriate habitat (e.g., ocean), we used the quadrat to the south and west to avoid sampling where a call could not occur. We calculated areas of each land cover within each quadrat within the GIS and exported data into SPSS™ 13.0 (SPSS Inc., Chicago, Ill., 2005) for analyses.

To determine which habitat characteristics best predicted sighting frequency, we used Stepwise Multiple Linear Regression Analysis (MLR; Zar 1996) for only those locations in which an animal was sighted and where the sighting was verified. As a result, analyses for raccoons and opossums included 51 quadrats each, skunks included 35 quadrats, and foxes included 31 quadrats. As there were fewer verified reports for foxes and skunks, there were fewer quadrats to sample. Land cover categories examined for MLR tests examined in analyses are listed in Table 1. We computed loading variables in the final regression models to interpret the relative impact of coefficients in the models using Pearson Correlation Analyses. We also compared results of verified and unverified MLR models to determine whether unverified reports per capita led to the same predictions as verified reports per capita.

We used Forward Stepwise Logistic Regression to identify habitat characteristics related to the presence or absence of an animal group (Zar 1996). For this analysis, we used 50 separate non-adjacent quadrats in which at least one of the 4 animal groups was present through a verified sighting. The reason for this stipulation was to reduce the error associated with classifying quadrats as absent when no phone calls were made. If ≥1 calls were made, it is possible that an animal could be reported. We

Table 1. Selected land cover category definitions for multiple linear regression analyses.

Land cover category	Definition
Bays and estuaries	Inlets that extend into the land
Canals	Use for pleasure boats and shipping, not streams
Commercial	Shopping centers, resorts, warehouses, campgrounds, junkyards
Communication tower corridors	Transmission towers for television and telephones
Community recreational facilities	Large, open areas of turf with fencing, parking, drainage
Disturbed land	Areas of bare soil or rock
Electrical power facilities	Substations, power plants, utility right of ways
Extraction	Strip mines (active or abandoned), sand and gravel pits, quarries
Herbaceous upland nonforested	Transitional area between marsh and upland forest
High-density residential	Over six dwellings per 0.405 ha, or under construction
Horse farms	Farms with pastures that stable and train horses (sporting)
Industrial	Pulp and paper mills, timber, mineral, oil and gas processing
Industrial food processing	Vegetable processing plants, sugar, meat, seafood processing
Institutional	Education, religious, health, government, correction facilities
Low-density residential	0.5 to 2 dwellings per 0.405 ha, or under construction
Medium-density residential	2 to 5 dwellings per 0.405 ha, or under construction
Mixed shrub-scrub wetland	Shrub bogs, willow swamps, shrub mangroves
Mixed upland nonforested	Shrubs cover less than 60% of the total area
Nonvegetated wetlands	Hydric surfaces lacking vegetation
Open land	Inactive land with street pattern but without structure
Other recreational areas	Swimming beaches, race tracks, marinas, fish camps, stadiums
Row crops	Tomatoes, potatoes, beans, tobacco, others
Sand pine	Forest in Ocala National Forest, often scrubby brush understory
Shrub and brushland	Saw palmettos, gallberry, wax myrtle, coastal scrub
Solid waste disposal	Sanitary landfills and other waste disposal areas
Spoil areas	Elevated areas formed along canals, often near bays or estuaries
Streams	Rivers, creeks, canals, and other linear water bodies >0.01 km
Tree crops	Citrus groves and abandoned tree crops such as pecans
Tree plantations	Coniferous pine and forest regeneration
Unimproved pastures	Pasturelands, grasslands with under 25% canopy cover
Upland coniferous pine forest	Non-hydric pine flatwoods
Upland hardwood forest	Oak, pine, hickory, Brazilian pepper, live oak, wax myrtle
Upland mixed forest	Mixed coniferous, hardwood, Australian pine
Water supply facilities	Water treatment, wells for residential and municipalities
Wetland coniferous forest	Cypress, pond pine, hydric pine flatwoods
Wetland hardwood forests	Bay and mangrove swamps, mixed hardwoods
Wetland mixed forest	Less than 67% cover of hardwoods or evergreen conifers
Woodland pastures	Pasturelands, grasslands with 25 to 100% canopy cover

evaluated modified categories for LR analyses to account for some land cover subcategories with minimal data.

