Outdoor fecal deposition by free-roaming cats and attitudes of cat owners and nonowners toward stray pets, wildlife, and water pollution

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Objective—To estimate cat population size, management, and outside fecal deposition and evaluate attitudes of cat owners and nonowners to stray animal control, water pollution, and wildlife protection.

Design—Cross-sectional survey.

Sample Population—294 adult residents of Cayucos, Los Osos, and Morro Bay, Calif.

Procedures—Telephone survey.

Results—The region's cat population was estimated at 7,284 owned and 2,046 feral cats, and 38% of surveyed households owned a mean of 1.9 cats/household. Forty-four percent of cats defecated outside > 75% of the time. Annual fecal deposition (wet weight) by owned cats in the 3 communities was estimated to be 77.6 tonnes (76.4 tons). Cat owners were more likely to oppose cat licensing and impounding stray cats and support trap-neuter-return for stray cats and less likely to be concerned about water pollution, than were noncat owners.

Conclusions and Clinical Relevance—Feral cats represented a sizeable proportion (22%) of the free-roaming cats in this area and could be contributing 30.0 tonnes (29.5 tons) of feces to the environment per year. However, feral cats are not the principal source of fecal loading because owned cats defecating outdoors contribute an estimated 77.6 tonnes (76.4 tons) or 72% of the annual outdoor fecal deposition. (*J Am Vet Med Assoc* 2006;229:74–81)

Abbreviations

CI	Confidence interval
MDFW	Mean daily fecal weight
TNR	Trap-neuter-return

The owned cat population in the United States is estimated to be approximately 70.8 million, with 31.6% of households owning a cat.[1] The feral cat population represents an additional unknown number of cats, which could be sizable because 7% to 25% of households admit to feeding free-roaming cats and many thousands of cats are euthanized annually in shelters.[2-9] Other evidence for a large feral cat population is suggested by surveys indicating that 14% to 32% of cats are acquired as strays[2-7,10,11] and by population models indicating that births among stray cats account for the difference between projected and observed rates of change in population size.[12]

Although much attention has been focused on the effect of free-roaming cats on wildlife, little consideration has been given to the contribution of owned and feral cats to fecal pollution. Results of several studies[13,14] suggest that pet feces contribute to bacterial loading of streams and coastal waters. A study[15] of *Escherichia coli* ribotypes in Morro Bay, Calif, and its inflows reveals that 2.5% of all isolates are of felid origin, with a higher proportion (7.4%) from felids at the Pismo Seep downstream from Los Osos. In the southern sea otter (*Enhydra lutris nereis*) range from Half Moon Bay to Point Conception near Santa Barbara, Calif, *Toxoplasma gondii*, a protozoan parasite shed only in the feces of felids,[16] caused 16% of southern sea otter deaths that were evaluated from 1998 to 2001.[17] Fifty-two percent of dead and 38% of live southern sea otters sampled from 1998 to 2004 were infected with *T gondii*.[18] A study[19] of risk factors for *T gondii* exposure in sea otters found that otters sampled near heavy freshwater outflows are 3 times as likely to be at risk for infection as otters sampled near low freshwater outflow. The most unexpected finding of that study[19] was that sea otters from the Morro Bay area are 9 times as likely to be infected with *T gondii* as otters from any other area on the central California coast. This finding suggests that, as a high-risk site, the Morro Bay area is an ideal location for an ecological study of this zoonotic parasite, the first phase of which is the present study of cat management and outdoor fecal deposition. Although wild felids can shed *T gondii* oocysts in their feces, domestic cats are far more abundant than mountain lions or bobcats in California coastal watersheds.[20] Domestic cats shed 3 to 349 million *T gondii* oocysts 3 to 5 days after consuming infected animal tissues, with a longer prepatent period when fed tachyzoites or oocysts.[21-25] Although oocyst shedding usually occurs after initial infection and lasts no longer than 3 weeks, cats superinfected with *Isospora felis*, treated with large doses of corticosteroids, deprived of food, or reexposed to *T gondii* years after initial infection may shed oocysts again, albeit in lesser quantity.[21,26,27] To our knowledge, no studies have attempted to quantify the contribution

