Note

Free-roaming cat interactions with wildlife admitted to a wildlife hospital

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ABSTRACT Free-roaming domestic cats are a major anthropogenic source of morbidity and mortality to wild birds and mammals in the United States. Permitted wildlife rehabilitators routinely treat cat-caused injuries. However, extent of these activities is under-reported in the scientific literature. To determine incidence, age class, mortality, diversity and frequency of species affected, nature of injuries, time in care, and temporal and geospatial trends associated with interactions between free-roaming cats and wildlife, we conducted a retrospective analysis on 20,921 records from small birds and mammals presented to the Wildlife Center of Virginia (WCV), USA between 2000 and 2010. Cat interaction was the second greatest cause of small-mammal admissions (14.8%), fourth greatest cause of mammal mortality (70.8%), fourth greatest cause of bird admissions (13.7%), and second greatest cause of avian mortality (80.8%). Eighty-three species were admitted following interactions with cats. Age of wildlife admitted following cat interaction varied by class; juvenile mammals were captured most frequently (40.5%), followed by neonates (34%), then adults (25.5%). However, adults were documented most frequently in birds (42.7%), followed by juveniles (37.2%), then nestlings (20.1%). Birds were more likely to have interactions with cats in rural areas, whereas degree of urbanization did not differ for mammals. Eighty-eight percent of cat interactions occurred between April and September, indicating a strong seasonal trend. Our findings indicate that free-roaming cats substantially contribute to admissions in a wildlife rehabilitation hospital and even with veterinary intervention, release potential is limited. Reducing the number of free-roaming cats will reduce interactions with wildlife and decrease the need for medical assistance.

KEY WORDS domestic cat, free-roaming, interaction, mortality, rehabilitation, Virginia, wildlife.

Free-roaming cats have been identified as a major source of anthropogenic mortality for birds and mammals in the contiguous United States (Forbush 1916, Coleman and Temple 1996, Erickson et al. 2005, Loss et al. 2013). Captured prey may be consumed, left at the capture site, or brought back to human households by owned cats allowed access to the outdoors. Studies have extrapolated from prey brought home to estimate losses to wildlife populations, but the results are conservative (Coleman and Temple 1996, Lepczyk 2004, Krauze-Gryz et al. 2012). A recent cat tracking study indicates that wildlife brought home by free-roaming cats represents <25% of the wildlife captured (Loyd et al. 2013).

The magnitude of mortality may be best observed in permitted wildlife rehabilitation facilities that treat hundreds of thousands of injured and orphaned wildlife across North America annually. In part, the mission of these organizations is to treat injured and orphaned animals so that they might be returned with full function to the wild where they may continue to contribute to the population. Cat interaction is consistently a leading cause of patient admissions in the wildlife rehabilitation community (WILD-ONe database, Wildlife Center of Virginia, Waynesboro, VA); however, incidence reporting in the peer-reviewed literature is usually limited to specific time periods, number of individuals admitted (i.e., patients), and outcome or disposition (e.g., released, died, euthanized, permanent placement; Jessup 2004, Schenk and Souza 2014, Scheelings 2015). Although it is not appropriate to use these incident data to assess trends at the population level, they provide valuable insight into the species and life stages most affected, temporal and geospatial trends associated with free-roaming cat interactions, and mortality associated with injuries. These data are conservative indicators of cat interactions with wildlife because admission to rehabilitation facilities necessitates that injured wildlife be observed by humans who then seek medical assistance.

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The political, social, public health, and conservation issues surrounding free-roaming cats are complicated (Peterson et al. 2012, Wald et al. 2013, Lohr and Lepczyk 2014). Despite growing evidence that free-roaming cats reduce wildlife populations through direct (i.e., lethal, consumption) and indirect (i.e., sublethal effects resulting from altered prey behavior to avoid immediate predation risk) predation (Lepczyk 2004, Cresswell 2008, Balogh et al. 2011, Stracey 2011, Bonnington et al. 2013), spread disease to other wildlife species (Miller et al. 2002, Anderson et al. 2003, Conrad et al. 2005), negatively affect environmental health (Dabritz et al. 2006), and transmit zoonotic pathogens to humans (Gerhold and Jessup 2013), cat management on the landscape remains contentious (Longcore et al. 2009, Lepczyk et al. 2010, Dauphiné 2011, Loyd and Hernandez 2012, Wald et al. 2013). There are an estimated 50–157 million free-roaming cats in North America (Schmidt et al. 2007, Dauphiné and Cooper 2009). Approximately 57 million of these are pet cats allowed to roam outside for a portion of the day (Winter 2004). Of the estimated 1.4–3.7 billion birds and 6.9–20.7 billion mammals killed annually by cats within the United States, 69% of bird predation and 89% of mammal predation is associated with free-ranging cats (Loss et al. 2013). These free-ranging free-roaming cats are typically unregulated. The regulations that do exist are almost exclusively at the city or county level. Although sheltering, adoption, and euthanasia have been the traditional management tools, expanding free-roaming cat populations and growing pressure from cat and animal rights advocacy groups for no-kill shelters have led to alternative strategies (Longcore et al. 2009, Wald et al. 2013). One of the most popular of these strategies is trap-neuter-release or trap-neuter-return (TNR), which claims that sterilizing, feeding, and maintaining colonies of cats will eventually reduce free-roaming cat populations (Levy et al. 2003, Slater 2004). However, there is scant scientific evidence to indicate that this strategy, on its own, can meet this goal (Longcore et al. 2009; Lepczyk et al. 2010, 2015; Lohr et al. 2013). Meanwhile, free-roaming cats, sterilized or not, continue to prey on wildlife.

Although there are many positive characteristics (and some issues) associated with wildlife rehabilitation, the greatest benefit is arguably the ability to educate the public on conservation issues (Tribe and Brown 2000). Documenting the impact on local wildlife admitted to rehabilitation facilities is the first step in education, which eventually leads to a change in human behavior and hopefully partial or full resolution of the conservation issue. The objectives of this study were to review incidence of cat interactions with wildlife admitted to the Wildlife Center of Virginia (WCV), USA from 2000 to 2010 and characterize patient age category, mortality, nature of injuries, duration in care, and temporal and geospatial trends. To address these objectives, we developed hypotheses related to the cause of admission, age, season, rescue location, injury status, and duration of care (Table 1).