To determine whether animals were selecting certain habitats or using habitats based on availability in the landscape, we compared the observed distribution with the distribution predicted by chance using a Goodness of Fit test (Zar 1996). We evaluated the number of animals in the quadrat (per capita) divided by the human population to address the assumption that increased and repeated reports might lead to more verified reports. We defined the observed frequency for a species (animal group) as the frequency that an animal group occurred per habitat type, per capita, and the expected frequency as the proportion of habitat type relative to all habitat types multiplied by total observed frequency. If the proportion of habitat available in all quadrats was equal to the proportion of habitats selected by an animal group, no selection occurred. However, if the observed proportion of habitat selected was greater than the expected proportion of availability of habitat, animal groups selected habitats.

To assess the influence of human demographics on the results, we compared predictions from the verified sightings data to predictions from the data from unverified sightings. We assumed that unverified sightings should reflect greater demographic influence. We obtained human census tract information from the U.S. Census Bureau (2004) and selected income, age, population, and housing characteristics as rough indicators of demographic influence. Although the level of demographics should match the level of data collected (Rindfuss et al. 2004), ungrouped, household-level demographics were not available to compare with household level phone call reports. As quadrats often contained >1 census tract, we used the mean value of the demographic characteristics for tracts in each quadrat tested against unverified reports per capita. In cases where the absolute values of correlations were >0.30 between 2 or more demographic variables, we selected only 1 of the variables for analysis.

Results

The Stepwise Multiple Linear Regression analysis showed that relative habitat-use for raccoons, estimated by verified animal control reports per capita, can be predicted (df = 45, r^2 = 0.79, $P < 0.001$) using habitat characteristics (Table 1). The final regression model included a constant, bus and truck terminals, streams, medium-density residential, industrial, commercial, wetland, mixed-forest areas, and communication tower corridors. The number of verified raccoon sightings increased with increases in areas containing one of these constants. Wetland mixed forests, on the other hand, were most closely associated with a decrease in sightings. The model that was based on unverified sightings gave substantially different results (502.446 + 1.052 × bus and truck terminals + 0.001 × medium density housing + 0.074 × sewage and wastewater treatment plants + 0.001 × high-density residential + 0.019 × communication tower corridors + 0.029 × solid waste disposal – 0.005 × tree crops + 0.055 × railroads) than the model based on verified sightings, suggesting that only verified sightings should be used to model raccoon habitat-use.

Forward Logistic Regression indicated that raccoon presence and absence may be predicted (χ^2 = 18.15 df = 3, $P < 0.001$) by testing areas of land cover against verified raccoons per capita. Logistic Regression Analysis indicated that raccoons were less likely to be present in upland hardwood forest, shrub and brushland, and tree crop areas in the county.

The results from the Chi–square Goodness of Fit test suggest that, on a landscape scale, raccoons were selecting certain land cover categories rather than using them based on availability (Table 2). The proportional distribution of animal control reports for raccoons weighted by mean human population size was significantly different (χ^2 = 474, df= 14, $P < 0.001$) from the proportional distribution of available habitat land covers. This indicates that raccoons were avoiding areas with upland hardwood forest, shrub and brushland, and tree crops in the area (Figure 1).

The Stepwise Multiple Linear Regression analysis showed that relative habitat-use for opossums, estimated by verified animal control reports per capita can be predicted (F = 15.37, df = 49, r^2 = 0.74, $P < 0.001$) using habitat characteristics (Table 3). The final regression model included constant, high-density residential areas, streams, and golf

Table 2. Coefficients from Stepwise Multiple Linear Regression analyses testing verified raccoons per capita against areas of land cover in Brevard County, Florida.

Raccoon land cover category	Coefficient	*P*	Loading
Constant	1143.697	<0.001	
Bus and truck terminals	0.798	0.001	0.285
Streams	0.013	0.004	0.367
Medium-density residential	0.001	0.004	0.395
Industrial	0.002	0.015	0.266
Commercial	0.001	0.024	0.379
Wetland mixed forest	–0.006	0.024	–0.287
Communication tower corridors	0.018	0.027	0.257