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of cats to fecal loading in any area, despite the fact that 40% to 88% of owned cats are allowed outdoors all or part of the time and have ample opportunity to defecate outside.[2,3,10,28]

The purposes of the study reported here were to estimate the owned and feral cat population size, establish how owned cats were managed, estimate the amount of fecal deposition into the environment caused by domestic cats, and determine the attitudes of cat owners versus noncat owners with regard to stray pet management, water pollution, and wildlife conservation.

Materials and Methods

Telephone survey design—The telephone survey was based on the 2002 to 2003 Estero Bay Community phone book published by Sun Bulletin of Morro Bay, Calif, and included the communities of Cayucos, Los Osos, and Morro Bay. Business listings and duplicate listings for the same address were excluded from the sampling frame. The remaining listings were counted, yielding 11,747 telephone numbers. The telephone listings were not sorted by community and were considered too large to stratify by community before sampling. The required sample size of 323 was estimated on the basis of an AVMA estimate (95% CI) that 30% of US households own cats.[29] Because the proportion of cat-owning households in each community was unknown and assumed to be 30% for each of the 3 strata, a stratified sample size calculation would yield a smaller sample size.[30] From Census 2000 data, households in Cayucos, Los Osos, and Morro Bay represented 11.3%, 47.8%, and 40.9% of occupied households, respectively.[31] Sampling based on proportional allocation implied that if the target sample size of 323 was achieved, it should consist of 37 respondents from Cayucos, 154 from Los Osos, and 132 from Morro Bay. The sample size was multiplied by 4 to account for refusals to participate, and division of the listed telephone numbers by this value yielded a 1-in-9 systematic sample. The starting interval and page number of the directory were randomized.[a] The questionnaire was given exempt approval under a human subjects protocol by the University of California Internal Review Board.

Community households and area—The number of occupied households in each community was obtained from Census 2000 data (**Table 1**).[31] The area of each community was determined by contacting the city engineer and obtaining the area served by the urban reserve sewage line or future sewage line for Los Osos (**Table 2**). Total human population in the 3 communities was 27,644 (Cayucos, 2,943; Los Osos, 14,351; and Morro Bay, 10,350) in an area of 11.5 miles^2 (29.4 km^2). Among the communities, the median age of residents ranged from 43 to 46 years, mean number of persons per household ranged from 2.1 to 2.4, and median annual income in 1999 ranged from $34,400 to $46,600.[31]

Cat population—The mean number of cats per household in each community was calculated as the total number of cats owned in the last 12 months divided by the number of households responding (adjusted to account for householders who stated they did not own cats and did not wish to participate in the survey). Pet-owning households are more likely to respond to a survey about pet ownership,[32] so the adjustment was intended to reduce bias attributable to nonresponse. The total cat population was calculated by taking the adjusted mean number of cats per household times the number of occupied households as indicated in Census 2000. The variance for this estimator was calculated as follows:

$$\text{Variance} = N^2 \frac{s^2}{n} \times \frac{N-n}{N}$$

where N is the number of households, s^2 is the sample variance for the mean number of cats per household, and n is the sample size. Cat density for each community was estimated by dividing the cat population size by the community area in hectares (1 hectare = 10,000 m^2 or 2.47 acres). The feral cat population was estimated by asking householders if they had fed a stray cat in the past month and, if so, how many. This methodology has been used in surveys from San Diego and Santa Clara Counties, California; Massachusetts; and Alachua County, Florida.[2-3,8] The number of feral cats divided by the 377 households (including households without cats that refused to complete the survey) provided an estimate of the mean number of feral cats per household. Multiplication of this estimate

Table 1—Survey responses and adjusted estimates of the owned cat population of 3 communities in California.

