Temporal trends in intake and outcome data for animal shelter and rescue facilities in Colorado from 2000 through 2015

Sloane M. Hawes MSW

Bridget A. Camacho MSW

Philip Tedeschi MSSW

Kevin N. Morris PhD

From the Institute for Human-Animal Connection, Graduate School of Social Work, University of Denver, Denver, CO 80208.

Address correspondence to Dr. Morris (kevin.morris@du.edu).

OBJECTIVE

To measure temporal trends in animal shelter and rescue intakes and outcomes for dogs and cats in Colorado from 2000 through 2015 and compare trends from 2008 through 2015 with previously reported trends from 2000 through 2007.

DESIGN

Serial cross-sectional study.

SAMPLE

76 animal shelter and rescue facilities with annual intake and outcome data consistently reported to the state of Colorado from 2000 through 2015.

PROCEDURES

Data were collected for dogs and cats each year during the study period on 5 annual scales: number of animals taken in, number of animals taken in/1,000 state residents, animal outcomes as a percentage of intakes (species-specific scales), and annual live release rate as a function of intakes and outcomes. Aggregate data were analyzed for temporal trends by linear regression modeling.

RESULTS

Decreases in annual intake and euthanasia rates and a concurrent increase in live release rate were observed for both species. The decreases observed for cats from 2008 through 2015 contrasted with the previously reported findings of increased rates of intake and euthanasia from 2000 through 2007.

CONCLUSIONS AND CLINICAL RELEVANCE

We believe that these temporal trends suggested substantial improvements in intake and outcome data for sheltered cats and dogs across Colorado that reflected changes in unhoused animal populations, along with the impact of resource allocation to spay-neuter programs, adoption marketing, intershelter transfers, and evidence-based improvements in operations. The findings indicated that consistent data collection and interorganizational collaboration can be used to optimize animal shelter capacity and outcomes across a statewide shelter system. (*J Am Vet Med Assoc* 2019;254:363–372)

Many animal shelter and rescue facilities collect intake and outcome data to assess their individual performance, and efforts are underway to aggregate data on a national level in the United States.[1] However, few studies[2–8] have included measurement of the complex dynamics of annual shelter performance of an entire state's shelter and rescue system over an extended period.

A study[2] of dog and cat intake, euthanasia, and adoption statistics in New York City animal shelters from 1894 through 1994 offered an important historical perspective on shelter performance across a single city based on 12 data points during the 100-year span. During that period, an approximately 10-fold decrease was identified in the annual number of animals euthanized/10,000 animals taken in, starting around 1930. In another study,[3] annual data from New Hampshire animal shelters from 1983 through 2005 were analyzed. Linear trends in intake and euthanasia rates for cats increased until a government-funded spay-neuter program was initiated in 1994, at which point the intake and euthanasia rates for cats began decreasing through the end of the study in 2005. In the same study, linear trends in intake and euthanasia rates for dogs were already declining between 1983 and the initiation of the spay-neuter program in 1994. The trend continued until 2000, when a slight increase or stabilization in the intake and euthanasia rates for dogs occurred. In another study,[4] 165 animal shelters and animal control agencies in Ohio were surveyed in 1996 and again in 2004, revealing a 39% decrease

ABBREVIATIONS

LRR	Live release rate
PACFA	Pet Animal Care Facilities Act
RTO	Returned to owner
SNR	Shelter-neuter-return
TNR	Trap-neuter-return

in the number of dogs euthanized between surveys, likely driven by a 17% decrease in intake rates and a 19% increase in adoption rates during that period. On the other hand, the number of cats euthanized increased by 14% during the same period, with a 26% increase in the number of adoptions that was unable to offset the 20% increase in the number of intakes. Although these findings may be useful for assessing the influence of individual program interventions on shelter performance or for understanding how overall changes in shelter performance may be achieved over time, they do not capture the dynamics of how an entire state can optimize and then sustain its total capacity to serve cats and dogs without homes.

Reports of previous studies[5,6,9] have documented the difficulties encountered in trying to collect standardized and state-mandated data from animal shelters and rescue organizations. Colorado's PACFA mandates that all animal shelter and rescue facilities that handle more than any combination of 24 dogs and cats/y or have > 15 dogs and cats housed in a central facility must be licensed by the state's department of agriculture, meet defined physical facility standards, be available for inspection by the state commissioner, and submit an annual animal intake and outcomes report.[7] The PACFA regulations are enforced through inspections, civil fines, and license suspension, denial, and revocation. Beyond increasing oversight on shelter and rescue operations, this legislation resulted in the collection of intake and outcome data for dogs, cats, and other species from animal shelters and rescues across Colorado starting in 2000. A previous study[8] of temporal trends in annual intake and outcome data from 104 shelter and rescue facilities with consistent data reporting from 2000 through 2007 showed that across several scales, dog intake, live release, and euthanasia rates remained unchanged or decreased slightly with time, whereas cat intake and euthanasia rates increased and LRRs decreased over this 8-year period. These findings, reinforced by those of a longer-term study[10] of temporal trends in intake and outcome data from 4 large shelters in the metropolitan Denver area from 1989 through 2010, supported decisions by Colorado shelter facilities and associations to focus more resources on improving outcomes for cats while at least maintaining existing outcomes for dogs.[11]

The purpose of the study reported here was to assesses temporal trends in intake and outcome data from a subgroup of Colorado shelter and rescue facilities that consistently reported these data during the 8-year period from 2008 through 2015, which represented a period equal to that covered in the previous study[8] (2000 through 2007). Specifically, we sought to assess the temporal trends identified in the previous 8-year period, the later 8-year period, and the entire 16-year period using aggregate data for each year on 5 shelter performance scales: number of dogs and cats taken in, number of dogs and cats admitted/1,000 state residents, dog and cat outcomes (ie, adoptions, RTOs, transfers, euthanasias, and deaths or other outcomes otherwise unaccounted for) as a percentage of the number of intakes, LRR as a function of the total number of intakes, and LRR as a function of the total number of outcomes. The aim was to provide insights into the potential impacts of directed and collaborative resource allocation on animal shelter dynamics across an entire state over more than a decade and a half.

