Seroprevalence of *Dirofilaria immitis*, feline leukemia virus, and feline immunodeficiency virus infection among dogs and cats exported from the 2005 Gulf Coast hurricane disaster area

Julie K. Levy, DVM, PhD, DACVIM; Charlotte H. Edinboro, DVM, PhD; Carmen-Susan Glotfelty, BS; Patricia A. Dingman, BS; Aundria L. West, BS; Kathy D. Kirkland-Cady, BS

Objective—To determine seroprevalence of dirofilariasis in dogs and seroprevalences of dirofilariasis, FeLV infection, and FIV infection in cats exported from the Gulf Coast region following the 2005 hurricanes.

Design—Seroprevalence survey.

Animals—1,958 dogs and 1,289 cats exported from Louisiana, Mississippi, and Texas between August 20 and December 31, 2005.

Procedures—141 animal welfare groups in 37 states and Alberta, Canada, reported results of serologic testing. Risk factors for infection, including age, sex, neuter status, breed, and state of rescue, were examined by means of univariate and multivariate logistic regression.

Results—Seroprevalence of dirofilariasis in dogs was 48.8%. Sexually intact dogs were 1.6 times as likely to have dirofilariasis as were neutered dogs, dogs in the ancient breed group were 2.2 times as likely and dogs in the guarding breed group were 1.7 times as likely to have dirofilariasis as were dogs in the herding breed group, and dogs from Mississippi were significantly less likely to have dirofilariasis than were dogs from Texas. Seroprevalences of dirofilariasis, FeLV infection, and FIV infection in cats were 4.0%, 2.6%, and 3.6%, respectively. Seroprevalence of FIV infection was significantly higher in adult cats than in juveniles and in males than in females.

Conclusions and Clinical Relevance—Results suggest that dogs and cats exported from the 2005 Gulf Coast hurricane disaster area had disease rates similar to those for animals in the region prior to the hurricanes. (*J Am Vet Med Assoc* 2007;231:218–225.

The largest natural disaster in the history of the United States began when Hurricane Katrina made landfall as a category 3 hurricane near the Louisiana-Mississippi border on August 29, 2005. The damage to the area was compounded when Hurricane Rita made landfall near the Louisiana-Texas border less than a month later, on September 24. These 2 storms exacted a heavy toll on humans, animals, and property throughout the Gulf Coast region. Thousands of animals were caught in the storms, with an estimated 15,000 cattle, 6.2 million chickens, and numerous other agricultural animals killed.[1,2]

From the Department of Small Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, FL 32610-0126 (Levy, Glotfelty, Dingman, West, Kirkland-Cady); and Exponent Incorporated Health Group, 149 Commonwealth Dr, Menlo Park, CA 94025 (Edinboro).

Supported by a grant from the American Society for the Prevention of Cruelty to Animals.

The authors thank Drew Kirby for technical assistance.

Address correspondence to Dr. Levy.

Abbreviations

OR	Odds ratio
CI	Confidence interval

The number of dogs and cats affected by the 2005 Gulf Coast hurricane disaster will never be known. It has been estimated that up to 50,000 dogs and cats were left behind when their owners evacuated.[1,3,4] In addition, an unknown number of stray dogs and cats roamed freely throughout the region at the time of the disaster. As an indicator of the number of affected animals, an online database (www.petfinder.com) listed profiles of 17,000 found animals and 22,000 pet rescue requests by October 2005.[1]

Temporary mass shelters for dogs and cats rescued from the hurricane disaster area became operational within days after Hurricane Katrina hit. Ultimately, more than 11,000 rescued animals passed through makeshift shelters in Gonzalez and Monroe, La, and Hattiesburg,

Slidell, and Tylertown, Miss.[1,5,a] An additional 1,700 animals that were evacuated with their owners were cared for in a temporary shelter in Baton Rogue, La.[a] Most of the temporary shelters were closed by the end of October, and thousands of animals that had not been reunited with their owners or adopted into new homes were sent to animal welfare groups throughout the United States and Canada. In addition, a large, but unknown, number of dogs and cats was removed from the area by unaffiliated agencies and individuals.