Community	Total HHs (No.)	Cat owners (No.)/survey respondents (No.)	No. respondents plus refusals from noncat owners	Mean No. of cats for all HHs	Cat population (crude estimate)*	Cat population (adjusted estimate)†	95% CI of adjusted estimate	Cat density per hectare (acre)
Cayucos	1,387	17/43	53	0.57	1,129	785	376–1,194	4.8 (1.9)
Los Osos	5,851	76/139	175	0.67	5,893	3,912	3,066–4,758	3.3 (1.3)
Morro Bay	5,006	49/112	149	0.52	3,933	2,587	1,907–3,267	1.6 (0.7)
Total	**12,244**	**142/294**	**377**	**NA**	**10,955**	**7,284**	**5,349–9,219**	**NA**

*Crude estimate based on mean number of cats owned for all households (HHs) that completed a telephone interview multiplied by the total number of occupied households. †Adjusted estimate based on mean number of cats owned by all HHs that completed a telephone interview and 83 HHs that did not own a cat and did not wish to participate multiplied by the total number of occupied HHs.
NA = Not applicable.

Table 2—Estimates of the proportion and number of HHs with cats defecating outside and estimated mean ± SEM (grams [ounces]) daily fecal loading of the environment per HH in 3 communities in California.

Community	Area (hectares [acres])	HHs with outdoor fecal deposition (% [SEM])	95% CI	Point estimate for No. of HHs	95% CI	Mean ± SEM daily HHs with fecal loading (g [oz])*
Cayucos	164 (410)	30.2 (7.0)	16.5–44.0	419	229–610	79.9 ± 19.9 (2.8 ± 0.7)
Los Osos	1,200 (3,000)	36.7 (4.1)	28.7–44.7	2,147	1,678–2,616	55.3 ± 5.5 (1.9 ± 0.2)
Morro Bay	1,578 (3,946)	27.7 (4.2)	19.4–36.0	1,386	971–1,800	43.7 ± 7.6 (1.5 ± 0.3)

*MDFW for all cats in the HH.

by the number of households from Census 2000 yielded an estimate for the number of feral cats in the 3 communities.

MDFW—The daily amount of fecal deposition for a cat was calculated for 20 groups of adult cats between the ages of 18 and 75 months (13 males and 21 females; mean age, 30 months; and mean body weight, 5.9 kg [13.1 lb]) and 10 groups of kittens between the ages of 3 to 8 months (6 males and 14 females; mean age, 4 months; mean body weight, 2.0 kg [4.4 lb]) by collecting feces from each group or cat for 5 days during a 7-day period. The cats were housed at the University of California-Davis cat colony and had access to water and dry food ad libitum. Cats were weighed during the week of feces collection. Adult cats were housed as follows: 15 singly, 2 in a group of 5, 2 in a group of 3, and 1 group of 4. All kittens were grouped in pairs. For groups, the MDFW was calculated as the total weight of feces divided by the number in the group. Feces were collected from sawdust litter during daily cage cleaning, sealed in plastic bags, and weighed on a balance[b] at 22°C within 48 hours of defecation. A 10-mL (0.33-fluid oz) volume of sawdust weighed 0.6 g (0.02 oz), so the contribution of sawdust to fecal weight was considered negligible. All estimates of fecal loading were based on wet weight. Variance of the MDFW was calculated as for a cluster with equal sample sizes.[30] To estimate MDFW as a percentage of body weight, the MDFW was regressed on cat weight (group mean weight for cats housed together) by use of the generalized estimating equations approach.[c] This methodology handles correlated measures for continuous explanatory variables and is robust against departures from normality.[33] Distributions of the MDFWs for adults and kittens were generated with commercial software.[d]