Materials and Methods

Data compilation

Intake and outcome data for all PACFA-licensed facilities from the years 2000 through 2015 were obtained from the Colorado Department of Agriculture. These data had been gathered annually from all licensed shelter facilities that housed or fostered ≥ 15 animals in any year and from all rescue facilities that handled ≥ 24 dogs or cats in any year. Only data from the 76 animal shelters and rescue groups with reported data for all 16 years were included in the study. Additional data fields (eg, types of intakes) have been added to the PACFA data collection process since 2008, but only data regarding those fields for which information had been collected since 2000 were included in the study.

Information was obtained regarding numbers of dogs and cats taken in by the shelter and rescue facilities as owner relinquishments or strays and through in-state and out-of-state transfer partnerships. These data were then collapsed into a singular category (intake) because facility intake data prior to 2008 did not include the specific numbers of animals in each category of impounded, relinquished, or transferred in. Additionally, numbers of cats and dogs that were euthanized, adopted, RTO, transferred out, and died or were otherwise unaccounted for in outcome counts (died or other) were also obtained as outcome data. Outcomes for cats brought to the shelter and rescue facilities through TNR and SNR programs were accounted for within program-specific reports or were classified as either RTO or as "other" following their spay or neuter procedures. Animals sent to other shelter and rescue facilities in the state were classified as transfers. Such transfers did not include animals moved offsite for temporary foster care.

Annual data from the 76 facilities were aggregated for each species, and the data were summarized on 3 scales: total number of animals taken in per year; total number of animals taken in/1,000 state residents/y, adjusted for the percentage of total state intakes represented by the facilities; and the percentage of total number of animals taken in represented by each species (cat or dog) per year. Animals euthanized on owner request and those classified as dead on arrival were excluded from total intake counts. The state resident-based statistic was calculated by adjusting the total number of state residents reported in the Colorado State Demography Office State and

County Population Estimates[12] by the percentage of total number of dog or cat intakes represented by the 76 facilities. This adjustment to the data subset resulted in the same numbers of animals/1,000 state residents as when calculated from the total intake and outcome data divided by the total number of state residents, and it was therefore deemed a more accurate representation of this variable statewide than the unadjusted statistic. Descriptive statistics were calculated for each scale and species for each year on a statewide basis.

Annual LRRs for dogs and cats from included facilities were computed on 2 scales (as a function of total facility intakes per year and as a function of total facility outcomes per year) as follows:

$$LRR_{(\text{total intakes})} = (\text{number of adoptions} + \text{number of RTOs} + \text{number transferred out})/\text{total intakes}$$

$$LRR_{(\text{total outcomes})} = (\text{number of adoptions} + \text{number of RTOs} + \text{number transferred out})/\text{total outcomes}$$

Transfers of animals between multiple in-state shelters may have resulted in some animals being represented in intake data more than once. The maximum proportion of possible intake errors in this regard, assuming all transfers were between the 76 facilities included in the study, was calculated by dividing the aggregate annual number of transfers by the aggregate annual number of intakes for each species. The facilities included in the study represented 80% of those that reported transfers in 2015.

Statistical analysis

Because temporal trends were expected to be monotonic over any interval, linear regression analysis was performed to identify simple increases or decreases over time in the aggregated annual data for each of the 5 metrics of interest. Data from the earlier 8-year period in the previous study[8] (2000 through 2007), the subsequent 8-year period in the present study (2008 through 2015), and the entire study period (2000 through 2015) were analyzed. For linear regression plots, the y-intercept represented the magnitude of each metric at the beginning of each of the 3 study intervals and the slope represented the amount of change per year. Visual inspection of scatterplots of the data provided no evidence of systematic heteroscedasticity. No correction for autocorrelation was incorporated into the analyses, although the influence of data from a previous year on the next would generally flatten the observed trends. Slopes with P values ≤ 0.05 were deemed to be significantly different from 0, whereas those with P values > 0.05 were considered to represent no significant change over the evaluated period. Because of the exploratory nature of the analyses, no adjustments for the multiplicity of testing were incorporated. Hence, the overall type I error rate might have exceeded the α value (ie, 0.05) for individual tests.

Total change, final value, and percentage change over the study period were calculated for all trend (linear regression) lines with slopes significantly different from 0. Total change was calculated as the slope multiplied by the number of years in the regression analysis. The final value of the trend line was calculated by adding the total change to the y-intercept value, and percentage change was calculated as 100 times the total change divided by the y-intercept value. For trend lines with slopes not significantly different from 0, the final value was assumed to be the same as the y-intercept value. Data were reported as predicted values from linear regression analyses and not as observed values. Thus, values for the first year of any of the 3 study periods were reported as the y-intercept for the linear equation, and values for any subsequent year were reported as calculated from the y-intercept and slope.

Because of the ordinal nature of the collected data, Spearman rank correlation coefficients (r_s) were calculated to determine the correlations between paired data. Standard definitions (eg, strong correlation, r_s = 0.60 to 0.79; very strong correlation, r_s = 0.80 to 1.00) were used to report strength of correlations.

Results

Temporal trends in the shelter and rescue facility intake and outcome data for dogs and cats were summarized for total number of animals taken in per year **(Table 1)**, number of animals taken in/1,000 state residents per year **(Table 2)**, each type of outcome as a percentage of the total number of intakes per year **(Table 3)**, and LRR as a percentage of total intakes and percentage of total outcomes **(Table 4)**. To illustrate the variability in the data and depict the relationships between different facility outcomes, outcome data for dogs and cats were graphically displayed as percentages of intakes **(Figure 1)**.

Over the entire 16-year period (2000 through 2015), the estimated human population in the state of Colorado steadily increased from 4,338,831 to 5,456,584.[12] At the same time, the number of shelter and rescue facilities with consistently reported annual intake and outcome data for dogs and cats decreased from 104 for the period from 2000 through 2007 (as in the previous study[8]) to the 76 facilities included in the present study. These facilities were deemed to represent the core of animal shelter capacity in the state and included all of the top 10, 17 of the top 20, and 33 of the top 50 facilities as ranked by total intakes in 2015. The 3 facilities not represented in the sample that were included in the top 20 for total intake in 2015 were all founded after 2000 and therefore excluded. Although some of the shelter and rescue facilities in Colorado that did not meet the minimum animal handling or housing requirements for PACFA registration and reporting were not included in the sample, they were deemed unlikely to have represented an important portion of capacity, given the low number of animals permitted outside of licensing.