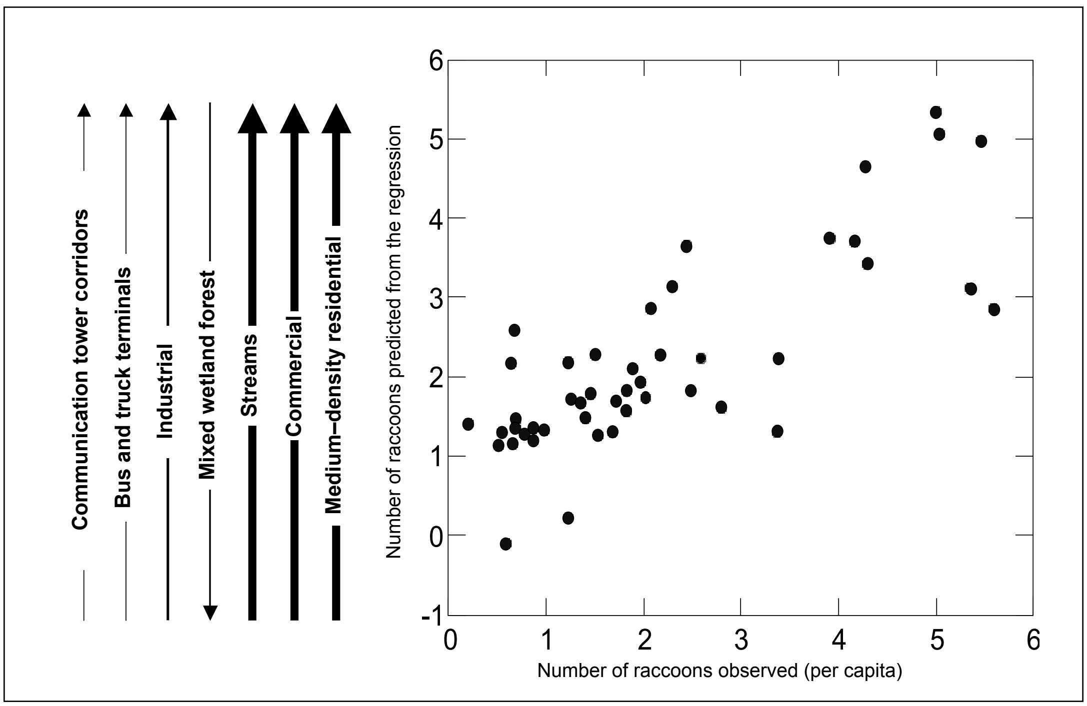

Figure 1. Scatter plot from the final model of the Stepwise Multiple Linear Regression ($P < 0.001$) testing the number of verified raccoons per capita per quadrat against areas of land covers. The x axis indicates the number of raccoons per capita within the quadrat. The y axis indicates the unstandardized predicted number of raccoons from the regression. We calculated loadings (shown as weighted directional arrows) using Pearson Correlations on variables in the final model.

courses (Figure 2). Golf courses were most closely associated with a decrease in opossum sightings. The model that was based on unverified sightings gave substantially different results (i.e., 0.002 × high-density residential + 0.154 × water supply plants + 0.001 × medium-density residential) than the model based on verified sightings, suggesting that only verified

Table 3. Coefficients from Stepwise Multiple Linear Regression analyses to test verified opossums per capita against areas of land cover in Brevard County, Florida.

Opossum land-cover category	Coefficient	*P*	Loading
Constant	725.535	0.019	
High-density residential	0.002	<0.001	0.650
Streams	0.025	0.041	0.291
Golf courses	-0.004	0.028	-0.004