The scale of the disaster necessitated an unprecedented response. Public health agencies and animal welfare groups quickly developed guidelines for rescuing, decontaminating, sheltering, documenting, and exporting animals from the Gulf Coast region.[6] Preventive health care guidelines regarding testing for infectious diseases, parasite control, and vaccination were developed to protect both animal and human health.[6] To facilitate the emergency response, some jurisdictions relaxed health certificate and importation regulations. Nevertheless, control of contagious diseases was a priority, both in the temporary shelters and in the locations where animals were transferred. Staff at temporary shelters implanted identification microchips, provided routine vaccinations, and administered first-aid care prior to transferring unclaimed animals with their medical records to animal welfare groups outside of the Gulf Coast region. In general, however, much less documentation was available for animals removed by unaffiliated agencies and individuals.

In previous studies that evaluated the risks that pet owners would leave their pets behind when evacuating during a rapid-onset (ie, a chemical spill)[7] or slow-onset (ie, a flood warning)[8,9] disaster, ownership of multiple pets, a lack of preparation, low attachment to one's pets, and a lack of previous veterinary care were found to be associated with an increased risk of pet evacuation failure. If failure to evacuate pets during the 2005 Gulf Coast hurricane disaster was similarly associated with a lower rate of previous veterinary care, then it is possible that rescued animals were at increased risk for diseases routinely controlled by chemoprophylaxis (ie, dirofilariasis), neutering and vaccination (ie, FeLV and FIV infection), and testing (ie, dirofilariasis, FeLV, and FIV infection). The purpose of the study reported here, therefore, was to determine seroprevalence of dirofilariasis in dogs and seroprevalences of dirofilariasis, FeLV infection, and FIV infection in cats that were exported from the Gulf Coast region following the 2005 hurricanes.

Materials and Methods

Study participants—Because there was no master directory of animal welfare groups that exported

Figure 1—Origin of and destination for 3,247 dogs and cats exported from the 2005 Gulf Coast hurricane disaster area to 141 animal welfare groups in 37 states and Alberta, Canada.

animals from the hurricane disaster area, an effort was made to contact all groups that may have exported animals from official shelters and all groups that may have participated in private rescue missions outside of the official system. In November 2005, a contact list was compiled from results of an Internet search for groups that received media coverage of their rescue efforts or that posted information on their own Web sites and from lists of involved animal welfare groups compiled by national humane organizations. This list was used to contact, by surface mail and e-mail, 350 groups believed to have received animals exported from the Gulf Coast hurricane disaster area. In addition, a nontargeted appeal for study participation was made via the e-mail list service of the Association of Shelter Veterinarians and a separate e-mail list service representing 1,250 animal welfare groups nationwide. Each group received a letter requesting participation in the study and a form for reporting testing results. Criteria for inclusion included any ownerless dog or cat exported from the hurricane disaster area and tested for at least one of the diseases included in the study.

Data collection—Animal welfare groups that received dogs and cats exported from the hurricane disaster area between August 29 and December 31, 2005, were asked to submit results of serologic testing for dirofilariasis, FeLV infection, and FIV infection performed at the time of initial evaluation by the group. These diseases were selected because animal welfare groups commonly screen animals for these diseases prior to adoption. Participating groups were also asked to submit, for each animal included in the study, information on rescue date, city and state of rescue, original and current identification, microchip number, sex, neuter status, estimated age at the time of rescue, and testing date. The apparent predominant breed was assigned for each animal on the basis of knowledge of the animal's history or phenotype. Not all animals were tested for all infections, and not all data were available for each animal. Results were entered into a spreadsheet[b] and checked for duplicate entry of animals that may have been submitted by > 1 animal welfare group. Missing and ambiguous data were identified, and groups were contacted in an attempt to obtain complete data for each animal.

Diagnostic testing—Serologic testing was performed by participating animal welfare groups according to their usual protocols. A variety of point-of-care test kits and reference laboratories were used for testing, and no attempts were made to standardize testing procedures among groups. A diagnosis of dirofilariasis was made in dogs on the basis of detection of circulating antigen or microfilaria and in cats on the basis of detection of circulating antigen. Because dirofilariasis can only be reliably detected in animals that have been infected for at least 6 months, only animals estimated to be at least 7 months old were included in analyses of dirofilariasis. In cats, a diagnosis of FeLV infection was made on the basis of detection of circulating viral antigen, and a diagnosis of FIV infection was made on the basis of detection of circulating antiviral antibodies.