Table 1—Results of linear regression analysis of dog and cat intake and outcome data (total annual numbers) reported by 76 consistently reporting animal shelter and rescue facilities in Colorado from 2000 through 2015, 2000 through 2007, and 2008 through 2015.

	Dogs						Cats					
Data type, by period	**Slope**	***P* value***	**y-intercept**	**Total change**	**Final value**	**Percentage change**	**Slope**	***P* value***	**y-intercept**	**Total change**	**Final value**	**Percentage change**
Intake												
2000–2015	–677.6	0.01	82,147	–10,164	71,983	–12.4	–10.1	0.97	54,329	NC	54,329	NC
2000–2007	–39.3	0.88	79,125	NC	79,125	NC	2,199.2	< 0.001	46,623	15,394	62,017	33.0
2008–2015	–2,517.0	0.005	83,953	–17,619	66,334	–21.0	–2,178.0	< 0.001	61,809	–15,246	46,563	–24.7
Euthanasia												
2000–2015	–797.4	< 0.001	18,159	–11,961	6,198	–65.9	–804.7	0.02	23,925	–12,071	11,855	–50.5
2000–2007	51.3	0.85	15,555	NC	15,555	NC	1,276.8	0.01	16,676	8,938	25,614	53.6
2008–2015	–1,087.0	< 0.001	12,427	–7,609	4,818	–61.2	–2,832.1	< 0.001	24,548	–19,825	4,723	–80.8
Adoption												
2000–2015	–22.6	0.91	31,627	NC	31,627	NC	250.7	< 0.001	23,702	3,761	27,463	15.9
2000–2007	–276.6	0.08	31,525	NC	31,525	NC	457.4	0.008	23,212	3,202	26,414	13.8
2008–2015	–1,279.2	0.06	36,836	NC	36,836	NC	400.3	0.04	24,950	2,802	27,752	11.2
RTO												
2000–2015	–182.3	0.31	26,948	NC	26,948	NC	84.5	0.14	2,291	NC	2,291	NC
2000–2007	–140.4	0.28	27,290	NC	27,290	NC	–6.1	0.83	2,583	NC	2,583	NC
2008–2015	519.9	0.47	22,544	NC	22,544	NC	137.8	0.57	2,804	NC	2,804	NC
Transfer												
2000–2015	180.3	< 0.001	3,510	2,705	6,215	77.1	196.7	< 0.001	1,980	2,951	4,931	149.0
2000–2007	326.6	< 0.001	2,984	2,286	5,270	76.6	354.9	< 0.001	1,383	2,484	3,867	179.6
2008–2015	12.4	0.85	5,554	NC	5,554	NC	–28.2	0.79	4,384	NC	4,384	NC
Died or other												
2000–2015	129.9	0.03	1,026	1,949	2,975	189.9	215.4	0.002	724	3,231	3,955	446.3
2000–2007	–91.4	0.07	1,606	NC	1,606	NC	82.7	0.32	1,322	NC	1,322	NC
2008–2015	54.4	0.81	2,524	NC	2,524	NC	551.2	0.025	1,140	3,858	4,998	338.5

*P value represents whether the slope of the linear regression line (ie, the temporal trend line) was significantly different from 0.
Values of $P \leq 0.05$ were considered significant. The r^2 value for all identified significant trends was > 0.50.
NC = Not calculated.
Outcome data included dogs and cats that were adopted, RTO, transferred to another facility or euthanized or that died or had other outcomes otherwise unaccounted for.

Table 2—Results of linear regression analysis of dog and cat intakes and outcomes/1,000 state residents as reported by the same facilities for the same periods as in Table 1.

	Dogs						Cats					
Data type, by period	**Slope**	***P* value***	**y-intercept**	**Total change**	**Final value**	**Percentage change**	**Slope**	***P* value***	**y-intercept**	**Total change**	**Final value**	**Percentage change**
Intake												
2000–2015	–0.08	0.11	20.5	NC	20.5	NC	–0.07	0.40	14.1	NC	14.1	NC
2000–2007	0.24	0.04	19.5	1.7	21.2	8.6	0.64	< 0.001	11.9	4.5	16.4	37.6
2008–2015	–0.20	0.15	20.1	NC	20.1	NC	–0.43	< 0.001	14.6	–3.0	11.6	–20.6
Euthanasia												
2000–2015	–0.19	< 0.001	4.5	–2.9	1.7	–63.3	–0.22	0.01	6.1	–3.3	2.8	–54.1
2000–2007	0.06	0.30	3.8	NC	3.8	NC	0.37	0.005	4.1	2.6	6.7	63.2
2008–2015	–0.23	< 0.001	3.0	–1.6	1.4	–53.7	–0.66	< 0.001	5.8	–4.6	1.2	–79.7
Adoption												
2000–2015	0.12	< 0.001	7.5	1.8	9.3	24.0	0.03	0.25	6.2	NC	6.2	NC
2000–2007	0.03	0.62	7.7	NC	7.7	NC	0.15	0.009	5.9	1.1	7.0	17.8
2008–2015	0.16	0.03	8.3	1.1	9.4	13.5	0.16	0.051	5.8	NC	5.8	NC
RTO												
2000–2015	–0.09	0.001	7.0	–1.4	5.7	–19.3	0.02	0.21	0.6	NC	0.6	NC
2000–2007	0.05	0.09	6.7	NC	6.7	NC	0.00	0.50	0.6	NC	0.6	NC
2008–2015	0.00	0.95	5.9	NC	5.9	NC	0.04	0.49	0.6	NC	0.6	NC
Transfer												
2000–2015	0.05	< 0.001	0.8	0.8	1.6	89.3	0.04	< 0.001	0.6	0.6	1.2	100.0
2000–2007	0.10	< 0.001	0.7	0.7	1.4	100.0	0.09	< 0.001	0.4	0.6	1.0	157.5
2008–2015	0.03	0.22	1.4	NC	1.4	NC	0.00	0.87	1.0	NC	1.0	NC
Died or other												
2000–2015	0.04	0.02	0.2	0.6	0.8	300.0	0.05	0.004	0.2	0.8	1.0	375.0
2000–2007	–0.01	0.21	0.4	NC	0.4	NC	0.02	0.27	0.3	NC	0.3	NC
2008–2015	0.03	0.62	0.6	NC	0.6	NC	0.14	0.03	0.2	1.0	1.2	490.0

Population estimates were obtained from the Colorado State Demography Office State and Population Estimates.[12]
See Table 1 for remainder of key.