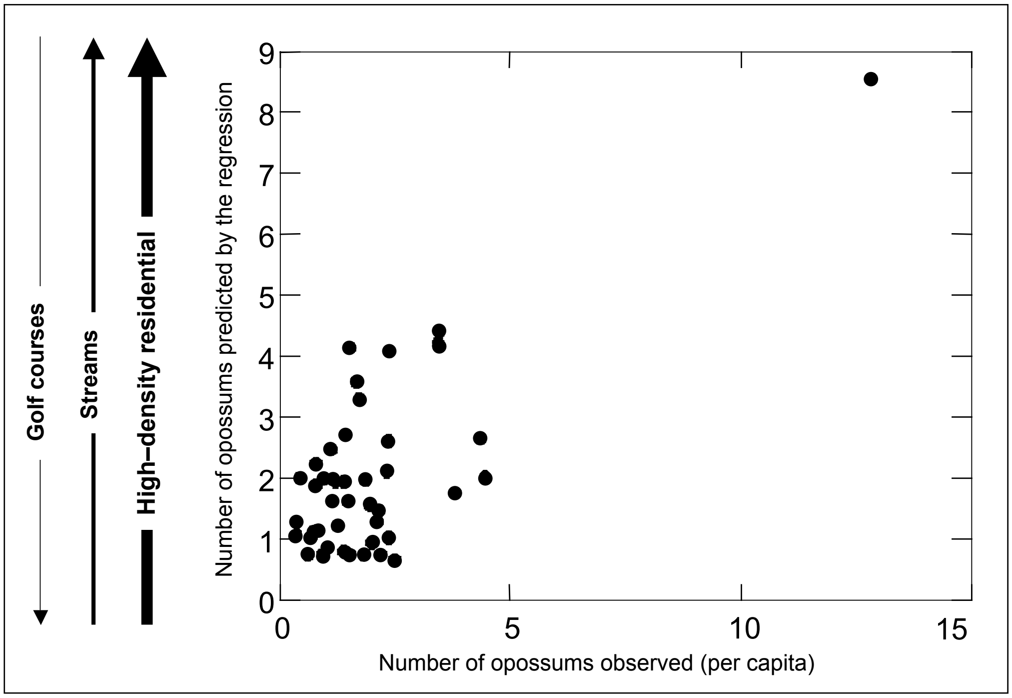

Figure 2. Scatter plot from the final model of the Stepwise Multiple Linear Regression ($P < 0.001$) testing the number of verified opossums per capita per quadrat against areas of land covers. The x axis indicated the number of foxes per capita within the quadrat. The y axis indicated the unstandardized predicted number of foxes from the regression. We calculated loadings (shown as weighted directional arrows) using Pearson Correlations on variables in the final model.

sightings should be used to model opossum abundance.

Forward Logistic Regression indicated that opossum presence and absence may be predicted ($\chi^2 = 40.496$, df = 6, $P < 0.001$) by testing areas of land covers against verified opossums per capita. Logistic Regression Analysis indicated that opossums were less likely to be present in low-density residential areas, upland coniferous pine forests, and mixed scrub-shrub wetland, and would be more likely to be present near bays, estuaries, and row crops in the county.

The results from the Chi–square Goodness of Fit test suggests that, on a landscape scale, opossums in Brevard County were selecting certain land-cover categories rather than using them based on availability. In particular, this suggests that opossums selected high-density residential areas near streams more often than expected and selected golf courses less than expected. The proportional distribution of animal control reports for opossums weighted by mean human population size was significantly different ($\chi^2 = 456$, df = 22, $P < 0.001$) from the proportional distribution of available habitat land covers.

The Stepwise Multiple Linear Regression Analysis indicated that relative habitat-use

Table 4. Coefficients from Stepwise Multiple Linear Regression analyses testing verified skunks per capita against areas of land cover in Brevard County, Florida.

Skunk land-cover category	Coefficient	*P*	Loading
Constant	119.907	0.019	
Airports	0.0001	< 0.001	0.894
Woodland pasture	–0.003	0.028	0.105
Roads and highways	0.002	0.002	0.335
Streams	0.005	0.003	0.037
Other recreational areas	0.007	0.009	0.120
Horse farms	0.005	0.025	0.071
Bays and estuaries	0.006	0.032	0.063