Risk factors—Risk factors that were evaluated included age (juvenile [< 7 months old] vs adult), sex, neuter status, breed, and state of rescue. Cats were grouped as being purebred or of mixed breeding for purposes of analysis. On the basis of reported or apparent predominant breed, dogs were categorized into 4 breed groups (ancient, guarding, herding, or hunting) developed in previous studies[10,11] of the canine genome. In those studies, genetic analysis of 85 dog breeds allowed identification of 4 breed group clusters. The first cluster consisted of ancient breeds of Asian and African origin, such as the Akita, Chow Chow, Chinese Shar-Pei, Alaskan Malamute, Siberian Husky, and Basenji. The second cluster consisted of guarding breeds, such as the Rottweiler, Mastiff, Newfoundland, Bulldog, Boxer, and German Shepherd Dog. The third cluster consisted of herding breeds and sight hounds, including the Greyhound, Borzoi, Belgian Sheepdog, Collie, and Shetland Sheepdog. The fourth cluster consisted of hunting breeds, including Labrador Retrievers,

Table 1—Results of univariate analysis of risk factors associated with seroprevalence of dirofilariasis among dogs exported from the 2005 Gulf Coast hurricane disaster area.

Variable	Categories	No. tested	No. of positive results	Prevalence (%)	OR	95% CI	*P* value
State							
	Louisiana	1,309	665	50.8	1.1	0.7–1.7	0.5
	Mississippi	215	74	34.4	0.6	0.4–1.0	0.03
	Texas	97	46	47.4	Referent	NA	NA
Sex							
	Male	994	487	49.0	1.0	0.9–1.2	0.8
	Female	938	453	48.3	Referent	NA	NA
Neuter status							
	Sexually intact	1,110	547	49.3	1.7	1.3–2.2	< 0.001
	Neutered	322	118	36.6	Referent	NA	NA
Breed group							
	Ancient	227	122	53.8	1.8	1.2–2.8	0.005
	Guarding	661	352	53.3	1.8	1.2–2.6	0.002
	Hunting	872	393	45.1	1.3	0.9–1.8	0.2
	Herding	149	58	38.9	Referent	NA	NA

Values represent results of testing for 1,958 dogs ≥ 7 months old. Numbers for each variable do not add up to 1,958 because information was not available for all dogs.
NA = Not applicable.

spaniels, terriers, pointers, and hounds. For the present study, dogs representing 1 of the 85 breeds were assigned to the designated breed cluster. Dogs representing breeds not yet assigned to a cluster were assigned to the cluster with the most closely related breeds. For example, American Bulldogs and pit bull–type breeds were assigned to the guarding breed cluster for analysis. Some breeds of dogs in this study have not yet been assigned to a genetic cluster.

Statistical analysis—Seroprevalence was defined as the number of animals with positive test results divided by the number of animals tested. The χ^2 test was used to determine whether individual potential risk factors were significantly associated with seropositivity. Univariate logistic regression was used to calculate ORs and their 95% CIs. Risk factors determined to be significant in univariate analyses were analyzed by means of multivariate logistic regression. Potential confounders were retained if they changed other factors' ORs by at least 10%. For unequally distributed risk factors, analyses were stratified to account for potential confounding. Interactions between risk factors were tested and retained if *P* values were significant. All analyses were performed with statistical software.[c,d] Values of $P < 0.05$ were considered significant.

Table 2—Results of multivariate analysis of risk factors associated with seroprevalence of dirofilariasis among dogs exported from the 2005 Gulf Coast hurricane disaster area.

Variable	Categories	OR	95% CI	*P* value
State				
	Louisiana	1.1	0.7–1.8	0.6
	Mississippi	0.6	0.3–1.0	0.04
	Texas	Referent	NA	NA
Neuter status				
	Sexually intact	1.6	1.2–2.1	0.002
	Neutered	Referent	NA	NA
Breed group				
	Ancient	2.2	1.3–3.8	0.003
	Guarding	1.7	1.1–2.6	0.03
	Hunting	1.3	0.8–2.0	0.3
	Herding	Referent	NA	NA

Results

Study participants—A total of 141 animal welfare groups representing 37 states and Alberta, Canada, that had received dogs and cats exported from the 2005 Gulf Coast hurricane disaster area between August 29 and December 31, 2005, agreed to participate in the study (**Figure 1**). Participating groups reported test results for 1,958 dogs and 1,289 cats. Twenty groups accepted only cats, 75 groups accepted only dogs, and 46 groups accepted both cats and dogs. The number of animals enrolled in the study by each group ranged from 1 to 322 (median, 9 animals; mean, 26 animals).