The percentage of total intakes by the 76 included facilities steadily declined from > 95% of all dogs and cats taken in by all reporting Colorado shelter and rescue facilities in 2000 to 65% of dogs and 71% of cats in 2015. This decrease in the percentage of total intakes was attributable to the exclusion of data from some of the original subgroup of shelters included in the previous study[8] owing to inconsistent

Table 3—Results of linear regression analysis of dog and cat outcomes as a percentage of intakes as reported by the same facilities for the same periods as in Table 1.

	Dogs						Cats					
Outcome, by period	**Slope**	***P* value***	**y-intercept**	**Total change**	**Final value**	**Percentage change**	**Slope**	***P* value***	**y-intercept**	**Total change**	**Final value**	**Percentage change**
Euthanasia												
2000–2015	–0.94	< 0.001	22.6	–14.1	8.5	–62.4	–1.61	< 0.001	44.5	–24.2	20.4	–54.3
2000–2007	0.07	0.82	19.6	NC	19.6	NC	0.78	0.14	36.0	NC	36.0	NC
2008–2015	–1.08	< 0.001	15.1	–7.6	7.5	–50.1	–4.20	< 0.001	41.0	–29.4	11.6	–71.7
Adoption												
2000–2015	0.77	< 0.001	36.3	11.6	47.9	31.8	0.55	0.11	43.6	NC	43.6	NC
2000–2007	–0.33	0.18	39.8	NC	39.8	NC	–1.08	0.03	49.7	–7.6	42.1	–15.2
2008–2015	1.34	0.009	40.8	9.4	50.2	23.0	2.91	0.003	39.2	20.4	59.6	52.0
RTO												
2000–2015	–0.31	< 0.001	34.5	–4.7	29.9	–13.5	0.16	0.15	4.3	NC	4.3	NC
2000–2007	–0.16	0.053	34.5	NC	34.5	NC	–0.21	0.01	5.5	–1.5	4.0	–26.7
2008–2015	0.31	0.40	29.3	NC	29.3	NC	0.45	0.31	4.5	NC	4.5	NC
Transfer												
2000–2015	0.30	< 0.001	4.1	4.5	8.6	109.8	0.39	< 0.001	3.4	5.9	9.3	172.1
2000–2007	0.41	< 0.001	3.8	2.9	6.7	75.5	0.48	0.002	3.1	3.4	6.5	108.4
2008–2015	0.28	0.09	6.5	NC	6.5	NC	0.26	0.10	7.0	NC	7.0	NC
Died or other												
2000–2015	0.21	0.03	1.1	3.2	4.3	286.4	0.46	0.005	1.0	6.9	7.9	690.0
2000–2007	–0.11	0.09	2.0	NC	2.0	NC	0.02	0.87	2.9	0.1	3.0	4.8
2008–2015	0.21	0.55	3.0	NC	3.0	NC	1.35	0.08	1.3	9.5	10.8	726.9

See Table 1 for key.

Table 4—Results of linear regression analysis of dog and cat LRRs as a function of total annual intakes and outcomes as reported by the same facilities for the same periods as in Table 1.

	Dogs						Cats					
LRR, by period	**Slope**	***P* value***	**y-intercept**	**Total change**	**Final value**	**Percentage change**	**Slope**	***P* value***	**y-intercept**	**Total change**	**Final value**	**Percentage change**
Intake												
2000–2015	0.61	0.002	75.6	9.2	84.8	12.1	1.10	0.004	51.2	16.5	67.7	32.2
2000–2007	–0.08	0.77	78.1	NC	78.1	NC	–0.80	0.07	58.3	NC	58.3	NC
2008–2015	1.49	0.03	77.3	10.4	87.7	13.5	3.63	< 0.001	50.7	25.4	76.1	50.1
Outcome												
2000–2015	0.73	< 0.001	76.0	11.0	87.0	14.4	1.17	0.002	53.0	17.6	70.6	33.1
2000–2007	0.02	0.94	78.3	NC	78.3	NC	–0.80	0.12	59.9	NC	59.9	NC
2008–2015	1.04	0.007	81.1	7.3	88.4	9.0	3.24	< 0.001	55.0	22.7	77.7	41.2

See Table 1 for key.

reporting as well as the exclusion of the new shelter and rescue facilities that began operations after 2000. These changes in the state human population and decreasing intake represented in the consistently reporting subgroup were accounted for in the per capita calculations.

Intake

From 2000 to 2015, the trend (linear regression) line indicated that the annual number of dogs taken in by shelter and rescue facilities decreased by 12.4%. Most of this decrease occurred in the period from 2008 through 2015, during which a 21.0% decrease was observed. When growth of Colorado's human population was accounted for, intake data for dogs remained unchanged from 2000 to 2015. By the end of the period from 2008 through 2015, the intake rate for dogs for the 76 facilities was approximately 66,000/y or 20.1/1,000 state residents/y.

Trend lines for cats indicated an increase in the annual number of cats and number of cats/1,000 state residents taken in by facilities during the period from 2000 through 2007, followed by a decrease in the period from 2008 through 2015. For example, from 2000 to 2007, a 37.6% increase in the number of cat intakes/1,000 state residents was observed, followed by a 20.6% decrease from 2008 to 2015. This pattern resulted in trend lines with no slope across the entire study period for both scales for cats, with approximately 54,000 cats or 14.1 cats/1,000 state residents taken into the shelter and rescue facilities every year. By the end of the period from 2008 through 2015, the intake rate for cats was approximately 46,500/y or 11.6/1,000 state residents/y.

Euthanasia

Trend lines indicated that the annual number of dogs euthanized and number of dogs euthanized/1,000 state residents decreased by > 60% from 2000 to 2015. Most of this decrease occurred between 2008 and 2015. By the end of the period from 2008 through 2015, the euthanasia rate for dogs had decreased to approximately 4,800/y, 1.4/1,000 state residents/y, or 7.5% of dog intakes/y.