STUDY AREA

We conducted this study on wildlife patients admitted to the WCV in Waynesboro, Virginia, USA between 2000 and 2010. Patients were admitted from across Virginia; the majority (86.5%) were from the surrounding 5 rural counties (Albemarle, Augusta, Nelson, Rockbridge, and Rockingham) and 5 urban independent cities (Charlottesville, Harrisonburg, Lexington, Staunton, and Waynesboro). Housing densities in rural counties ranged from 7.0–22.4 housing units/km^2 and from 225.7–710.0 housing units/km^2 in urban cities (U.S. Census Bureau 2012). Twenty-nine percent of Virginia households (876,000) own cats, and the average number of owned cats per household is 2.1 (American Veterinary Medical Association 2012). The authors were unable to determine the number of households in Virginia with indoor-outdoor cats or estimate the number of free-roaming feral cats in Virginia.

METHODS

We reviewed 20,921 original medical records of small wild birds and small wild mammals admitted for rehabilitation. The care and treatment of wildlife was conducted by licensed veterinarians under rehabilitation permits issued by the United States Fish and Wildlife Service and the Virginia Department of Game and Inland Fisheries. We defined cat interaction as any case where the rescuer observed a cat and the injured wildlife together resulting in admission for medical care. We classified cases where the rescuer suspected cat interaction or where there was medical suspicion of a cat interaction without documented history as unknown cause of admission. We excluded 2,970 records of large non-passerine birds (e.g., raptors, wading birds, waterfowl, adult Galliformes; 1,537 cases) and larger mammals (1,433 cases) from the analysis because we considered them too large to be prey for free-ranging cats. Mammals excluded from analysis included American black bears (*Ursus americanus*; 62 cases), white-tailed deer (*Odocoileus virginianus*) fawns (913 cases), bobcats (*Lynx rufus*; 14 cases), semi-aquatic mammals (28 cases), canids (200 cases), adult raccoons (*Procyon lotor*; 89 cases), adult striped skunks (*Mephitis mephitis*; 18 cases), and adult woodchucks (*Marmota monax*; 109 cases).

Data collected from each patient included species, admission date, age category, cause of admission, county or independent city of rescue, health status, injury type, disposition, disposition date, and duration of care. Standardized field codes were used throughout the study to maintain consistency over time. In some cases, species were listed as unknown or classified as a species group (e.g., thrush species), usually from the challenge of identifying nestling birds or from inadequate identification experience of new personnel. We did not use species groups to assess total number of species admitted.

Age categories included nestling or neonate (i.e., young altricial birds still within the nest, young precocial birds still covered in down, young dependent mammals), juveniles

Table 1. Summary of study categories and research hypotheses regarding wildlife patients admitted to the Wildlife Center of Virginia, Waynesboro, Virginia, USA, 2000–2010.

Research category	Hypotheses			
Cause of admission	$H_0 1$	No difference between the frequencies of patients admitted from cat interactions vs. other causes of admission.	$H_A 1$	Frequency of patients admitted from cat interaction is different than patients admitted for other reasons.
	$H_0 2$	No difference in the frequency of cat interaction admissions between species.	$H_A 2$	Frequency of cat interaction admissions is different between species.
	$H_0 3$	No difference in mortality between species admitted from cat interaction vs. other causes of admission.	$H_A 3$	Mortality of species admitted from cat interaction is different than mortality in species admitted from other causes of admission.
Age category	$H_0 1$	No difference in the frequency of patients admitted from cat interaction based on life stage.	$H_A 1$	Frequency of patients admitted from cat interaction differs based on life stage.
Seasonal patterns	$H_0 1$	Frequency of patients admitted from cat interaction is consistent throughout the year.	$H_A 1$	Frequency of patients admitted from cat interaction differs throughout the year.
Rescue locations	$H_0 1$	No difference in the frequency of patients admitted from cat interactions based on urban vs. rural rescue locations.	$H_A 1$	Frequency of patients admitted from cat interaction is greater in urban vs. rural rescue locations.
	$H_0 2$	Species count of patients admitted from cat interaction does not differ based on urban vs. rural rescue locations.	$H_A 2$	Species count in patients admitted from cat interaction is lesser in urban vs. rural rescue locations.
Impact of injury status	$H_0 1$	Mortality of patients categorized as either injured or healthy does not differ between patients admitted from cat interaction vs. other causes of admission.	$H_A 1$	Patients admitted from cat interaction and categorized as either injured or healthy will have a greater mortality compared to injured and healthy patients admitted from other causes of admission.
	$H_0 2$	No difference in the frequency of clinical presentation categories in patients admitted from cat interaction.	$H_A 2$	Frequency of clinical presentation categories differ in patients admitted from cat interaction.
Durations of care	$H_0 1$	No difference in duration of care between cat interaction patients categorized as injured vs. healthy.	$H_A 1$	Patients admitted from cat interaction have a shorter duration of care if categorized as injured vs. healthy.

(i.e., fledgling altricial birds, precocial birds lacking down but not yet adult size, young mammals not fully dependent on a parent but not yet adult size), and adults (i.e., independent and full adult size but not necessarily adult plumage or pelage).

Health status (i.e., healthy vs. injured) and injury category (i.e., nervous system abnormalities, skin lesions, ocular trauma) were assigned on the basis of the patient's history, a physical examination, ancillary diagnostic tests, gross necropsy, histological examination, or a combination thereof. When there were multiple injuries to the same patient, the ultimate cause or the most significant or life-threatening injury was recorded. Not all patients admitted for rehabilitation were injured; many were displaced, orphaned, or did not need to be rescued. Animals with no apparent injuries following a thorough veterinary examination regardless of the cause of admission were given a clinical presentation classification of none, indicating a healthy patient.