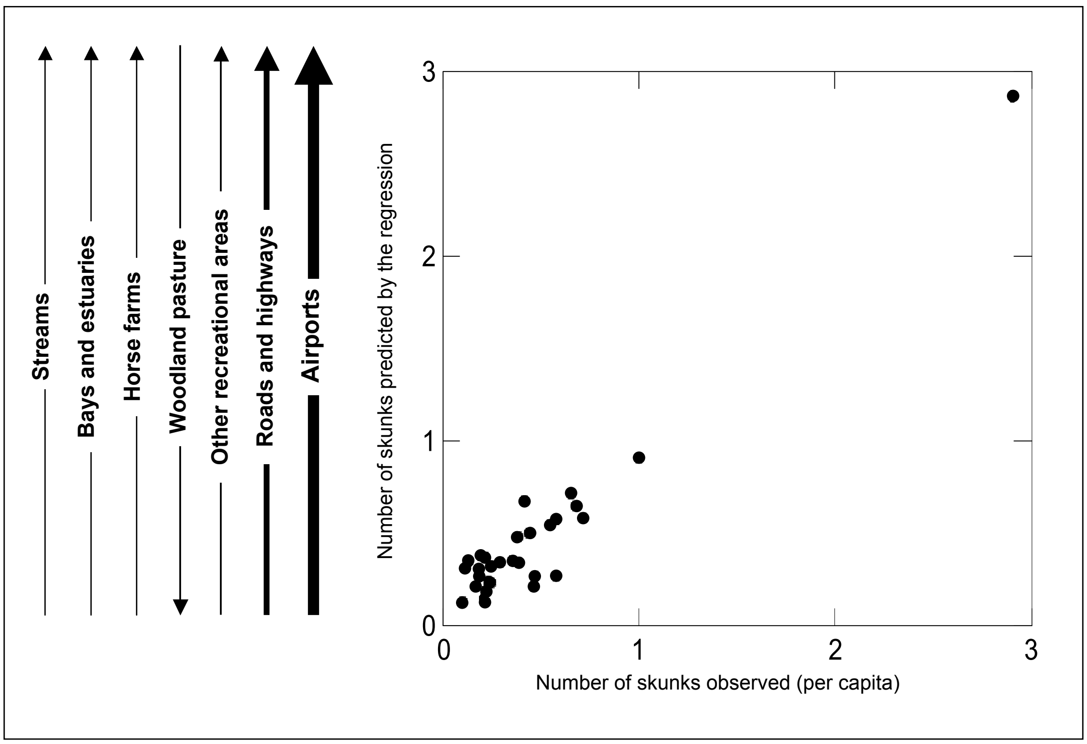

Figure 3. Scatter plot from the final model of the Stepwise Multiple Linear Regression *(P* < 0.001) testing the number of verified skunks per capita per quadrat against areas of land covers. The x axis indicated the number of skunks per capita within the quadrat. The y axis indicated the unstandardized predicted number of skunks from the regression. We calculated loadings (shown as weighted directional arrows) using Pearson Correlations on variables in the final model.

for skunks, estimated by verified animal control reports per capita, can be predicted (F = 46.1, df = 30, r^2 = 0.96, P < 0.001) using habitat characteristics (Table 4). The final model included a constant: airports, woodland pastures, roads and highways, streams, recreational areas, horse farms, bays, and estuaries. Woodland pasture, on the other hand, was most closely associated with a decrease in sightings (Figure 3). However, MLR results for unverified reports about skunks per capita led to a different mixture of relative habitat-use (F = 15.710, df = 31, r^2 = 0.792, P < 0.001). The model based on unverified sightings gave substantially different results (229.441 + 0.026 ×s and pine + 0.015 × other recreational areas + 0.001 × institutional land cover categories) than the model based on verified sightings and suggests that only verified sightings should be used to model skunks per capita.

Forward Logistic Regression indicated that the presence or absence of skunks may be predicted by testing areas of land covers against verified skunks per capita (χ^2 = 46, df = 8, P < 0.001). Logistic Regression Analysis indicated that skunks were more likely to be present in medium-density residential and institutional areas, freshwater marshes, streams, wetland forest, barren land, abandoned tree crops, and community recreational facilities.

The results from the Chi–square Goodness of Fit test suggests that, on a landscape scale, skunks were selecting certain land cover categories rather than using them based on availability. The proportional distribution of animal control reports for skunks weighted by mean human population size was significantly different (χ^2 = 47, df = 7, P < 0.001) from the proportional distribution of available habitat land covers. This suggests that on a landscape scale, skunks in Brevard County were selecting certain land covers, rather than using habitats based on availability. In particular, skunks were selecting airports, roads and highways, recreational areas, horse farms, bays, and estuaries and were using woodland pasture less than expected.

The Stepwise Multiple Linear Regression Analysis showed that relative habitat-use for foxes, estimated by verified animal control reports per capita can be predicted (F = 8, df = 31, r^2 = 0.82, P < 0.001) using habitat characteristics (Table 5). The final regression model included a constant, spoil areas, row crops, industrial areas, golf courses, and airports. Golf courses were associated with a decrease in fox sightings (Figure 4). However, the model using unverified sightings gave substantially different results (0.0001 × tree crops + 0.0001 × wetland hardwood forest) from the model based on verified sightings, which suggests that only verified sightings should be used to model fox abundance.

Forward Logistic Regression indicated that fox presence and absence may be predicted (χ^2 = 20, df = 3, P < 0.001), testing areas of land covers against verified foxes per capita. Logistic Regression Analysis indicated that foxes were less likely to be present in extraction and shrub and brushland and more likely to be present near bays and estuaries.

The results from the Chi–square Goodness of Fit tests indicated that foxes were selecting certain land cover categories rather than using land covers based on availability. The proportional distribution of animal control reports for foxes weighted by mean human population size was significantly different (χ^2 = 29, df = 7, P < 0.001) from the proportional distribution of available habitat land covers. This suggests that on a landscape scale, foxes in Brevard County were selecting certain land covers, rather than using habitats based on availability. In particular, this indicates that foxes were selecting bays and estuaries more than expected by chance and selecting extraction categories and shrub and brushland less than expected.