Most animals were exported from Louisiana (1,309 dogs and 860 cats), followed by Mississippi (215 dogs and 221 cats) and Texas (97 dogs and 58 cats). The state of rescue was unknown for 487 (15.0%) of the 3,247 animals (337 dogs and 150 cats). Microchip numbers were reported for only 1,921 (59.2%) animals, including 1,328 (67.8%) dogs and 593 (46.0%) cats.

All dogs were classified as adults. Juveniles (ie, dogs < 7 months old) and dogs of unknown age were excluded because of the inability to accurately perform heartworm testing in dogs < 7 months old. Of the 1,958 dogs, 532 (27.2%) were sexually intact females, 156 (8.0%) were spayed females, 250 (12.8%) were females of unknown neuter status, 578 (29.5%) were sexually intact males, 166 (8.5%) were castrated males, and 250 (12.8%) were males of unknown neuter status. Sex of the remaining 26 (1.3%) dogs was not reported. A predominant breed assigned either on the basis of knowledge of the dog's history or on the basis of phenotype was available for 1,909 (97.5%) dogs. Predominant breed assignment was not recorded for 10 (0.5%) dogs, and 39 (2.0%) dogs were classified as mixed breeds of undetermined phenotype. Of the 1,958 dogs, 227 (11.6%) were assigned to the ancient breeds cluster, 661 (33.8%) were assigned to the guarding breeds cluster, 149 (7.6%) were assigned to the herding breeds cluster, and 872 (44.5%)

Table 3—Results of univariate analysis of risk factors associated with seroprevalence of FeLV infection among cats exported from the 2005 Gulf Coast hurricane disaster area.

Variable	Categories	No. tested	No. of positive results	Prevalence (%)	OR	95% CI	*P* value
State							
	Louisiana	857	21	2.4	1.4	0.2–29.1	0.7
	Mississippi	221	4	1.8	1.1	0.1–25.2	1.0
	Texas	58	1	1.7	Referent	NA	NA
Sex							
	Male	568	12	2.1	0.7	0.4–1.5	0.4
	Female	657	19	2.9	Referent	NA	NA
Neuter status							
	Sexually intact	551	19	3.4	2.1	0.9–5.1	0.1
	Neutered	419	7	1.7	Referent	NA	NA
Age							
	< 7 months	303	7	2.3	Referent	NA	NA
	≥ 7 months	983	27	2.8	1.2	0.5–2.8	0.7
Breed							
	Purebred	48	0	0.0	NC	NA	NA
	Mixed	1,238	34	2.8	Referent	NA	NA

Values represent results of testing for 1,289 cats. Numbers for each variable do not add up to 1,289 because information was not available for all cats.
NC = Not calculable.

were assigned to the hunting breeds cluster. Breed groups were not distributed evenly across states. For example, 39.8% (521/1,309) of the dogs from Louisiana, 54.0% (116/215) of the dogs from Mississippi, 64.9% (63/97) of the dogs from Texas, and 51.0% (172/337) of the dogs for which state of rescue was not specified were classified as hunting breeds. Of the dogs assigned to breed groups, 67.4% (58/86) of the dogs from Texas, 79.2% (756/954) of the dogs from Louisiana, and 88.2% (172/195) of the dogs from Mississippi were reportedly sexually intact. Of the 1,415 dogs with known neuter status that could be assigned to breed groups, 1,097 (77.5%) were sexually intact. Of these, 476 of the 646 (73.7%) hunting breed dogs were intact, 420 of the 493 (85.2%) guarding breed dogs were intact, 117 of the 162 (72.2%) ancient breed dogs were intact, and 84 of the 114 (73.7%) herding breed dogs were intact.

Of the 1,289 cats, 986 (76.5%) were classified as adults, and 303 (23.5%) were classified as juveniles (ie, < 7 months old). There were 309 (24.0%) sexually intact females, 208 (16.1%) spayed females, 141 (10.9%) females of unknown neuter status, 244 (18.9%) sexually intact males, 212 (16.4%) castrated males, 114 (8.8%) males of unknown neuter status, and 61 (4.7%) cats of unknown sex. A total of 1,241 cats (96.3%) were classified as mixed breeds, and 49 (3.7%) were classified as purebred.