Precise rescue coordinates were not recorded on admission; thus, precise spatial analysis was not possible for this study. To assess if urbanization played a role on cat interactions with wildlife, we classified rescue locations as either metropolitan (urban) or nonmetropolitan (rural) based on the 2006 National Center for Health Statistics Urban-Rural Classification Scheme for counties (NCHSURCS; Ingram and Franco 2012). We defined rural counties as human populations <50,000 individuals and urban counties as those with >50,000 individuals. The 2006 version of the NCHSURCS was representative of the time the data were collected.

Final outcome or disposition was recorded as released, euthanized, died in care, transferred for further rehabilitation, or permanently placed. We considered overall mortality to be the combination of patients that were euthanized and those that died from severity of their injuries.

Statistical Analysis

We extracted data from patient records and organized them in a computerized database (Microsoft Excel 2007, Redmond, WA, USA). We calculated descriptive statistics within the same program to determine frequency of cat interactions (i.e., overall, by age category, and by rescue location); number of species admitted following cat interactions; and mortality, health status, and duration of care associated with cause of admission.

We used chi-square analyses to test for homogeneity in proportions of cat interactions and non-cat interactions by age group in mammals and birds to investigate if cat interactions were underrepresented or overrepresented within age classes compared to patients admitted for other reasons. Data transformation was not required for chi-square analyses. We used additional chi-square analyses to test for homogeneity in proportions of cat interactions by rescue location and health status for mammals and birds. For all chi-square tests, the expected count used in each contingency table was >5.

We conducted standard t-tests for equality of means to analyze differences in duration of care for healthy, injured, and all wildlife admitted following cat interaction compared to similar groups of patients admitted for other reasons. We used these tests to investigate whether patients interacting with cats required more or fewer rehabilitation resources compared to non-cat interaction patients. We conducted Levine's test for equality of variance and if $P < 0.2$, we did not assume equal variance for the t-test. We conducted chi-square and t-test analyses using dedicated statistical software (IBM SPSS Statistics for Windows, Version 22.0.

Armonk, NY). We concluded statistical tests were significant at $\alpha = 0.05$.

RESULTS

Between 2000 and 2010, 11,144 small mammals and 9,777 small birds were admitted to WCV. Cat interaction was the second leading cause of admission for small mammals (14.8%) and the fourth leading cause of small bird admissions (13.7%). More common causes of admission included orphan (46.2%) in small mammals and orphan (34.9%), unknown trauma (14.2%), and unknown non-trauma (14.2%) in birds. Twenty-one mammal species and one unknown mammal group were categorized on admission as cat interaction, representing 73.3% of small mammal species admitted during the study period. Sixty-two bird species and one unknown bird group were admitted following cat interactions, representing 64.3% of small bird species admissions.

Frequency of admissions caused by cat interaction varied among species. The greatest frequency in small mammals was found in eastern chipmunks (*Tamias striatus*; 52.7%), eastern cottontails (*Sylvilagus floridanus*; 26.1%), and southern flying squirrels (*Glaucomys volans*; 22.5%; Table 2). Records indicated no admissions with cat interactions in 2 species of bats and 6 species of small rodents (28% of mammal admissions). Small birds with the greatest frequency of cat interactions included mourning doves (*Zenaida macroura*; 20.6%), American robins (*Turdus migratorius*; 20.5%), and northern cardinals (*Cardinalis cardinalis*; 22.1%; Table 3). Records indicated no documentation of cat interactions in 35 species (36% of admissions) of small birds admitted for rehabilitation.

Cat interaction was the fourth leading cause of mortality in small mammals. Mortality rate (died + euthanized) in small-mammal groups from cat interaction was 70.8% (Table 4). Cat interactions were the second most frequent cause of mortality in small birds and 80.8% of cases were euthanized or died of their injuries (Table 4). More frequent causes of mortality rates included unknown trauma (85.6%), hit by vehicle (79.9%), and unknown non-trauma (76.9%) in small mammals and unknown trauma (88.9%) in birds.

Mortality rate varied among wildlife species admitted from cat interaction. Many species were represented by only a small number of individuals so we analyzed only the 10 most frequently admitted bird species and mammal groups. In the small bird category, gray catbirds (*Dumetella carolinensis*) had the least mortality rate (67.6%, $n = 25$) and unidentified finches (house finches [*Carpodacus mexicanus*] and purple finches [*Haemorhous purpureus*]) had the greatest mortality rate (88.5%, $n = 46$; Table 4). Within the small-mammals group, the Virginia opossum (*Didelphis virginiana*) had the least mortality rate (28.6%, $n = 6$) and the bat group had the greatest (84.4%, $n = 27$; Table 4).

Small juvenile mammals had the greatest frequency of cat interaction, followed by neonates, then adults (Table 2). Of the small birds admitted for cat interaction, adults were admitted most frequently, followed by juveniles, and nestlings (Table 3). Frequency of patients per age category

Table 2. Small mammal species with documented cases of cat interaction admitted to the Wildlife Center of Virginia, Waynesboro, Virginia, USA, 2000–2010 characterized by number admitted, number attributed to cat interactions (% of admissions in parentheses), and age class of cat-caught individuals (% of cat-caught admissions in parentheses).