Unverified reports for animal groups were weakly related to several demographic characteristics, which may indicate bias associated with those reports that could not be confirmed by an animal control officer. Bias for unverified reports per capita for raccoons (r = 0.400, P = 0.060) and opossums (r = 0.5, P < 0.001) were positively related to renter-occupied housing. No significant uncorrelated demographics were related to unverified reports about skunks. Fox bias was negatively correlated with the number of housing units (r = −0.47, P = 0.007).

Discussion

Some of the results from the analyses for raccoons agreed with those from other studies, while those from several land-cover categories did not agree. The analyses of verified calls per capita in this study showed that raccoon abundance was highest in areas zoned as commercial, including bus and truck terminals, industrial areas, communication tower corridors, and areas near streams. Other studies using conventional assessment techniques also showed that raccoons were found in urban and residential areas, particularly with streams nearby (Hoffman and Gottschang 1977, Anthony 1990, Rosatte et al. 1991, and Dijak and Thompson 2000). Raccoons also may be trapped in commercial and industrial areas (Rosatte et al. 1990, 1991). However, we

Table 5. Coefficients from Stepwise Multiple Linear Regression analyses to test verified foxes per capita against areas of land cover in Brevard County, Florida.

Fox land cover category	Coefficient	*P*	Loading
Constant	193.031	<0.001	
Spoil areas	0.003	<0.001	0.528
Row crops	0.014	0.001	0.271
Industrial	0.001	0.046	0.058
Airports	0.001	0.001	0.282
Golf courses	-0.0003	0.004	-0.223

reported reduced sightings in forested areas, shrub and brushland, and tree crops, while Hoffmann and Gottshang (1977) and Broadfoot et al. (2001) reported that raccoons preferred woodland area. It is likely that reduced visibility of animals in forested and shrubby areas would lead to reduced animal sighting reports in these areas. Therefore, the results from sighting data should be viewed with caution when visibility of the animals is an issue.

The analysis of opossums provided results similar to the findings for raccoons. The comparison of habitat availability relative to habitat usage indicated that raccoons selected some habitats and avoided others. Abundance of opossums was positively associated with high-density residential areas and streams and negatively associated with golf courses and wooded areas. We also found that opossums were found less often in low-density residential areas, upland coniferous pine forests, and mixed scrub wetlands. Sinclair et al. (2005) reported that opossums were abundant in areas with manicured lawns, low amounts of pavement, bare ground, and canopy cover. Crooks (2002) found high densities of opossum near residential areas, while Dijak and Thompson (2000) identified stream density as a factor in opossum abundance. Similar to the situation with raccoons, opossums may not have been identified in forested areas due to visibility constraints.

Some of the results of the current study for skunks largely agree with other studies conducted on spotted skunks, while some studies agree with studies conducted on striped skunks. Our analyses showed that skunks were more likely to be present in medium-density residential areas, along freshwater marshes, near streams, wetland forests, barren land, institutional areas, community recreational facilities, and abandoned tree crop land. Ehrhart (1974) and Kinlaw (1995) demonstrated that urban eastern spotted skunk den sites are often associated with wooded areas and not with wetlands near the Kennedy Space Center, Florida. However, striped skunks were associated with fields, industrial areas, streams, wetlands, and residential areas (Rosatte et al. 1991, Larivière and Messier 2000, Broadfoot et al. 2001). When the results of other studies are combined, they yield results similar to those of our study with the grouped skunk category.

The results from this study using verified reports of foxes in a category that contained 2 species of foxes (gray and red) were fairly consistent with the combined results from studies on each species. In our study, foxes were positively associated with a land cover mixture containing spoil areas, airports, row crops, and industrial areas, and were negatively associated with golf courses. Foxes were present in areas with bays and estuaries, and less likely to be found in areas of mineral extraction, shrub or brushland. Lewis et al. (1993) found radio-collared red foxes using agricultural lands, wetlands, estuaries, flood control channels, riparian areas, and vacant lands. Fritzell (1990) showed that gray foxes often were associated with wooded areas, rocky areas, and fields. However, contrary to findings by Lewis et al. (1993), foxes in our study avoided golf courses, which often were surrounded by resorts, residential areas, and commercial areas.