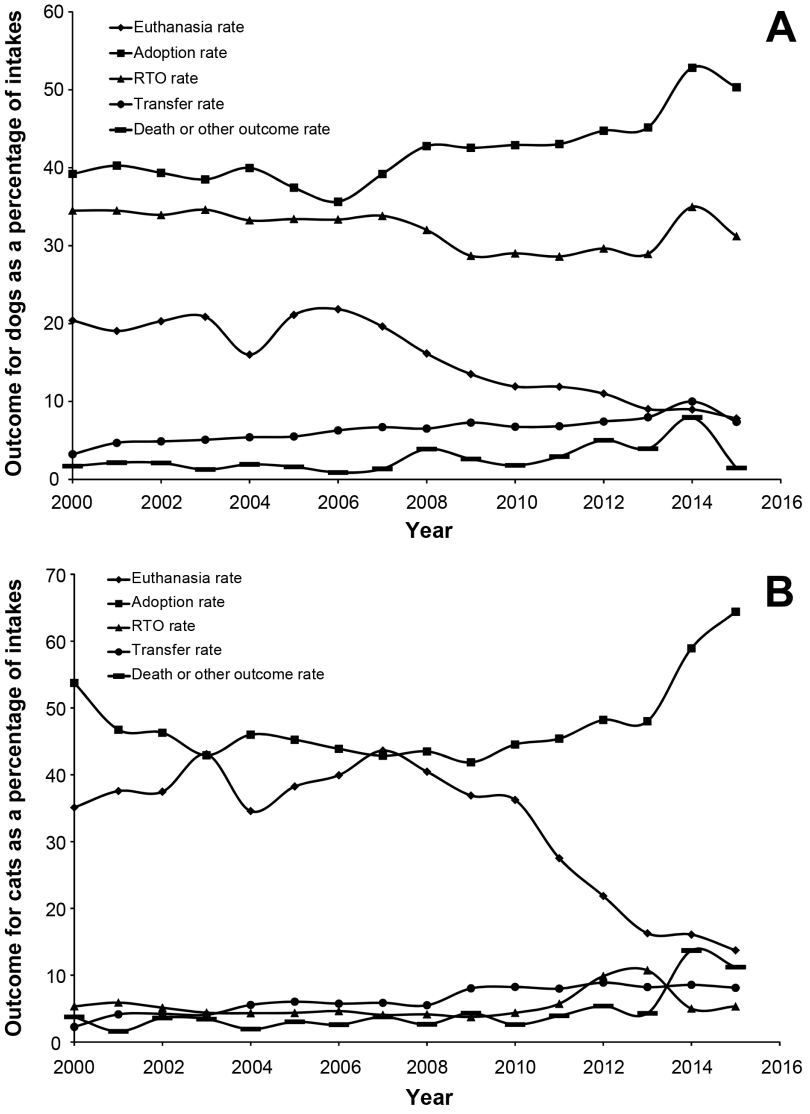

Figure 1—Annual outcome data for dogs (A) and cats (B) from 76 consistently reporting animal shelter and rescue facilities in Colorado as a percentage of intakes from 2000 through 2015.

From 2000 to 2015, trend lines for cats indicated that the annual number of cats euthanized, number euthanized/1,000 state residents, and euthanasia as a percentage of cat intakes decreased by > 50%. Similar to the trends observed in the cat intake data, these scales generally increased from 2000 to 2007 and then decreased from 2008 to 2015. In contrast to the intake data, the substantial decreases in euthanasia rates from 2008 to 2015 resulted in trend lines that decreased across the entire study period. By the end of the period from 2008 through 2015, the euthanasia rate for cats had decreased to approximately 4,700/y, 1.2/1,000 state residents/y, or 11.6% of cat intakes/y.

Adoption

Trend lines indicated that the annual number of dogs adopted from 2000 to 2015 remained unchanged, even during the two 8-year subperiods. However, when adjusted for human population growth, the trend line for dog adoptions over the entire 16-year period indicated a 24.0% increase. Dog adoptions as a percentage of dog intakes increased by 31.8% from 2000 to 2015, with most of this increase occurring during the period from 2008 through 2015. Dog adoption as a percentage of intakes over the entire 16-year period was very strongly inversely correlated ($r_s = 0.97$; $P < 0.001$) with dog euthanasia as a percentage of intakes over the same period. By the end of the period from 2008 through 2015, the adoption rate for dogs was approximately 36,800/y, 9.4/1,000 state residents/y, or 50.2% of dog intakes/y.

Trend lines indicated that the annual number of cats adopted from 2000 through 2015 increased by 15.9%, with fairly equivalent percentage increases over the two 8-year subperiods. However, when accounting for human population growth, the only trend line for this scale that had a significant slope was that from 2000 to 2007, during which a 17.8% increase was observed. Overall, cat adoptions as a percentage of cat intakes from 2000 to 2015 remained constant at approximately 44%. However, the percentage of cats adopted from 2000 through 2007 decreased by 15.2% before increasing by 52.0% between 2008 and 2015. Similar to the dog adoption rate, cat adoptions as a percentage of cat intakes was strongly inversely correlated ($r_s = 0.79$; $P < 0.001$) with cat euthanasia as a percentage of cat intakes over the same period. By the end of the period from 2008 through 2015, the adoption rate for cats was approximately 27,800/y, 5.8/1,000 state residents/y, or 59.6% of cat intakes/y.

RTO

Trend lines indicated that the annual number of dogs returned to their owners remained constant from 2000 to 2015. However, an overall decrease of 19.3% was observed from 2000 to 2015 when human population growth was taken into account, with a concurrent decrease of 13.5% as a percentage of dog intakes. The trend lines for each RTO scale had no slope when analyzed as the two 8-year subperiods. By the end of the period from 2008 through 2015, the RTO rate for dogs was approximately 22,500/y, 5.9/1,000 state residents/y, or 29.3% of dog intakes.

No significant trends were identified in any RTO scale for cats across the entire 16-year period. By the end of the period from 2008 through 2015, the RTO

rate for cats was approximately 2,800/y, 0.6/1,000 state residents/y, or 4.5% of cat intakes.

Transfers

Trend lines indicated that the annual number of dogs transferred from 1 of the 76 shelter and rescue facilities to other facilities increased by 77.1% during the entire 16-year period. Most of this increase occurred between 2000 and 2007, during which a 76.6% increase was observed. The slope of the trend line for the period from 2008 through 2015 indicated no change. A similar pattern was observed when human population growth was accounted for, with much of the 89.3% increase in the trend line for 2000 to 2015 occurring during the period from 2000 through 2007. This pattern was also observed when transfers were considered as a percentage of dog intakes, with an increase of 109.8% from 2000 to 2015 driven largely by a 75.5% increase from 2000 to 2007. None of the slopes of the trend lines for these 3 scales were significant for the period from 2008 through 2015. By the end of that period, the transfer rate for dogs was approximately 5,600/y, 1.4/1,000 state residents/y, or 6.5% of dog intakes.