Dirofilariasis—Overall, 956 of the 1,958 (48.8%) dogs were positive for dirofilariasis. There was no difference in seroprevalence between male and female dogs (**Table 1**). However, seroprevalence was higher among sexually intact dogs than among neutered dogs and was higher for dogs exported from Louisiana or Texas than for dogs exported from Mississippi. Seroprevalence was highest among dogs classified in the ancient breed group, followed by dogs in the guarding, hunting, and herding groups. Among the breeds with the most dogs represented, 135 of 195 (69.2%) dogs presumptively identified as Rottweilers, 85 of 137 (62.0%) dogs presumptively identified as Chow-Chows, 120 of 227 (52.9%) presumptively identified as German Shepherd Dogs, 168 of 332 (50.6%) dogs presumptively identified as Labrador Retrievers, and 105 of 249 (42.2%) dogs presumptively identified as pit bull–type dogs were positive for dirofilariasis.

Factors for state of rescue, neuter status, and breed group were retained in the final multivariate model for risk of dirofilariasis among dogs exported from the hurricane disaster area (**Table 2**). When other factors were accounted for, sexually intact dogs were 1.6 times as likely to have dirofilariasis as were neutered dogs. Dogs in the ancient breed group were 2.2 times as likely and dogs in the guarding breed group were 1.7 times as likely to have dirofilariasis as were dogs in the herding breed group. Finally, dogs from Mississippi were significantly less likely to have dirofilariasis, compared with dogs from Texas.

Multivariate analysis of data for only those dogs exported from Louisiana yielded similar results. Sexually intact dogs were more likely to have dirofilariasis than were neutered dogs (OR, 1.9; 95% CI, 1.4 to 2.6), and dogs in the ancient breed group (OR, 2.3; 95% CI, 1.3 to 4.2) or guarding breed group (OR, 2.0; 95% CI, 1.2 to 3.4) were significantly more likely to have dirofilariasis than were dogs in the herding breed group.

Only 176 adult cats were tested for dirofilariasis, of which 167 were from Louisiana. Results were positive for 7 of the 176 (4.0%) cats, all of which were sexually intact (6 females and 1 male) and of mixed breeding. No difference in seroprevalence was found between females and males (OR, 6.9; 95% CI, 0.8 to 58.2). However, sexually intact cats were significantly ($P < 0.001$) more likely to have dirofilariasis (7/48) than were neutered cats (0/93). Of 163 cats tested for all 3 infections, 2 of 6 cats with dirofilariasis were also seropositive for FIV infection. These were both sexually intact female cats.

FeLV and FIV infection—Results of testing for FeLV infection were positive for 34 of 1,286 (2.6%) cats (**Table 3**). There were no significant differences in sero-

Table 4—Results of univariate analysis of risk factors associated with seroprevalence of FIV infection among cats exported from the 2005 Gulf Coast hurricane disaster area.

Variable	Categories	No. tested	No. of positive results	Prevalence (%)	OR	95% CI	*P* value
State							
	Louisiana	843	32	3.8	1.1	0.3–6.9	0.9
	Mississippi	192	5	2.6	0.8	0.1–5.7	0.7
	Texas	58	2	3.4	Referent	NA	NA
Sex							
	Male	547	27	4.9	2.3	1.2–4.4	0.01
	Female	634	14	2.2	Referent	NA	NA
Neuter status							
	Sexually intact	515	18	3.5	0.9	0.5–1.8	0.8
	Neutered	417	16	3.8	Referent	NA	NA
Age							
	< 7 months	285	0	0.0	NC	NA	< 0.001
	≥ 7 months	956	45	4.7	Referent	NA	NA
Breed							
	Purebred	42	1	2.4	0.6	0.1–4.8	0.7
	Mixed	1,199	44	3.7	Referent	NA	NA

Values represent results of testing for 1,289 cats. Numbers for each variable do not add up to 1,289 because information was not available for all cats.

prevalence among groups when cats were grouped on the basis of age, sex, neuter status, breed, or state of rescue.

Results of testing for FIV infection were positive for 45 of 1,241 (3.6%) cats (**Table 4**). Again, there were no significant differences in seroprevalence among groups when cats were grouped on the basis of neuter status, breed, or state of rescue. However, seroprevalence was significantly higher for adult cats than for juveniles and for male cats than for female cats.