Overall, our use of verified sightings of animals as a source of data to evaluate habitat associations and relative abundance of raccoons, opossums, skunks, and foxes looks promising. In general, our findings tended to be similar to those from other studies that used more

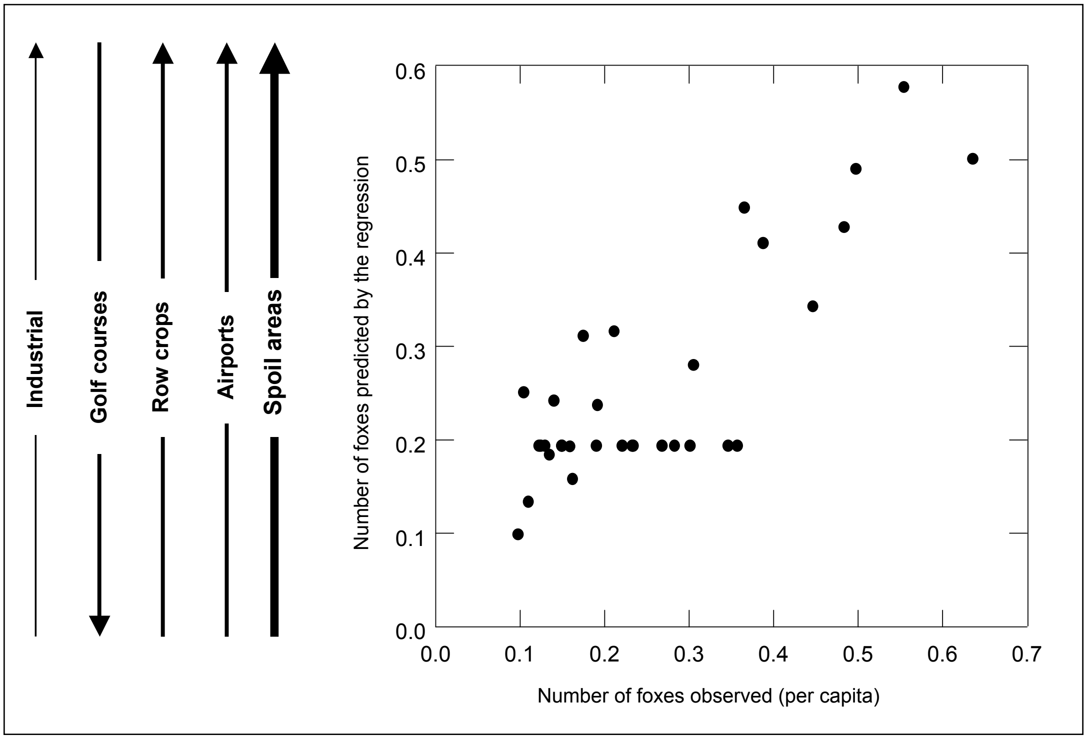

Figure 4. Scatter plot from the final model of the Stepwise Multiple Linear Regression ($P < 0.001$) testing the number of verified foxes per capita per quadrat against areas of land covers. The x axis indicated the number of foxes per capita within the quadrat. The y axis indicated the unstandardized predicted number of foxes from the regression. We calculated loadings (shown as weighted directional arrows) using Pearson Correlations on variables in the final model.

rigorous techniques. One of the big drawbacks to using sighting data is the tendency to underreport in areas with lower visibility. Areas with low visibility should be excluded from analyses, or perhaps, a weighting scheme could be developed to adjust sighting numbers in areas with restricted visibility. Combining information from animal control reports with radiotelemetry studies would allow increased information about activity on private residences and forested areas, maximize capture efforts, and reduce the costs associated with studies in urban and suburban areas. Unfortunately, radiotelemetry data were not available for any of the animal groups in the study area for direct comparison at the time of analyses.

Our technique requires certain restrictions to be effective. It is important to use only 1 call per address per animal type per year to determine a point location for each verified call. In this way, repeated reports from 1 sampling address with multiple phones can be eliminated. It is important to sample areas with people and phones present to allow a person to call and report an animal. Only verified reports per capita should be used to evaluate distribution and abundance as evidenced by the difference between verified and unverified models. Verified reports need to be per capita to allow for the potential of receiving a telephone call from each quadrat sampled, as the number of reports an agency receives may be related to human population size. To minimize overestimation of raccoon, opossum, skunk, and fox habitat-use, reports need to be per capita per quadrat. Our results indicated that it is important to create categories based on the biology of the species and analyze each landcover subcategory prior to creating categories. In addition, grouping of species in the reports can create problems. For example, grouping foxes and skunks in our study may have had a significant effect on the final model. As such, it is important for officers to clearly identify the species and whether an animal was present onsite to prevent grouping.