Trend lines for cats indicated that the annual number transferred to other facilities increased by 149.0% from 2000 to 2015, with most of this increase attributable to the 179.6% increase from 2000 to 2007. A similar pattern was observed for the number of cats transferred/state residents and the number of transfers as a percentage of cat intakes. Accounting for population growth across the entire 16-year period, cat transfers doubled over the 16-year period, with a 157.5% increase observed for the period from 2000 through 2007 specifically. Cat transfers as a percentage of cat intakes increased by 172.1% from 2000 to 2015, with an increase of 108.4% observed for the period 2000 through 2007. None of the slopes of the trend lines for these 3 scales were significant for the period from 2008 through 2015. By the end of the period from 2008 through 2015, the transfer rate for cats was approximately 4,400/y, 1.0/1,000 state residents/y, or 7.0% of cat intakes.

The maximum proportion of possible intake errors under the assumption that all reported transfers were among the 76 shelter and rescue facilities included in the study (and not other excluded facilities) was estimated as 10.0% for dogs (in 2014) and 8.9% for cats (in 2012). Mean overall maximum error rates for the 16-year period were 6.4% for dogs and 6.3% for cats.

Death or other outcome

Trend lines for the annual number of dogs that died or had another unaccounted-for outcome had no significant slope for the two 8-year study periods, but they indicated a 189.9% increase in this variable over the entire 16-year period. A similar pattern was observed for the other 2 scales. By the end of the period from 2008 through 2015, the rate of dogs reported as dead or having some other unaccounted-for outcome was approximately 2,500/y, 0.6/1,000 state residents/y, or 3.0% of dog intakes.

In contrast to the data for dogs, substantial overall increases were observed for cats on all 3 scales involving this outcome for the period from 2008 through 2015. The annual number of cats reported as dead or having another outcome increased by 446.3% from 2000 to 2015, whereas values for these data accounting for human population growth and as a percentage of cat intakes increased by 375.0% and 690.0%, respectively. By the end of the period from 2008 through 2015, the rate of cats reported as dead or having some other unaccounted-for outcome was approximately 5,000/y, 1.2/1,000 state residents/y, or 10.8% of cat intakes.

LRRs

Trend lines indicated that the LRR for dogs as a function of intakes increased by 12.1% from 2000 to 2015, with no significant change from 2000 to 2007 and an increase of 13.5% from 2008 to 2015. The LRR for dogs as a function of outcomes increased by 14.4% from 2000 to 2015, with no change identified from 2000 to 2007 and an increase of 9.0% identified 2008 to 2015. By the end of the period from 2008 through 2015, the LRRs for dogs as a function of intakes and outcomes had increased to 87.7% and 88.4%, respectively.

For cats, trend lines for LRR as a function of intakes increased by 32.2% from 2000 to 2015, with no change identified from 2000 to 2007 and a 50.1% increase identified from 2008 to 2015. The LRR as a function of outcomes increased by 33.1%, with no change identified from 2000 to 2007 and a 41.2% increase identified from 2008 to 2015. By the end of the period from 2008 through 2015, the LRRs for cats as a function of intakes and outcomes had increased to 76.1% and 77.7%, respectively.

Discussion

Although some animal shelter and rescue facilities included in the previously reported trend analysis[8] were excluded from the present study, the present study included 16 years of intake and outcome data from 76 facilities with consistently reported data across 5 scales, representing the most comprehensive analysis of statewide animal shelter data to date. The 5 scales that were used provided a detailed description of statewide shelter and rescue intake and outcome dynamics for dogs and cats. Total numbers of dogs and cats reflected the magnitude of the data used in the study, use of numbers/1,000 state residents allowed adjustment for human population growth and a decreasing percentage of the total intakes, outcomes as a percentage of intakes more directly reflected facility performance as a function of the animals they took in, and the 2 LRR scales represented a measure commonly used by animal shelters to assess their performance and as an indicator of possible long-term animal warehousing. Our findings

built upon previously reported findings for the same state from 2000 through 2007,[8] wherein dog intake and euthanasia rates generally decreased or remained unchanged and those for cats increased. The trend lines for the period from 2008 through 2015 indicated significant improvements since the previous period in outcomes, particularly in euthanasia rates, for dogs and cats as assessed across all scales used.

Although not observed on the human population–adjusted scale, the total number of dogs taken in by shelters and rescue facilities decreased between 2008 and 2015. Several factors likely contributed to this trend, including a wide variety of legislative and subsidized programs aimed at increasing spay and neuter rates. In 2008, the PACFA legislation was amended to include a statutory requirement by which the State of Colorado mandates that all sexually intact animals adopted or transferred from PACFA-licensed facilities be spayed or neutered within 90 days following adoption. Various subsidized spay-neuter programs operate throughout Colorado, including clinics run by the shelter and rescue facilities themselves. State-sponsored programming has been funded since 2001 through an optional donation on the Colorado tax form to the Pet Overpopulation Fund, and fees from a dedicated "Adopt a shelter pet" vehicle license plate subsidize spay-neuter programs through grants.[13] These facility-specific and statewide programs may have supported the improvements in dog intake data identified in the present study, most likely by decreasing the total number of dogs in the population. Analysis of intake trends for owner surrenders and strays or adult versus juvenile animals, among other intake categories, would be useful for exploring this possibility further.

It is important to note that in contrast to the 12.4% decrease from 2000 to 2015 in the annual number of dogs taken in by the 76 facilities in the present study, the total number of dogs taken in by all PACFA-licensed shelters and rescues increased by 16% during the same period (data not shown). Although the overall growth in shelter capacity to house animals in the state increased during this period, a major contributing factor to this discrepancy was the increase in dogs transferred into Colorado from out of state. By 2015, 30% of total dog intake in Colorado consisted of dogs from other states. In part, this increase indicates that the state's animal shelter and rescue facilities are more than meeting the needs of the animals in their local communities and are, therefore, expanding capacity into other states.