Fecal loading—The estimate of the annual load of feces deposited outside for each community was calculated by creating a new variable, daily outdoor cat deposition, for households with cats defecating outside; the variable is represented by $(\sum p)f$, where p is the proportion of feces outside for each cat and f is equal to MDFW. Individual MDFWs for the cats > 6 or ≤ 6 months of age in the telephone survey were randomly selected[d] from the respective adult or kitten distributions of experimentally sampled cats. The mean and variance of the daily outdoor fecal cat deposition for each community were estimated by finding the best-fitting statistical distribution for the data.[d] The proportion of households in each community with cats defecating outside was multiplied by the number of households in the community to estimate the number of households generating outdoor fecal cat deposition. Multiplication of the outdoor fecal cat deposition by the number of households generating it (N), the days per year (365), and 10^{-6} to obtain weight in metric tonnes provided an estimate of the annual mass of cat feces deposited into the environment. The variance (Var) of this estimator was calculated by use of the following equation:

$$\text{Var} = N^2 w^2 \text{Var}([\sum p]f)$$

where w is 3.65×10^{-4}. The lower and upper binomial CIs for the proportion of households generating outdoor cat fecal deposition were used to estimate least and greatest values for N. Thus, the lower CI for the smallest value of N represented the lower limit of fecal loading, and the upper CI for the largest value for N represented the upper limit. Dividing equation 2 by the community area (a) equaled the density of fecal loading. This measure was considered important because Cayucos had approximately one fourth the number of households of Los Osos or Morro Bay and is much smaller in area. Calculation of the density of fecal loading provided a rational method for comparisons among the communities. The variance of the density was calculated as follows:

$$\text{Var} = N^2 w^2 \frac{Var([\sum p]f)}{a^2}$$

As for the annual fecal loading, the upper and lower limits for the density were based on the least and greatest values of N (Table 2).

Assessment of attitudes—Respondents were asked to score their agreement with 7 statements about stray pet management, water pollution, and wildlife conservation on a scale of 1 to 5 (1 = strongly disagree, 2 = mostly disagree, 3 = neutral, 4 = mostly agree, and 5 = strongly agree). Mean responses for households with and without cats were compared by use of the Mann-Whitney U test[c] because histograms of the proportion of respondents at each level revealed skewed, non-Gaussian distributions. For the statement about water pollution, mean response was also compared by community by use of the Kruskal-Wallis test[c] because strong public opposition had been voiced in Los Osos over the planned construction of a sewage treatment plant. We hypothesized that certain statements would be correlated, so the Spearman rank correlation coefficient was calculated for the statements A and B, A and C, B and C, and F and G **(Table 3)**.

Results

Telephone contacts—In August and September 2003, 2,141 calls were attempted, 294 householders completed interviews, and 447 householders declined to participate. Of the latter, 83 stated they did not own cats. Sixteen telephone numbers corresponded to vacationers or part-time residents, 87 yielded busy or fax tones, 254 calls were not answered, 873 calls were routed to voicemail or answering machines, and 170 calls could not be completed as dialed or were directed to residents who had moved out of the study area. Two callbacks were attempted to numbers that did not result in an answer initially, numbers corresponding to voicemail or answering machines, and numbers that yielded busy signals on the first attempt.

Cat population estimates—One hundred forty-two of the 294 (48.3%, unadjusted) respondents owned cats. Poststratified estimate of the variance for this proportion was 0.000843, or a 95% CI of 5.7% for the estimated proportion.[30] This represented a nominal increase of the desired 5% limit for the 95% CI used in the sample-size calculation. The CI under poststratification is generally somewhat larger than a nonstratified sample, but the increase was small and suggested the sample size was adequate.[30] Forty-three of the 294 (14.6%) respondents were from Cayucos, 139 (47.9%) from Los Osos, and 112 (38.1%) from Morro Bay. Adjusting for refusals to participate from households without cats, 38% (95% poststratified CI, 33% to 43%) of households owned a mean of 1.9 cats (95% CI, 1.7 to 2.0 cats). The mean number of owned cats for all households and cat density for each community were determined (Table 1). Twenty-four of the 294 (8.2%) respondents indicated that they fed strays, and the mean number of strays fed by a household was 2.6 (95% CI, 1.7 to 3.5). Adjusting for households that did not own cats and declined to participate in the survey, 6.4% of all households were feeding strays. The 63 stray cats reported for the 377 households were equivalent to a mean of 0.167 stray cats per occupied house-

Table 3—Distribution of responses (No. [%]) of cat owners and noncat owners to various statements regarding cat management, water pollution, and wildlife conservation.