Seven cats were seropositive for both FeLV and FIV infection. All 7 were adult mixed-breed cats, and 6 were males.

Discussion

Of the 3 diseases examined in the present study, dirofilariasis was the most common among dogs and cats exported from the 2005 Gulf Coast hurricane disaster area, reflecting the high prevalence of this disease in the southeastern United States. A previous study[12] estimated that prevalence of dirofilariasis among dogs within 150 miles of the Atlantic or Gulf coasts or Mississippi River was 45% to 50%, with prevalence being higher in select areas. Of the approximately 375 dogs rescued after Hurricane Floyd struck North Carolina in 1999, 67% were reported to have dirofilariasis.[13,e]

Despite the availability of effective prophylactic treatments for dirofilariasis, the American Heartworm Society estimates that nationally only 59% of households use preventives and that, of these, only two thirds comply with current recommendations regarding administration.[e] The infection rate among dogs in the present study may have been particularly high in part because at least some of these dogs were likely to have been strays or pets that did not receive regular veterinary care and heartworm prophylaxis. This theory is supported by the fact that only 22.8% of the dogs and 43.2% of the cats for which neuter status was known were neutered.

In the aftermath of the 2005 Gulf Coast hurricanes, large numbers of dogs infected with *Dirofilaria immitis* were concentrated together by flooding, at feeding stations, and in temporary shelters. Often, these dogs were confined with lost pets that may have previously been receiving prophylactic medication but that had missed 1 or more doses because of the disaster. Given that the *D immitis* transmission season in Louisiana extends at least until December,[14] additional transmission was likely to have occurred in the aftermath of the hurricane prior to rescue or in temporary shelters where not all dogs received prophylactic medication. Because of the inability to detect circulating antigen or microfilaria during the first 5 to 9 months of infection,[15] it is likely that some dogs and cats in the present study for which initial test results were negative were in fact infected and that prevalence values for infection in this report were underestimated. For this reason, retesting has been recommended for all rescued dogs at least 6 months after the initiation of prophylactic treatment.[15,16]

Since dirofilariasis is at least regionally endemic in all states except Alaska, dogs exported from the disaster area were unlikely to have had a perceptible impact on the overall prevalence of dirofilariasis, even in areas where infection was rare. In areas with a low prevalence of dirofilariasis, new infections are believed to be primarily associated with translocation of infected dogs from regions of higher prevalence.[15] The *D immitis* transmission season is nearly year-round in the Gulf Coast states and extends from July through October in the northernmost states.[17] During these months, native dogs that lived in close proximity to microfilaremic dogs exported from the hurricane disaster area may have been at risk of infection if not receiving prophylactic medication.

The American Heartworm Society developed guidelines for preventing the spread of dirofilariasis and for treating rescued dogs in the wake of the hurricanes.[16] Routine prophylactic treatment was recommended for all rescued dogs and for all dogs housed in proximity to rescued dogs, regardless of test results. This would provide protection for dogs not currently infected as well as reduce the number of circulating microfilaria, potentially decreasing the risk of transmission from infected dogs. In areas where transmission was of high concern and rapid microfilaricidal treatment was desired, the guidelines suggested a strategy to minimize the risk of adverse reactions in rescued dogs while providing for moderately rapid clearance of microfilaria. In addition, the guidelines recommended that all infected dogs undergo adulticide treatment within 6 months of diagnosis.

Because dirofilariasis is much less common in cats than dogs, serologic tests are less reliable in cats than in dogs, and cats are considered unlikely to transmit the infection, the American Heartworm Society suggested that routine screening of all cats was not the best use of limited resources during the disaster response.[16] Only 176 of 986 (17.8%) adult cats were tested for dirofilariasis, and of these, only 7 (4.0%) had positive antigen assay results. This rate was consistent with a previous report[18] of the prevalence of dirofilariasis in cats in the southeastern United States. In earlier work,[19,20] the sensitivity of heartworm antigen testing in cats has been reported to range from 68% to 86%, and the specificity has been reported to range from 98% to 99%. The reported sensitivity suggests that false-negative test results are possible and that cases of dirofilariasis in cats may, therefore, not be diagnosed. The high reported specificity implies that few false-positive test results will result from testing cats for dirofilariasis. Therefore, the true prevalence of dirofilariasis among cats exported from the hurricane disaster area may have been higher than the reported prevalence.