Mammal species	Mammal admissions	Cat-caught admissions	Cat-caught neonates	Cat-caught juveniles	Cat-caught adults
Virginia opossum	2,585	21 (0.8)	8 (38.1)	12 (57.1)	1 (4.8)
Eastern fox squirrel (*Sciurus niger*)	76	5 (6.6)	1 (20)	2 (40)	2 (40)
Eastern gray squirrel (*Sciurus carolinensis*)	2,604	306 (11.8)	156 (50.1)	103 (33.7)	47 (15.4)
Southern flying squirrel	213	48 (22.5)	9 (18.8)	16 (33.3)	23 (47.9)
Eastern chipmunk	148	78 (52.7)		15 (19.2)	63 (80.8)
Woodchuck	115	1 (0.9)		1 (100)	
Eastern harvest mouse (*Reithrodontomys humulis*)	1	1 (100)			1 (100)
European house mouse (*Mus musculus*)	19	1 (5.3)			1 (100)
Hispid cotton rat (*Sigmodon hispidus*)	1	1 (100)			1 (100)
Norway rat (*Rattus norvegicus*)	10	1 (10)			1 (100)
Long-tailed shrew (*Sorex dispar*)	1	1 (100)			1 (100)
Northern short-tailed shrew (*Blarina brevicauda*)	4	2 (50)			2 (100)
Unidentified mice, rats, shrews, moles, and voles	433	65 (15.0)	35 (53.8)	13 (20.0)	17 (26.2)
Eastern cottontail rabbit	4,134	1,079 (26.1)	340 (31.5)	504 (46.7)	235 (21.8)
Big brown bat (*Eptesicus fuscus*)	71	3 (4.2)			3 (100)
Eastern red bat (*Lasiurus borealis*)	19	3 (15.8)			3 (100)
Hoary bat (*Lasiurus cinereus*)	4	1 (25)			1 (100)
Little brown bat (*Myotis lucifugus*)	40	5 (12.5)		1 (20)	4 (80)
Silver-haired bat (*Lasionycteris noctivagans*)	11	1 (9.1)			1 (100)
Unidentified bat species	201	19 (9.5)	6 (31.6)		13 (68.4)
Least weasel (*Mustela nivalis*)	3	1 (33.3)			1 (100)
Striped skunk	113	3 (2.7)	3 (100)		
Raccoon	306	3 (1.0)	3 (100)		
Total	11,112	1,649 (14.8)	561 (34.0)	667 (40.4)	421 (25.5)

Table 3. Small birds admitted to the Wildlife Center of Virginia, Waynesboro, Virginia, USA, 2000–2010 characterized by number admitted, number attributed to cat interactions (% of admissions in parentheses), and age class of cat-caught individuals (% of cat-caught admissions in parentheses).

Bird species	Bird admissions	Cat-caught admissions	Cat-caught nestlings	Cat-caught juveniles	Cat-caught adults
Ruffed grouse (*Bonasa umbellus*)	17	1 (5.9)	1 (100)		
Wild turkey (*Meleagris gallopavo*)	45	3 (6.7)	1 (33.3)	1 (33.3)	1 (33.3)
Sora (*Porzana carolina*)	3	1 (33.3)			1 (100)
American woodcock (*Scolopax minor*)	16	2 (12.5)			2 (100)
Mourning dove	724	149 (20.6)	34 (22.8)	36 (24.2)	79 (53.0)
Rock pigeon	340	10 (2.9)		2 (20)	8 (80)
Black-billed cuckoo (*Coccyzus erythropthalmus*)	6	1 (16.7)	1 (100)		
Yellow-billed cuckoo (*Coccyzus americanus*)	17	1 (5.9)			1 (100)
Chimney swift (*Chaetura pelagica*)	248	5 (2.0)		2 (40)	3 (60)
Common nighthawk (*Chordeiles minor*)	3	2 (66.7)		1 (50)	1 (50)
Ruby-throated hummingbird (*Archilochus colubris*)	85	9 (10.6)		1 (11.1)	8 (88.9)
Downy woodpecker (*Picoides pubescens*)	50	8 (16.0)			8 (100)
Northern flicker (*Colaptes auratus*)	110	9 (8.2)		1 (11.1)	8 (88.9)
Red-bellied woodpecker (*Melanerpes carolinus*)	69	6 (8.7)		1 (16.7)	5 (83.3)
Yellow-bellied sapsucker (*Sphyrapicus varius*)	33	7 (21.2)		1 (14.3)	6 (85.7)
Eastern wood-pewee (*Contopus virens*)	4	1 (25.0)			1 (100)
Eastern phoebe (*Sayornis phoebe*)	106	10 (9.4)	2 (20)	4 (40)	4 (40)
Eastern kingbird (*Tyrannus tyrannus*)	8	2 (25.0)		1 (50))	1 (50)
Yellow-throated vireo (*Vireo flavifrons*)	2	1 (50.0)	1 (100)		
Blue jay	683	131 (19.2)	21 (16.0)	75 (57.3)	35 (26.7)
American crow (*Corvus brachyrhynchos*)	284	1 (0.4)			1 (100)
Barn swallow (*Hirundo rustica*)	99	2 (2.0)	1 (50)		1 (50)
Tree swallow (*Tachycineta bicolor*)	12	2 (16.7)			2 (100)
Tufted titmouse (*Baeolophus bicolor*)	78	15 (19.2)	1 (6.7)	4 (26.7)	10 (66.7)
Black-capped chickadee (*Poecile atricapillus*)	9	1 (11.1)			1 (100)
Carolina chickadee (*Poecile carolinensis*)	6	4 (66.7)		3 (75)	1 (25)
White-breasted nuthatch (*Sitta carolinensis*)	6	3 (50.0)		1 (33.3)	2 (66.7)
Carolina wren (*Thryothorus ludovicianus*)	342	48 (14.0)	15 (31.3)	14 (29.2)	19 (39.6)
House wren (*Troglodytes aedon*)	134	9 (6.7)	1 (11.1)	4 (44.4)	4 (44.4)
Ruby-crowned kinglet (*Regulus calendula*)	3	1 (33.3)			1 (100)
Eastern bluebird (*Sialia sialis*)	242	29 (12.0)	4 (13.8)	10 (34.5)	15 (51.7)
American robin	1,319	271 (20.5)	49 (18.1)	154 (56.8)	68 (25.1)
Hermit thrush (*Catharus guttatus*)	5	1 (20)			1 (100)
Veery (*Catharus fuscescens*)	1	1 (100)			1 (100)
Wood thrush (*Hylocichla mustelina*)	57	15 (26.3)	4 (26.7)	4 (26.7)	7 (46.7)
Northern mockingbird (*Mimus polyglottos*)	279	33 (11.8)	18 (54.6)	11 (33.3)	4 (12.1)
Gray catbird	100	37 (37)	12 (32.4)	16 (43.2)	9 (24.3)
Brown thrasher (*Toxostoma rufum*)	42	12 (28.6)		3 (25)	9 (75)
European starling	1,179	57 (4.8)	13 (22.8)	20 (35.1)	24 (42.1)
Cedar waxwing (*Bombycilla cedrorum*)	98	11 (11.2)	1 (9.1)	4 (36.4)	6 (54.6)
Ovenbird (*Seiurus aurocapilla*)	7	1 (14.3)			1 (100)
Pine warbler (*Setophaga pinus*)	2	1 (50.0)			1 (100)
Northern cardinal	376	83 (22.1)	11 (13.3)	17 (20.5)	55 (66.3)
Indigo bunting (*Passerina cyanea*)	12	1 (8.3)			1 (100)
Rose-breasted grosbeak (*Pheucticus ludovicianus*)	11	1 (9.1)			1 (100)
Eastern towhee (*Pipilo erythrophthalmus*)	10	2 (20.0)			2 (100)
Field sparrow (*Spizella pusilla*)	12	2 (16.7)		1 (50)	1 (50)
White-crowned sparrow (*Zonotrichia leucophrys*)	3	1 (33.3)			1 (100)
White-throated sparrow (*Zonotrichia albicollis*)	18	4 (22.2)		1 (25)	3 (75)
Song sparrow (*Melospiza melodia*)	4	2 (50.0)			2 (100)
Brown-headed cowbird (*Molothrus ater*)	16	2 (12.5)			2 (100)
Red-winged blackbird (*Agelaius phoeniceus*)	12	2 (16.7)		1 (50)	1 (50)
Common grackle (*Quiscalus quiscula*)	593	63 (10.6)	15 (23.8)	23 (36.5)	25 (39.7)
Baltimore oriole (*Icterus galbula*)	11	2 (18.2)		2 (100)	
Evening grosbeak (*Coccothraustes vespertinus*)	1	1 (100)			1 (100)
House finch	118	14 (11.9)	3 (21.4)	3 (21.4)	8 (57.1)
Purple finch	11	1 (9.1)			1 (100)
Pine siskin (*Carduelis pinus*)	15	2 (13.3)			2 (100)
American goldfinch (*Carduelis tristis*)	132	13 (9.8)	1 (7.7)	4 (30.8)	8 (61.8)
House sparrow (*Passer domesticus*)	115	15 (13.0)	2 (13.3)	5 (33.3)	8 (53.3)
Dark-eyed junco (*Junco hyemalis*)	49	7 (14.4)			7 (100)
Unidentified passerine	1,251	189 (15.1)	53 (28.0)	61 (32.3)	75 (39.7)
Total	9,643	1,321 (13.7)	265 (20.1)	492 (37.2)	564 (42.7)