The euthanasia rates from 2000 through 2015 and 2008 through 2015 for dogs at the shelter and rescue facilities in the present study decreased on all 3 evaluated scales. Although the decrease in the annual number of dogs taken in likely influenced the euthanasia rates, the concurrent increases in adoption rates on a human population–adjusted scale and a percentage-of-intakes scale were also factors. This supposition was supported by the observation that euthanasia and adoption rates as a percentage of intakes were inversely correlated across the 16-year study period, which was not unexpected in that dogs leaving the facilities by adoption free up a facility's capacity to house those dogs that might otherwise have been candidates for euthanasia or vice versa. The observed trends in dog adoption rates may have been partly driven by the establishment of shelter- and community partner–based programs to address the behavioral and medical needs of animals that shelter and rescue facilities were previously unable to put up for adoption.[11,14] In addition, increases in online marketing and social media campaigns may have increased public awareness of animals available for adoption and improved public attitudes toward the benefits of adopting pets from shelter and rescue facilities. The RTO rates for dogs remained static across the entire study period and, therefore, were not likely to have been a major factor in the overall improvements in euthanasia rates. Whether that lack of change reflected a lack of effectiveness of microchip identification programs remains unknown.

Another factor that appeared to have improved outcomes for dogs in shelter and rescue facilities in Colorado was the increase in transfers among facilities over the 16-year period evaluated. As indicated previously, these interagency transfers represent an optimization of overall shelter capacity and programs on both an intrastate and interstate level. Shelter and rescue facilities with intake numbers that exceed capacity can find open space for excess dogs at partner facilities instead of having to euthanize animals to stay at or below maximum capacity. This networking between agencies is often regulated by formal agreements and has been facilitated by associations such as the Metro Denver Animal Welfare Alliance (formerly Metro Denver Shelter Alliance) and the Colorado Federation of Animal Welfare Agencies.[15,16] An additional way that interagency transfers can positively impact shelter outcomes is by moving dogs to facilities in more populous areas of the state or to specialized rescue facilities with access to specialized resources that can increase those animals' likelihood of adoption. The success of transfer networks, combined with decreases in shelter and rescue intake numbers, has driven the expansion of this model to surrounding states.

In contrast to the increases in numbers and human population–adjusted numbers of cats taken in from 2000 to 2007, these numbers decreased from 2008 to 2015, as shown in the present study. The lack of change observed in cat intake data over the entire 16-year period was attributable to these conflicting trends. The lower intake rates since 2008 likely reflected the deployment of substantially greater resources for spay-neuter and education programs focused on cats.

The decreasing trends in cat intake rates and the allocation of more resources to programs focused on improving their outcomes also likely influenced the observed improvements in the euthanasia and adoption trends across all scales assessed. Particularly,

cat euthanasia rates declined steeply between 2008 and 2015. Similar to the data for dogs, euthanasia and adoptions as percentages of cat intakes were inversely correlated over the 16-year period. However, the greater steepness of the negative slope for euthanasia, compared with the steepness of the positive slope for adoptions, from 2008 to 2015 was possibly influenced by less pressure on shelter or rescue capacity from decreases in intake rates. Like dogs, the increases in adoption rates observed for cats during the period from 2008 through 2015 might have reflected an increase in the effectiveness of adoption programs, including expansion of medical care provided to cats, optimization of facility capacity through interagency transfer programs, and effective marketing and social media campaigns.[11,17–20] The increases in the numbers of cat adoptions and in adoptions as a percentage of intakes were not reflected in the respective human population–adjusted values, suggesting that the pool of potential adopters was not yet at saturation and that room remains for Colorado shelters and rescues to improve cat adoption rates.

The RTO rates for cats remained at approximately 4% of intakes across the entire study period. As for dogs, the effect, if any, of microchip identification programs on this outcome remains unknown. Interagency transfers increased during the period from 2000 through 2007 but later stabilized at approximately 7%. This may have indicated that most of shelter and rescue facilities included in the present study were still running near maximum holding capacity despite the decrease in intakes. The recent increase in the number of cats that died or had other unaccounted-for outcomes was likely attributable to classification of cats in TNR and SNR programs as in the "other" outcome category by the current PACFA reporting process. No reports exist of large disease outbreaks that might have dramatically increased the number cats classified as having died in recent years.[11]

During the period from 2000 to 2007, the outcome categories of died or "other" individually accounted for such a low percentage of outcomes (≤ 2% of intakes) that for the purposes of analysis, these categories were combined. In the authors' experience, existing data collection processes for TNR and SNR programs are inconsistent across shelters, with some shelters reporting cats involved in TNR or SNR programs as strays in intake counts and then as "other" or RTO in outcome counts, whereas other shelters exclude such cats from intake counts and simply account for them when reporting on individual TNR or SNR programs. Tracking of TNR, SNR, and other innovative programs within the PACFA data reporting processes could be considered to better understand the prevalence of these programs and potential impacts on free-roaming cat populations in the community, including collection of data on LRRs when shelters offer these services for cats.[18–20] Overall, outcomes for cats, as indicated by the increase in adoption rates and decrease in euthanasia rates, improved dramatically from 2008 to 2015, compared with during the previous 8-year period, in large part likely because of a refocusing of shelter resources on various cat welfare concerns.

The LRRs for both dogs and cats increased over the 16-year study period, with much of that improvement noted from 2008 to 2015. We believe that the similar results found for the 2 LRR metrics as functions of intakes and outcomes indicate the absence of long-term warehousing of dogs and cats in the consistently reporting shelter and rescue facilities. It is important to note that the LRR in Colorado has been achieved through various shelter and rescue models, indicating that considerations such as data-driven resource allocation and interagency collaboration can substantially improve outcomes overall. Colorado would likely surpass the 90% LRR threshold if it were not actively transporting animals in from other states. However, at a certain point, the LRR may no longer be the most appropriate metric for shelter and rescue operations. The LRR has been the widely accepted metric for assessing the effectiveness of shelter and rescue operations but is limited in its ability to capture increasingly relevant considerations such as the cost of individual animal care, the capacity of the surrounding community to adopt additional animals, or the availability of pet-supportive services and pet-friendly policies in the surrounding community. As animal shelter and rescue facilities more effectively meet the needs of their communities' companion animal populations, the percentage of dogs and cats too medically or behaviorally unsound for immediate adoption is likely to increase. At some point, the LRR becomes a function of the resources a given community is able and willing to devote to saving animals with higher associated costs. Additional research is needed to understand how an increase in the LRR of shelter and rescue facilities influences animal welfare and public health outcomes, such as the incidence of animal bites, cruelty and neglect citations, or the prevalence of physical or mental health improvements in people who adopt or foster shelter or rescue animals.[21,22]