Statement	Cat ownership	Strongly agree	Mostly agree	Neutral	Mostly disagree	Strongly disagree	No. responding	*P* value*
A. I support programs to spay or neuter and release stray dogs and cats.	Cat owner	83 (59)	32 (23)	5 (4)	11 (8)	11 (8)	142	0.05
	All other	74 (49)	35 (23)	10 (7)	12 (8)	21 (14)	152	
B. I support trapping and impounding stray dogs and cats.	Cat owner	41 (29)	47 (33)	31 (22)	18 (13)	5 (4)	142	< 0.001
	All other	70 (46)	55 (36)	13 (9)	9 (6)	4 (3)	151	
C. The stray cat population should be left alone.	Cat owner	4 (3)	9 (6)	14 (10)	47 (33)	68 (48)	142	0.08
	All other	4 (3)	9 (6)	8 (5)	35 (23)	96 (63)	152	
D. Microchipping cats helps lost cats reunite with their owners.	Cat owner	52 (37)	42 (30)	33 (23)	5 (4)	9 (6)	141	0.49
	All other	54 (36)	43 (28)	34 (22)	9 (6)	12 (8)	152	
E. I am opposed to cat licensing.	Cat owner	40 (28)	15 (11)	35 (25)	24 (17)	28 (20)	142	< 0.001
	All other	15 (10)	16 (11)	27 (18)	27 (18)	66 (44)	151	
F. Water pollution in my community is a concern.	Cat owner	54 (38)	32 (23)	17 (12)	18 (13)	21 (15)	142	0.047
	All other	67 (44)	38 (25)	17 (11)	22 (15)	8 (5)	152	
G. I am concerned about the survival of threatened species† living near my community.	Cat owner	56 (41)	37 (27)	29 (21)	8 (6)	8 (6)	138‡	0.32
	All other	64 (43)	37 (25)	13 (9)	14 (10)	20 (14)	148	

*For comparison of mean response of owners versus nonowners of cats. †Sea otters and snowy plovers are examples. ‡Four respondents who strongly or mostly were concerned about sea otters but strongly disagreed or were neutral with respect to snowy plovers were omitted.

hold. Multiplying the 12,244 households by 0.167 yielded an estimate of 2,046 feral cats living in the 3 communities. Thus, feral cats represented 22% of the 9,330 cats living in the area.

Cat demographics—Mean age of the 263 owned cats (data not available for 7 cats) was 7.5 years (95% CI, 6.9 to 8.5 years), and there was no difference in the mean age of male and female cats (P = 0.48). Approximately half of the owned cats were male (46%). Ninety-two percent of females were spayed, and 96% of males were neutered. Among the 16 cats that were not spayed or neutered, 12 were ≤ 4 months old, 1 was 6 months old, and 3 were > 18 months. Three queens (2% of the 139 female cats in the survey) had had litters in the past 12 months (mean litter size, 6.5 kittens), 1 with an unknown number of offspring because that female gave birth before being acquired by the household. Fourteen percent of cats were acquired within the previous 12 months, with 26 of 38 (68.4%) coming from within the 3 communities or the San Luis Obispo County animal shelter. Fourteen percent of cats died or disappeared. Because the net inflow equaled the net outflow, the population was likely to be stable.

MDFW—The MDFW for adult cats was 40.2 g/d (1.42 oz/d; 95% CI, 34.0 to 46.4 g/d [1.20 to 1.64 oz/d]) and for kittens was 31.7 g/d (1.12 oz/d; 95% CI, 23.8 to 39.6 g/d [0.84 to 1.40 oz/d]). The MDFW linear regression line for weight of adult cats yielded an intercept of 12.9 and a slope of 0.0045 (g; P = 0.045), whereas a similar analysis of the kitten data yielded an intercept of 22.1 and a nonsignificant slope of 0.0076 (g; P = 0.22).