Table 4. Treatment outcomes for the 10 most frequently admitted mammal and bird species admitted for cat interaction to the Wildlife Center of Virginia between 2000–2010.

Class	Species	Total admitted	Cat-caught released	Cat-caught transferred	Cat-caught died	Cat-caught euthanized	Cat-caught total alive	Cat-caught total dead	Total Cat-caught admitted
Mammals									
	Virginia opossum	2,585	14 (66.7)	1 (4.8)	3 (14.3)	3 (14.3)	15 (71.4)	6 (28.6)	21 (0.8)
	Eastern fox squirrel	76	0	2 (40.0)	1 (20.0)	2 (40.0)	2 (40.0)	3 (60.0)	5 (6.6)
	Eastern gray squirrel	2,604	82 (26.8)	77 (25.2)	68 (22.2)	79 (25.8)	159 (52.0)	147 (48.0)	306 (11.8)
	Southern flying squirrels	213	11 (22.9)	14 (29.2)	14 (29.2)	9 (18.8)	25 (52.1)	23 (47.9)	48 (22.5)
	Eastern chipmunk	148	33 (42.3)	0	16 (20.5)	29 (37.2)	33 (42.3)	45 (57.7)	78 (52.7)
	Combined mice, rats, voles, moles, and shrews)	497	16 (20.8)	2 (2.6)	41 (53.2)	18 (23.4)	18 (23.4)	59 (76.6)	77 (15.5)
	Eastern cottontail	4,134	184 (17.1)	37 (3.4)	442 (41.0)	416 (38.6)	221 (20.5)	858 (79.1)	1,079 (26.1)
	Bats	350	4 (12.5)	1 (3.1)	11 (34.4)	16 (50.0)	5 (15.6)	27 (84.4)	32 (9.1)
	Striped skunk[a]	113	0	1 (33.3)	2 (66.7)	0	1 (33.3)	2 (66.7)	3 (2.7)
	Raccoon[a]	306	0	2 (66.7)	0	1 (33.3)	2 (66.7)	1 (33.3)	3 (1.0)
	All mammal species	11,144	345 (20.9)	136 (8.2)	597 (36.2)	571 (34.6)	481 (29.2)	1,168 (70.8)	1,649 (14.8)
Birds									
	Mourning dove	724	33 (22.1)	7 (4.7)	40 (26.8)	35 (23.5)	74 (49.7)	109 (73.2)	149 (20.6)
	Blue jay	683	4 (3.1)	27 (20.6)	31 (23.7)	48 (36.6)	52 (39.7)	100 (76.3)	131 (19.2)
	Carolina wren	342	5 (10.4)	4 (8.3)	9 (18.8)	32 (66.7)	7 (14.6)	39 (81.3)	48 (14.0)
	American robin	1,319	47 (17.3)	9 (3.3)	56 (20.7)	113 (41.7)	102 (37.6)	215 (79.3)	271 (20.5)
	Gray catbird	100	4(10.8)	8(21.6)	15(40.5)	10(27.0)	12(32.4)	25(67.6)	37(37.0)
	European starling	1,179	5 (8.8)	2 (3.5)	7 (12.3)	16 (28.1)	34 (59.6)	50 (87.7)	57 (4.8)
	Northern cardinal	376	9 (10.8)	2 (2.4)	11 (13.3)	40 (48.2)	32 (38.6)	72 (86.7)	83 (22.1)
	Unknown sparrow sp.	537	17 (18.8)	4 (4.3)	21 (22.6)	43 (46.2)	29 (31.2)	72 (77.4)	93 (17.3)
	Common grackle	593	9 (14.3)	1 (1.6)	10 (15.9)	26 (41.3)	27 (42.9)	53 (84.1)	63 (10.6)
	Unknown finch sp.	301	6 (11.5)	0	6 (11.5)	31 (59.6)	15 (28.8)	46 (88.5)	52 (17.3)
	All bird species	9,777	171 (12.9)	83 (6.3)	254 (19.2)	574 (43.5)	493 (37.3)	1,067 (80.8)	1,321 (13.5)