We believe the overall success that Colorado has achieved in supporting live outcomes for animals taken in by shelter and rescue facilities, as identified in the present study, is likely attributable to several factors. First, the accessibility and prevalence of spay-neuter programs might be starting to maintain the populations of dogs and cats at numbers that would allow all to find homes as pets following temporary housing in shelter and rescue facilities. Meanwhile, the increase in the overall number of shelters and rescue facilities has increased the total capacity across the state for both dogs and cats. These facilities are increasingly working collaboratively to optimize capacity. Adoptions as a percentage of intakes are increasing for both species, even further reducing pressure on facility capacity, and adoption and euthanasia rates are inversely correlated, as the present study showed. This dynamic is driven in part by decreasing intake. Although not a new concept, the effects

of increasing the adoption rate on the euthanasia rate of a shelter or rescue facility are perhaps even more direct than previously believed.

We believe that the 16 years of shelter and rescue facility data in the study reported here provide insight into the long-term animal sheltering dynamics in a state with a rapidly growing human population and afford an opportunity to assess the effects of data-driven decision-making on resource allocation for shelter- and rescue-related concerns. Although shelter and rescue facility staff indicated that resources were being directed to cats before analysis of the 2000–2007 data was performed in the previous study,[8] the findings of that first study spurred more rapid, concerted, and sustained deployment of those resources in Colorado. Such efforts included increases in the subsidies offered for spay-neuter programs, improvements in kenneling approaches to reduce stress-related diseases in cats, increases in basic medical care provided to animals, marketing and social media campaigns to increase adoption rates, and an overall increase in capacity of the facilities included in the present study as well as the more recently founded facilities that were not included. Findings for the period from 2008 through 2015, particularly those for cats, suggested the effectiveness of focusing resources on a species to improve shelter and rescue outcomes guided by system-wide data collection to assess progress. This bodes well for efforts aimed at collecting intake and outcome data across larger systems, including at the national level.[1]

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References

1. Shelter Animals Count. Animal data summary. Available at: shelteranimalscount.org/data/Explore-the-Data/dataset. Accessed Jan 8, 2017.
2. Zawistowski S, Morris J, Salman MD, et al. Population dynamics, overpopulation and the welfare of companion animals: new insights on old and new data. *J Appl Anim Welf Sci* 1998;1:193–206.
3. White SC, Jefferson E, Levy JK. Impact of publicly sponsored neutering programs on animal population dynamics at animal shelters: the New Hampshire and Austin experiences. *J Appl Anim Welf Sci* 2010;13:191–212.
4. Lord LK, Wittum TE, Ferketich AK, et al. Demographic trends for animal care and control agencies in Ohio from 1996 to 2004. *J Am Vet Med Assoc* 2006;229:48–54.
5. Sinski JB, Gagne P. Give me shelter: the state of animal sheltering in Kentucky's county shelter system. *Contemp Justice Rev* 2016;19:250–266.
6. Wenstrup J, Dowidchuk A. Pet overpopulation: data measurement issues in shelters. *J Appl Anim Welf Sci* 1999;2:303–319.
7. Colorado Department of Agriculture. Pet Animal Care Facilities Act (PACFA). Available at: www.colorado.gov/pacific/aginspection/pacfa. Accessed Oct 21, 2016.
8. Morris KN, Wolf JL, Gies DL. Trends in intake and outcome data for animal shelters in Colorado, 2000–2007. *J Am Vet Med Assoc* 2011;238:329–336.
9. Scarlett JM. Interface of epidemiology, pet population issues and policy. *Prev Vet Med* 2008;86:188–197.
10. Morris KN, Gies DL. Trends in intake and outcome data for animal shelters in a large US Metropolitan area, 1989 to 2010. *J Appl Anim Welf Sci* 2014;17:59–72.
11. Institute for Human-Animal Connection. Colorado animal shelter data trends 2000–2013 discussion group notes. Available at: www.du.edu/humananimalconnection/media/documents/pacfa-ihac-discussion.pdf. Accessed Nov 11, 2016.
12. Colorado Division of Local Government State Demography Office. Colorado county population forecasts in 1-year increments. Available at: demography.dola.colorado.gov/population/data/profile-county/. Accessed Oct 21, 2016.
13. Colorado Pet Overpopulation Fund. Available at: coloradopetfund.org. Accessed Feb 24, 2017.
14. Weiss E, Miller K, Mohan-Gibbons H, et al. Why did you choose this pet? Adopters and pet selection preferences in five animal shelters in the United States. *Animals (Basel)* 2012;2:144–159.
15. Metro Denver Animal Welfare Alliance. Available at: www.mdawalliance.org/. Accessed Feb 24, 2017.
16. Colorado Federation of Animal Welfare Agencies. Available at www.cfawa.org/cpages/home. Accessed Feb 24, 2017.
17. Fantuzzi JM, Miller KA, Weiss E. Factors relevant to adoption of cats in an animal shelter. *J Appl Anim Welf Sci* 2010;13:174–179.
18. Weiss E, Gramann S. A comparison of attachment levels of adopters of cats: free-based adoptions versus free adoptions. *J Appl Anim Welf Sci* 2009;12:360–370.
19. Slater MR, Miller KA, Weiss E, et al. A survey of the methods used in shelter and rescue programs to identify feral and frightened pet cats. *J Feline Med Surg* 2010;12:592–600.
20. Scarlett J, Johnston N. Impact of a subsidized spay neuter clinic on impounds and euthanasia on a community shelter and on service and complaint calls to animal control. *J Appl Anim Welf Sci* 2012;15:53–69.
21. Hawes S, Ikizler D, Loughney K, et al. Legislating components of a humane city: the economic impacts of the Austin, Texas "no kill" resolution (City of Austin Resolution 20091105–040). Available at: animalstudiesrepository.org/anilleg/1. Accessed Dec 22, 2018.
22. Morris K, Evans R, Smith S, et al. Oklahoma Humane Society Compassion Center Economic Impact Study. Available at: animalstudiesrepository.org/humsrorg/2. Accessed Dec 22, 2018.