Quantification of annual fecal loading—Forty percent of owned cats used the litter box exclusively, with 48% defecating outdoors ≤ 25% of the time. Thirty-six percent of owned cats defecated outside all the time, and 44% defecated outdoors > 75% of the time. Only 8% were managed at an intermediate level (26% to 75% of feces deposited outdoors). Estimates of the number of households with cats defecating outdoors were determined on the basis of the upper and lower 95% CIs for the proportion of households whose cats deposited feces outside (Table 2). These values were incorporated into the calculations to estimate the total wet weight of feces from owned cats entering the environment annually in each community (**Table 4**). Based on the 95% CI, a significantly greater mass of cat feces was deposited outdoors annually in Los Osos than Cayucos, but there was no difference in the total fecal load between Los Osos and Morro Bay. Cats in Los Osos accounted for 43.3 of 77.6 (56%) tonnes of the estimated mass of feces deposited outside by owned cats in the area. Mean density of fecal loading in Morro Bay (14 kg/hectare [12 lb/acre]; 95% CI, 6 to 24 kg/hectare [5 to 21 lb/acre]) was less than that of Cayucos (63 kg/hectare [56 lb/acre]) and Los Osos (36 kg/hectare [32 lb/acre), but did not significantly differ from the other 2 communities.

For fecal material collected from litter boxes, 4% of respondents dumped feces on or near their property, 9% discarded the feces in a toilet, and the remainder discarded feces into the garbage, usually in sealed plastic bags. If the estimated 2,046 feral cats in the area had an MDFW of 40.2 g (1.42 oz), they would contribute 30 tonnes (29.5 tons) of outdoor feces each year in addition to the estimated 77.6 tonnes (76.4 tons) of cat feces deposited by free-roaming owned cats. Therefore, owned cats were estimated to be responsible for 72% of outdoor fecal deposition and feral cats for the remainder.

Ninety-four percent of the cats ate dry food (34% exclusively), 54% ate canned food, 19% ate table scraps, and 7% ate raw meat. One-third of cats were kept

Table 4—Estimates of wet weight and density of fecal loading for owned cats defecating outside in 3 communities in California.

Community	Annual wet weight (tonne* [ton†])	95% CI‡ (tonne [ton])	Mean annual density (kg/hectare [lb/acre])§	95% CI‖ kg/hectare (lb/acre)
Cayucos	12.2 (12.0)	3.4–26.5 (3.3–26.1)	63 (56)	18–137 (16–122)
Los Osos	43.3 (42.6)¶	27.3–63.0 (26.9–62.0)	36 (32)	23–52 (21–46)
Morro Bay	22.1 (21.8)	10.2–38.4 (10.0–38.8)	14 (12)	6–24 (5–21)
Total	**77.6 (76.4)**	**40.9–127.9 (40.3–125.9)**	**26 (23)**	**NA**

*Metric tonne = 2,200 lb. †Imperial ton = 2,240 lb. ‡Variance based on $N^2\ w^2\ Var([\sum p]f)$, where N = Number of HHs, $w = 3.65 \times 10^{-4}$, p = proportion of feces defecated outside, and f = MDFW. §By use of area and number of HHs. ‖Variance based on $N^2\ w^2\ a^2\ Var([\sum p]f)$, where a = community area in hectares. ¶Based on the 95% CI, significantly ($P < 0.05$) different from Cayucos.

indoors exclusively, and cats allowed outdoors spent a mean of 12.8 h/d (95% CI, 11.6 to 13.9 hours) outside. There was no significant difference for the proportion of cats housed inside only for households with ≥ 3 cats, compared with households with 1 to 2 cats (39/103 [38%] vs 48/160 [30%], respectively). Owners observed 57% of their cats hunting at the time of the survey or at some time in the past (5 cats with missing data). One hundred fifty-eight (60%) cats had been examined by a veterinarian within the last 12 months (for 5 cats, the owners could not remember whether the cat had been evaluated by a veterinarian). Reasons owned cats were taken to a veterinarian in the greater Morro Bay area included 93 (59%) for vaccinations or health check; 34 (22%) for illness; 9 (6%) for euthanasia; 8 (5%) for neuter, spay, or declaw; 7 (4%) for injury caused by a vehicle accident, encounter with another cat, or wildlife interactions; and 7 (4%) for unknown reasons.