[a] Excluding adult animals too large to be considered prey for free-roaming cats.

differed for patients admitted for cat interaction compared to those admitted for other reasons (mammals: $\chi^2_2 = 350$, $P < 0.001$, birds: $\chi^2_2 = 130$, $P < 0.001$). A greater frequency of juvenile and adult birds and mammals were admitted for cat interaction compared to wildlife admitted for other reasons. A lesser percentage of nestling or neonates were admitted for cat interactions compared to wildlife admitted for other causes of rescue.

Wildlife admitted following cat interaction occurred throughout the year, but there was a strong seasonal trend. Cat interactions in April through September accounted for 88% of admissions in small mammals and 85% of small bird admissions (Fig. 1). Proportion of cat-caught admissions to all causes of admission each month (i.e., monthly incidence) remained relatively constant throughout the year but was less in January and February for small mammals (Fig. 2).

The 5 counties closest to WCV (i.e., Albemarle, Augusta, Nelson, Rockbridge, and Rockingham) and the 5 independent cities contained within them (i.e., Charlottesville, Waynesboro, Staunton, Lexington, and Harrisonburg) represented 86.5% of admissions included in this study and 90.9% of cases admitted for cat interactions. Small birds were more likely to interact with cats in rural areas (57.2%) than urban areas (42.8%; $\chi^2_1 = 4.7$, $P = 0.03$). There was no difference between small mammals caught by cats in rural (51.6%) versus urban (48.4%) settings ($\chi^2_1 = 0.2$, $P = 0.66$). Number of species caught in urban and rural areas was similar. Cat interaction occurred in 49 of the 86 bird species admitted from urban areas and 46 of the 89 bird species admitted from rural areas. Cat interaction was observed in 15 of the 26 known mammal species in urban areas and 15 of the 24 known mammal species admitted from rural areas.

Most wildlife admitted for cat interactions were classified as injured (85.9%) compared to healthy (14.1%) based on a medical examination. Birds with injuries represented 87.5% of cat interaction cases versus an 84.6% injury rate for mammals. Small birds admitted following cat interaction but found to be healthy on a medical examination had a greater

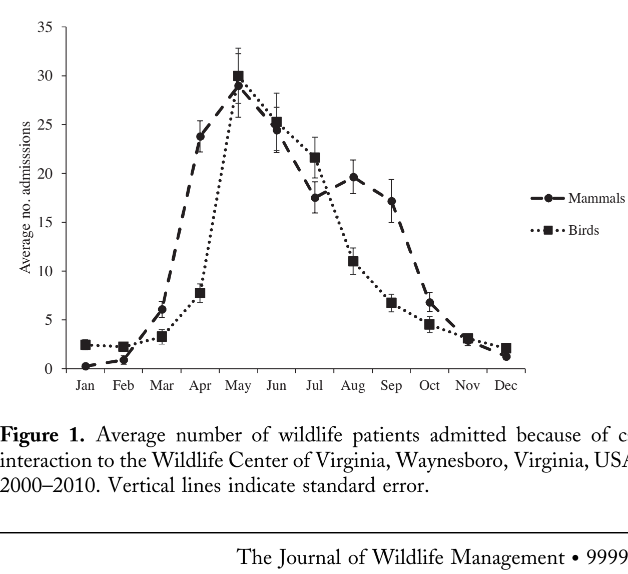

Figure 1. Average number of wildlife patients admitted because of cat interaction to the Wildlife Center of Virginia, Waynesboro, Virginia, USA, 2000–2010. Vertical lines indicate standard error.

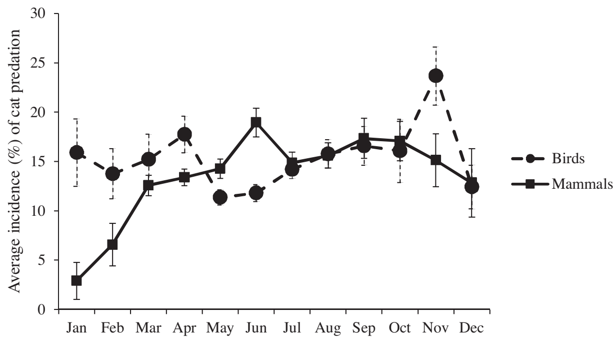

Figure 2. Average monthly incidence (i.e., the proportion of cat-caught admissions to all causes of admission each month) of wildlife patients admitted following cat interaction to the Wildlife Center of Virginia, Waynesboro, Virginia, USA, 2000–2010. Vertical lines indicate standard error.

mortality rate (55.8%) than healthy bird patients admitted for other reasons (46.7%; $\chi^2_1 = 5.134$, $P = 0.023$). There was no difference in mortality between healthy small mammals admitted following cat interaction (33.9%) and healthy mammals admitted for other reasons (28.7%; $\chi^2_1 = 3.237$, $P = 0.077$).

Wildlife diagnosed with injuries from cat interactions had a greater mortality rate (80.6%) than injured patients admitted for other reasons (73.1%; $\chi^2_1 = 62.165$, $P < 0.001$). Injuries associated with small birds admitted for cat interactions resulted in an 84.3% mortality rate, which was greater than birds injured in non-cat events (82.1%; $\chi^2_1 = 3.279$, $P = 0.037$, 1-tailed). Mammals injured by cats had a lesser mortality rate than injured birds (77.6%); however, mortality rates associated with cat interactions were still greater than those for injured mammals admitted for other reasons (64.0%; $\chi^2_1 = 91.165$), $P < 0.001$).