Certain data standardization requirements and automation could greatly decrease the time it takes to complete the analyses. When members of the public report animal locations to local agencies, reports of injured, trapped, and deceased animals should be investigated and recorded in a standardized format to facilitate use of this technique. We suggest that agencies dealing with wildlife include recording data in a GIS-compatible computer database along with the date, species, number reported, whether animals were verified, complete address location of the animal (with zip code), address of the person calling, evidence of animals being previously trapped or vaccinated (indicated by the presence of ear tags or other identification), status of the animal (alive, dead, or injured), reason for the request, and resulting action by the animal control officer. Recording information in this format will allow a seamless integration of the data into the GIS for rapid analysis.

The use of unverified sightings of animals as a source of data looks less promising. Our study indicated that analyses of unverified sightings produce slightly different results from analyses of verified sightings. In our study, however, there were surprisingly few observable effects of demographics. Reported sightings of raccoons and opossums were positively correlated with an increased number of renters, and foxes were negatively correlated with the number of housing units. The latter indicates that people in areas with a high number of housing units were not responsible for calling to report a fox when one was not observed by officers. However, the low demographic bias observed for unverified reports may be the result of some types of reports included in the unverified call database. In some situations, it was unclear in the records (8,215) whether or not an officer saw an animal at a location. While these reports may have resulted in a verified (although incomplete) report, we evaluated them as unverified. Also, repeated reports often led to multiple-verified reports and were included in the unverified reports database. Likewise, reports with incorrect or incomplete addresses (2,041 reports) often could not be mapped or analyzed. Therefore, we placed a large number of potentially verified reports in the unverified database. This may contribute to the minimal bias observed with unverified reports, as it is possible an animal was present at a location but left before BAS officers arrived.

Management implications

The technique introduced in this paper offers a source of additional information about where humans and wildlife are likely to interact in urban areas or where the animals may be trapped. Once identified, these areas can be used to deploy rabies-vaccine baits or facilitate other animal control techniques. This method could also be used as a preliminary study to rapidly assess, justify, and indicate where trapping studies should be conducted. It also may be used to evaluate areas where human–wildlife conflicts or nuisance wildlife events occur or identify hot spots where disease transmission is likely to occur between wildlife and domestic animals. Further, our technique may be used to analyze additional deceased and trapped animals over a large scale. For example, in cases where an immediate response to a rabies outbreak in raccoons or skunks is required, animal control data may be a relatively good, quick alternative to identify areas for rabies baiting or other control efforts (Anthony et al. 1990).

This technique allows for opportunistic live-trapping on residential properties with relatively low cost. Animal control data may then be used to evaluate the health of the population, perform a rapid assessment of habitat-use, or identify areas to improve the catch for additional trapping studies. Moreover, the presence of an animal control officer provides an independent confirmation of animal presence at a location and an opportunity to educate the public regarding human–wildlife conflicts (Curtis et al. 1993). If data are recorded in a standardized and GIS-compatible format, the current technique may be performed at a countywide scale or on a larger scale in a couple of weeks without additional field equipment or without obtaining additional permission from landowners.

The technique introduced in this paper is potentially useful for quickly assessing the relative distribution of raccoons, opossums, skunks, and foxes in urban areas. Analyses from verified animal control data per capita used to estimate relative habitat-use provides results similar, for the most part, to other studies using other sampling techniques. Unfortunately, as models differed between verified and unverified reports per capita for all species studied, unverified reports per capita can not be used to estimate mixtures of habitats for raccoons, opossums, skunks, and foxes.

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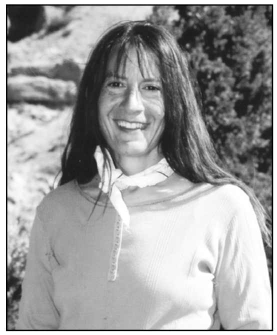

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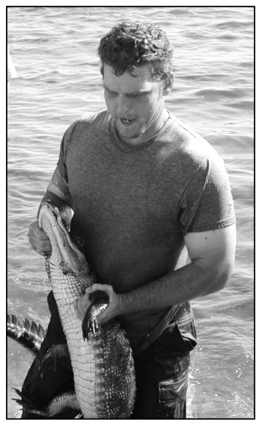

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