Attitude analysis—For all respondents, 76% strongly or mostly supported TNR programs for stray animals and 73% strongly or mostly supported trapping and impounding stray pets. Most respondents either strongly or mostly disagreed (84%) with no intervention for stray cats, and 55% believed microchipping would enhance return of lost cats to their owners, although almost 23% were neutral with regard to the effectiveness of microchipping. Twenty-nine percent of respondents strongly or mostly agreed that they were opposed to cat licensing. With regard to water pollution and wildlife preservation, 65% and 68%, respectively, of respondents either strongly or mostly agreed that they were concerned about these issues.

Cat owners differed significantly from noncat owners in mean response for the support of TNR programs, support of trapping stray animals ($P < 0.001$), opposition to cat licensing ($P < 0.001$), and concern about water pollution ($P = 0.047$). Differences among cities for mean response to the question about water pollution were not significant ($P = 0.11$).

None of the responses to statements about TNR programs, trapping and impounding stray animals, and intervention for stray cats were significantly correlated at the $\alpha = 0.05$ level and neither were responses to concern about water and wildlife protection.

Discussion

Although the MDFW of feces from cats evaluated at University of California-Davis was only 40.2 g (1.42 oz) for adults and 31.7 g (1.12 oz) for kittens, the annual environmental accumulation of feces from this moderately dense population was substantial. On the basis of the survey of cat owners, distributions of these MDFWs, when applied to domestic cats in the Morro Bay area, led to an estimate of 77.6 tonnes (76.4 tons) of outdoor cat feces deposited each year in the 3 communities, with an additional 30 tonnes (29.5 tons) deposited by feral cats. Cats from Los Osos accounted for 56% of the outdoor fecal deposition by owned cats, which is consistent with the fact that this area also had 54% of the estimated owned cat population. Ninety-four percent of the respondents' cats ate dry food, so the MDFWs generated for the surveyed population on the basis of the MDFW of cats housed at University of California-Davis and fed a dry food diet were likely representative of owned cats, but might not adequately have represented the MDFW of feral cats that subsist on a combination of wildlife and food provided by caregivers. Forty-four percent of owned cats defecated outside > 75% of the time, with 36% using the outdoors exclusively. Our estimates suggested that despite the fact that 40% of owned-cat feces were always collected in litter boxes, local environmental fecal deposition by free-ranging owned and feral cats was substantial. This finding is relevant when considering the potential impact of zoonotic pathogens shed in feline feces, such as *Campylobacter* and *Salmonella* spp; ascarids (eg, *Toxocara cati*); hookworms (*Ancylostoma* spp); and the protozoan parasites *Cryptosporidium* spp, *Giardia* spp, and *T gondii*. The estimate of the annual mass of fecal loading should be considered conservative because the estimate of the cat population size was adjusted downward to account for refusals to participate in the survey. Density of fecal loading was calculated as a mean value across the area of each community. Actual deposition was likely clustered around residences and feral cat feeding stations, resulting in localized higher impacts. Morro Bay area's annual mean precipitation is only 16.9 inches (42.9 cm) and occurs mostly from December to April.[34] Sparse, seasonal rainfall such as this may allow fecal material to concentrate for months in soil and then flush it out during major Pacific storm events.