The clinical presentation categories recorded in patients with cat interactions were similar among classes. The most frequently recorded primary injuries were damage to the muscles or internal organs (24.4% in birds, 25.8% in mammals) and skin (15.2% in birds, 28.7% in mammals). Other injuries included bone fractures (15.0% in birds, 5.5% in mammals), nervous system abnormalities (3.9% in birds, 7.0% in mammals), respiratory compromise (2.6% in birds), and general shock (5.0% in mammals).

Small mammal and bird patients admitted following cat interactions spent fewer days in care compared to patients admitted for other reasons when comparing cause of admission. Injury status influenced the duration in care depending on class. Healthy and injured small mammals with cat interactions had lesser duration in care compared to healthy and injured animals admitted for other reasons. Healthy and injured small birds admitted for cat interaction had the same duration in care as healthy and injured patients admitted for other reasons (Table 5).

DISCUSSION

Interactions with cats represented the fourth leading cause of bird admissions and the second leading cause in mammals admitted to the WCV in a 10-year period. Number and frequency of patients admitted for cat interaction varied depending on species, life stage, time of year, and in some cases degree of urbanization. Species more commonly admitted for cat interaction were those associated with humans or urban landscapes because they were more likely to be found and rescued by humans. The most frequently captured mammal species were ground dwelling (i.e., eastern chipmunks and eastern cottontails) or lived close to human built structures (i.e., southern flying squirrels). Eastern grey squirrels were the second most frequently admitted mammal to the hospital, but they were infrequently admitted for cat interaction compared to other species, likely because of their arboreal nature. The Virginia opossum was the third most common mammal species admitted for rehabilitation but was the least likely to be admitted from cat interaction. We speculate that this may be due to the defensive posturing behavior elicited by opossums in addition to a directed flight response (McManus 1970, Ladine and Kissell 1994), whereas most other prey species rely mainly on flight. This finding warrants further investigation to see if the trend is consistent throughout the wildlife rehabilitation community. Interactions with cats represented 10% of bat admissions over 11 years but resulted in the greatest mortality rate of all mammals included in this study. Half

Table 5. Comparison of days in care for healthy and injured wildlife admitted for either cat interactions or other reasons to the Wildlife Center of Virginia, 2000–2010.

			Differences in group means		
Class	**Cause**	**Mean days in care (SD)**	***n***	***t*-test**	***P***
Mammals	Cat interaction	5.5 (11.2)	6,458	9.7	<0.001
	Other	9.5 (29.6)			
	Cat interaction injured	4.8 (10.4)	3,562	7.1	<0.001
	Other injured	7.4 (17.0)			
	Cat interaction healthy	9.45 (13.8)	567	2.5	<0.012
	Other healthy	12.1 (40.0)			
Birds	Cat interaction	5.6 (12.8)	1,720	2.3	<0.019
	Other	6.4 (12.3)			
	Cat predated injured	5.2 (12.7)	6,436	0.23	0.82
	Other injured	5.2 (12.5)			
	Cat predated healthy	8.4 (13.6)	3,337	0.32	0.98
	Other healthy	8.4 (11.6)			

of those that died were euthanized, suggesting that the presenting injuries were severe. Bats possess delicate wing membranes and long slender bones that are frequently damaged when caught by cats. This finding agrees with other studies that suggest that free-roaming cat predation on bats may be significant and deserves further study (Ancillotto et al. 2013). Alternatively, bats are considered a rabies vector species in Virginia and bat patients admitted following cat interaction (a form of exposure) are routinely euthanized and tested for the rabies virus.

Bird species commonly encountered around human settlements represented most of the total birds admitted for cat interaction. American robins, mourning doves, blue jays (*Cyanocitta cristata*), and northern cardinals frequently forage on the ground or at bird feeders where they are susceptible to free-roaming cats. These species were the most frequently admitted because of cat interaction. Two non-native species, European starlings (*Sturnus vulgaris*) and rock doves (*Columba livia*), were rarely admitted following cat interaction (4.8% and 2.9% of admissions, respectively) despite being common in urban settings (Liberg 1984). Cats have been documented capturing both species (Woods et al. 2003, Baker et al. 2008); however, neutral or negative human attitudes toward them (Brown et al. 1979, Bjerke and Østdahl 2004) may result in a negative selection bias and fewer admissions to rehabilitation facilities. European starlings were not commonly captured by cats in other studies (Churcher and Lawton 1987, Barratt 1997) and previous researchers have speculated that cavity nesting birds and flocking species may reduce the likelihood of being captured by cats (Barratt 1997). The majority of species (73.3% mammal species, 63.3% bird species) admitted to the WCV had individuals admitted following cat interaction. Cats are indiscriminant hunters and capture prey based on availability and opportunity (Barratt 1997, Burton and Doblar 2004, Jessup 2004, van Heezik et al. 2010, Medina et al. 2011).

A large number of patients that enter wildlife rehabilitation facilities each year die despite supportive and therapeutic care. Many are euthanized because of the severity of their injuries or when their disabilities prevent them from meeting established release criteria (Miller 2012). Although one can assume that mortality would be higher if injured patients were left in the wild without assistance (the authors are unaware of a study testing this hypothesis), the stress associated with captivity, handling, and treatment and inadequacies in species-specific husbandry (e.g., diet, housing, enrichment) do inadvertently increase overall mortality. Patient mortality rate varies largely depending on species, circumstances of injury, intrinsic tolerance to stress, severity and chronicity of the injuries, patient age, available treatment resources, and caregiver skill. The reported mortality rates in this study reflect the consequence of the original injury and intrinsic factors associated with the act of rehabilitation. Interactions with cats were associated with significantly higher patient mortality for birds and mammals than mortality from all other pooled causes of injury. Of the patients admitted following cat interaction, 70.8% of birds and 80.8% of mammals were ultimately euthanized due the severity of their wounds or died while undergoing treatment.