Seroprevalences of FeLV and FIV infection were low in the present study, with values similar to prevalences reported in a recent national survey of pet and stray cats.[21] In particular, FIV infection was confined to adult cats, and the prevalence was significantly higher in males than in females. Testing for FIV is complicated by the availability of a whole virus vaccine that induces antibodies that are indistinguishable from those resulting from infection.[22] Thus, it is possible that some cats with positive FIV test results were vaccinated and not infected.

Results of the present study suggest that the prevalences of various infectious diseases among dogs and

cats exported from the 2005 Gulf Coast hurricane disaster area generally reflected disease rates prior to the hurricanes. The most important of the diseases examined was dirofilariasis in dogs because of its high prevalence and the resulting financial and logistical impacts on the groups that accepted dogs and cats from this area. Hundreds of infected dogs included in the present study were transferred to states with low prevalences of dirofilariasis, with the result that many recipients may have been unfamiliar with methods for treating dirofilariasis and preventing transmission or were unprepared for the costs and duration of treatment. As an example of the costs involved, the American Animal Hospital Association sponsored adulticide therapy for 725 animals sent to 103 shelters in 39 states and 2 Canadian Provinces at a cost of $246,106.[23]

The present study focused only on diseases of dogs and cats that were rescued from the hurricane disaster area and exported to other regions. Approximately 2 million people were displaced by the disaster, and many likely transported their pets with them when they relocated to new regions.[24] If pet ownership rates among these displaced individuals were similar to the national average, they may have owned more than 600,000 cats and 500,000 dogs.[25] These animals may also have transported pathogens to their new environments.

Because the present study relied on convenience sampling, caution should be exercised in extrapolating results to the general population of dogs and cats in these states. In particular, caution should be used in generalizing results to the population of dogs and cats in Mississippi and Texas, as data from few animals from these states were available. In addition, complete data were not available for all the rescued animals in this study. The seroprevalence data for dirofilariasis in cats were based on a small subset of cats rescued from Louisiana. The large number of sexually intact dogs may represent owner attitudes about neutering or a lack of routine veterinary care, especially for dogs in specific breed groups. Neuter status and breed group may be surrogates for other risk factors for dirofilariasis, such as outdoor housing or owners' socioeconomic status, in that there is no known biological basis for increased susceptibility to dirofilariasis among sexually intact dogs or dogs of the ancient and guarding breed groups. Dogs and cats in the present study may be different in other respects from those in the general population in these states, in that they survived and were rescued. Therefore, disease prevalences may be higher or lower than those for other animals in this region.

The 2005 Gulf Coast hurricane disaster revealed weaknesses in planning for a mass disaster affecting companion animals, including the potential for spread of various diseases. Infection control programs were compromised by overcrowding in temporary shelters where health care resources were overtaxed and by relocation of an unknown number of animals by independent rescue groups without documentation of their health status prior to arrival at other facilities. In addition, animals were frequently transferred from one agency to another after rescue, and important documentation was sometimes separated from the animals during the process. In this study, microchip numbers were available for only about half of the animals, and the state of rescue was unknown for 15%. This suggests that a high percentage of animals was transported from the area without first being processed and microchipped at one of the official rescue shelters or that this information was no longer available to the group reporting testing results. The lessons learned from this disaster have been the subject of a series of policy meetings regarding integration of animal rescue and disease prevention into the national disaster response system[3] and the introduction of new legislation to facilitate the evacuation of pets with their families.[26]

a. Bevan L, Southeast Regional Office, Humane Society of the United States, Tallahassee, Fla: Personal communication, 2006.
b. Excel 2003 SP2, Microsoft Corp, Redmond, Wash.
c. Epi Info 2002 Revision 1, CDC, Atlanta, Ga.
d. SPSS release 11.5.0, SPSS Inc, Chicago, Ill.
e. Nelson T, President, American Heartworm Association, Batavia, Ill: Personal communication, 2006.