Individuals admitted for cat interaction were more likely to be categorized as juveniles or adults and less likely to be categorized as neonates or nestlings compared to the pool of patients admitted for other reasons. These results may reflect the large number of healthy orphans admitted for rehabilitation thus lessening the percentage of cat-captured patients. Alternatively, the most common prey size for cats is about 1% of their body weight (Pearre and Maass 1998); therefore, smaller animals may be consumed or more easily killed by cats and less likely to be admitted for rehabilitation. Within the mammal group admitted for cat interactions, adults were captured by cats less frequently than juvenile and neonate patients. Reasons for this may include fewer adults available for capture compared to offspring, an increased level of difficulty in capturing larger prey, and adult animals being more likely to escape or defend themselves compared to less experienced younger animals. Removing young raccoons, skunks, and woodchucks from the study, thus eliminating the species altogether because the adults of these species are already excluded, would not change the age distribution because the sample size for these species was low. Adult and juvenile birds were admitted for cat interaction almost twice as often as nestlings, suggesting that foraging on or near the ground where cats most frequently hunt increases chances of being captured compared to being in a nest. The high frequency of adult avian prey could also be associated with availability because many adult birds are present year-round, whereas nestling and juvenile birds grow quickly to adult sizes. These numbers support popular avian conservation messages recommending that ground cover surrounding bird feeders and bird baths be kept back to decrease opportunities for cats to stalk unsuspecting wild prey (Cornell Lab for Ornithology 2014). As previously mentioned, smaller animals are more likely to be consumed or killed, making them less likely to be admitted for rehabilitation.

Number of wildlife patients admitted for cat interaction per month appears to depend on number of admissions in the same time period. Fewer cat interactions occur in winter when migratory birds are not present and many mammals are dormant and not available to hunting cats. Alternatively, fewer owned cats may be allowed outside during colder months. These findings agree with previous studies that suggest that greater numbers of wild animals are available and captured by cats during spring and summer during the breeding season (Frink et al. 1994, Loyd et al. 2013). Although not applicable to feral cats, these data suggest that a significant conservation impact may be achieved if owned indoor-outdoor cats are prevented from going outside between April and September.

Of the 10 closest counties and independent cities surrounding the WCV, half were urban and half were rural. Given that precise geographic rescue locations were not a part of the patient's record, we feel this classification scheme best represents the urban-rural population in our region. The urbanization results were contrary to our hypothesis because avian patients admitted for cat interaction were more common in rural areas, but degree of urbanization played no role in number of wild mammals captured by cats. More cat interactions on birds in rural areas may indicate greater avian abundance, more cats on the landscape for longer periods of time (i.e., barn cats), or more natural features that may hide cats as they stalk prey.

Injuries and clinical presentation of wildlife patients admitted for cat interaction were fairly consistent between classes and species. Frequent acute injuries found on physical examination included degloving wounds (i.e., avulsion of the skin from underlying tissues); pinpoint puncture wounds, often on opposite sides of the body, associated with the canine teeth that penetrate skin and deeper tissues; and skin lacerations. Additional symptoms including cardiovascular shock, neurologic deficits, and respiratory distress were likely associated with systemic infection. Systemic infection from cat bite wounds may occur within 15 hr (Talan et al. 1999) and is most often associated with *Pasteurella multocida*, a highly pathogenic bacteria that are part of a cat's oral flora (Dendle and Looke 2008, Freshwater 2008).

Patients were categorized as healthy if no injuries or clinical signs were observed on the intake physical examination; however, because of the small size of wounds caused by cat teeth and the prey's covering layer of fur or feathers, it is easy to miss injuries associated with cat bites. Small birds categorized as healthy and admitted because of cat capture had a significantly greater mortality than the pool of all other healthy birds admitted for other reasons. This highlights the importance of a thorough physical examination when there is a history of cat interaction and may justify the prophylactic use of antibiotics in these cases.

Mammals and birds admitted following cat interaction spent fewer days in care before being disposed than patients admitted for other reasons. This reflects the large number of cat victims that either die or are euthanized on or shortly after admission because of the severity of their injuries or compromised quality of life. Regardless of whether they were injured or healthy, mammals admitted for cat interaction were in rehabilitation for fewer days than mammals admitted for other reasons. This in combination with a greater mortality rate indicates that cat interaction leads to a faster death than many other causes of injury.

We made considerable efforts to obtain valid data throughout the study period; however, inherent biases exist and must be considered when interpreting the results of this study. The count of patients admitted to rehabilitation facilities underestimates the true prevalence of cat interaction with wildlife. Only animals that are injured, alive, and accessible to rescuers are eligible for rehabilitation, which makes admission numbers a conservative estimate. The rescuers were also required to witness the cat interaction for it to be included in this study. Without a history of being observed with a cat, patients were recorded in alternative categories of admission (e.g., undetermined trauma). Rescuers may be biased in their willingness or ability to assist certain species (e.g., non-native species, nuisance species, common species), which may also influence the data analyzed in this study. Throughout the study period, data categories were consistent; however, there were multiple admissions personnel and veterinarians recording patient information creating a possible reporting bias. Another limitation to the study is that because of the size of the dataset, it is possible to obtain statistically significant results that have no ecological meaning. Findings that are inconsistent with biological and medical observations should not be over interpreted.

MANAGEMENT IMPLICATIONS

Although the profile of patients admitted to wildlife rehabilitation centers cannot be used to predict population-level effects of free-roaming cats on a particular species or within specific areas, the documented number of species affected by cat interaction can be used by wildlife managers to anticipate those species that are likely to be affected by free-roaming cats within a given area or management unit. The documented seasonality of cat interaction with wildlife species may help guide resource managers in planning and implementing management of free-roaming cats to mitigate unacceptable impacts on priority species or within sensitive habitats for some species. Even when veterinary treatment and rehabilitative care are provided to patients admitted for cat interaction, mortality exceeds 70% for small mammals and 80% for birds. Strategies that reduce the number of cats on the landscape (e.g., enforced ordinances banning free-roaming cats), would greatly reduce interactions with wildlife and the number of wild animals in need of medical care.

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