References

1. Burns K. Summarizing a disaster, by the numbers. *J Am Vet Med Assoc* 2006;228:15–16.
2. Clark A. Loss of livestock reached millions. *J Am Vet Med Assoc* 2005;227:1379–1381.
3. Nolen RS, Rezendes A. Summit works toward national animal disaster plan. *J Am Vet Med Assoc* 2006;228:1835–1836.
4. Nolan RS. Katrina's other victims: animals' plight prompts outcry for change. *J Am Vet Med Assoc* 2005;227:1215–1216.
5. Kahler SC, Nolen RS. AVMA mounts preparedness, response to Katrina. *J Am Vet Med Assoc* 2005;227:1041–1042, 1045–1046.
6. Interim guidelines for animal health and control of disease transmission in pet shelters. CDC Web site. Available at: www.bt.cdc.gov/disasters/hurricanes/katrina/animalhealthguidelines.asp. Accessed Sep 3, 2006.
7. Heath SE, Voeks SK, Glickman LT. Epidemiologic features of pet evacuation failure in a rapid-onset disaster. *J Am Vet Med Assoc* 2001;218:1898–1904.
8. Heath SE, Kass PH, Beck AM, et al. Human and pet-related risk factors for household evacuation failure during a natural disaster. *Am J Epidemiol* 2001;153:659–665.
9. Heath SE, Beck AM, Kass PH, et al. Risk factors for pet evacuation failure after a slow-onset disaster. *J Am Vet Med Assoc* 2001;218:1905–1910.
10. Parker HG, Kim LV, Sutter NB, et al. Genetic structure of the purebred domestic dog. *Science* 2004;304:1160–1164.
11. Parker HG, Ostrander EA. Canine genomics and genetics: running with the pack. *PLoS Genet* 2005;1(5):e58.
12. Scoles GA, Dickson SL. New foci of canine heartworm associated with introductions of new vector species, *Aedes albopictus* in New Orleans and *Aedes sierrensis* in Utah. *Proc Am Heartworm Soc* 1995;27–35.
13. Hudson LC, Berschneider HM, Ferris KK, et al. Disaster relief management of companion animals affected by the floods of Hurricane Floyd. *J Am Vet Med Assoc* 2001;218:354–359.
14. Watts KJ, Reddy GR, Holmes RA, et al. Seasonal prevalence of third-stage larvae of *Dirofilaria immitis* in mosquitoes from Florida and Louisiana. *J Parasitol* 2001;87:322–329.
15. 2005 guidelines for the diagnosis, prevention and management of heartworm (*Dirofilaria immitis*) infection in dogs. American Heartworm Society Web site. Available at: www.heartwormsociety.org/AHS%20Guidelines-Canine2005PF.htm. Accessed Sep 3, 2006.
16. Devastating hurricanes: treatment recommendations for preventing evacuated pets from spreading heartworm disease.

American Heartworm Society Web site. Available at: www.heartwormsociety.org/katrina.htm. Accessed Sep 3, 2006.
17. Knight DH, Lok JB. Seasonality of heartworm infection and implications for chemoprophylaxis. *Clin Tech Small Anim Pract* 1998;13:77–82.
18. Levy JK, Snyder PS, Taveres LM, et al. Prevalence and risk factors for heartworm infection in cats from northern Florida. *J Am Anim Hosp Assoc* 2003;39:533–537.
19. Berdoulay P, Levy JK, Snyder PS, et al. Comparison of serological tests for the detection of natural heartworm infection in cats. *J Am Anim Hosp Assoc* 2004;40:376–384.
20. Snyder PS, Levy JK, Salute ME, et al. Performance of serologic tests used to detect heartworm infection in cats. *J Am Vet Med Assoc* 2000;216:693–700.
21. Levy JK, Scott HM, Lachtara JL, et al. Seroprevalence of feline leukemia virus and feline immunodeficiency virus infection among cats in North America and risk factors for seropositivity. *J Am Vet Med Assoc* 2006;228:371–376.
22. Levy JK, Crawford PC, Slater MR. Effect of vaccination against feline immunodeficiency virus on results of serological testing in cats. *J Am Vet Med Assoc* 2004;225:1558–1561.
23. Animal protection groups support heartworm cure for 725 Hurricane Katrina pets. American Association for the Prevention of Cruelty to Animals Web site. Available at: www.aspca.org/site/PageServer?pagename=press_073106. Accessed Oct 30, 2006.
24. Hsu SS. 2 million displaced by storms. *Washington Post* 2006; January 13:A3.
25. *2005-2006 national pet owner survey*. Greenwich, Conn: American Pet Products Manufacturing Association, 2006.
26. Nolen RS. Congress orders disaster planners to account for pets. *J Am Vet Med Assoc* 2006;229:1357.