Two additional aspects of the results raised issues of concern with regard to disposal of cat feces—a small percentage of cat owners who collected feces in litter boxes disposed of them in their yards (4%) or placed them in the toilet (9%). Some cat litter manufacturers

produce litter made from compostable, bio-friendly or recycled materials. Disposal of these materials in yards or compost piles is contraindicated because *T gondii* oocysts may survive composting and can remain viable for more than a year in soil.[35,36] Contaminated soil is an important source of infection for humans, herbivores, rodents, and birds.[37-40] Although conclusive evidence about survival of *T gondii* oocysts after sewage treatment is not yet available, results of 2 studies[41,42] suggest that exposure to sewage effluent or waste is associated with increased risk for *T gondii* infection in humans or other animals. Until more definitive information is available, cat feces should not be flushed down the toilet, even if the litter is flushable. At present, the recommended method for disposing of cat feces is to bag it securely and place it in garbage destined for landfills. Landfills are designed to contain the materials deposited in them and prevent contamination of surface and groundwater.

Despite small size, the cities of Cayucos, Los Osos, and Morro Bay appeared to be representative of many California cat-owning communities, with 38% of households owning cats (adjusted to account for households without cats that did not participate in the survey). Many households in the United States now have cell phones in addition to landline telephone connections. Scarborough Research Inc estimates that 62% of American adults owned a cell phone in 2003, whereas NOP World reports that 73% of 18 year olds had cell phones in 2004.[43,44] For young adults, a cell phone may be their only telephone. Thus, the present study may have underrepresented households with adult heads of household < 25 years old who are less likely to own cats and comprised 4% of the households in the surveyed communities.[1,31] The proportion of households with cats was nonetheless similar to estimates for Yolo[45] and Santa Clara[2] Counties in California and the state estimate of 35%,[1] although it was higher than more urbanized areas such as the city of Los Angeles,[46] Contra Costa/Alameda Counties,[47] and San Diego County.[3] The proportion of cats allowed access to the outdoors (67%) was similar to results of a survey in San Diego (63%); less than that of the Santa Clara study (86%); and greater than that of studies from Tufts University, Mass, and St Joseph County, Ind.[2-3,10,28] Inclement weather along the Eastern seaboard and in the Midwestern portions of the United States, particularly during the winter months, may explain regional differences in access of cats to the outdoors and result in different patterns of outdoor fecal deposition for cats from other areas of the country.

On the basis of the high proportion of owned spayed and neutered cats (92%) in this survey, which was higher than that of studies[2,3] of San Diego (84%) and Santa Clara (86%) cat owners, it seems that veterinarians and cat rescue agencies from the area of the present study have been highly successful in educating their clients about the importance of neutering pet cats to prevent cat overpopulation. Only 3 owned female cats had given birth to kittens in the prior 12 months, suggesting that most kittens were born to unowned cats. Long-term efforts to control cat populations in the Morro Bay area will depend on spaying and neutering feral cats and ongoing public education urging responsible pet ownership. The adjusted proportion of households feeding stray or feral cats (6.4%) was consistent with results of studies conducted in Santa Clara and San Diego Counties, California; Massachusetts; and Alachua County, Florida,[2,3,8] Estimates in the present study did not account for feral cat colonies on public or private lands and may have underestimated the feral cat population. Approximately 10 feral cat feeding stations existed in the area, but accurate estimates of the numbers of cats frequenting them would have entailed repeat observations over several weeks and was beyond the scope of this study. Reducing stray cat populations requires individuals dedicated to cat welfare, support from local veterinarians and cat rescue agencies, and funding to house, feed, and spay or neuter feral cats.[8] All of these elements must be present to ensure that efforts to limit the number of unowned or abandoned cats are successful. In San Luis Obispo County, the Division of Animal Services achieved a milestone in 2004 by finding homes for all adoptable cats and dogs that entered their facility in 2004.[48]

Although the effectiveness of TNR programs for feral cats is debated, support for TNR was high among all respondents, with 76% strongly or mostly in favor of it. Cat owners were more likely than noncat owners to support TNR programs. Statistics compiled on TNR from 2002 to 2003 indicate that 89% of individuals who responded to a survey on a Web site favored TNR programs for feral cat management.[49] A study[50] of employees on the Texas A&M University campus indicated that 55% favored TNR for stray cats. In the present study, most respondents (73%) strongly or mostly agreed with trapping and impounding stray pets, although cat owners were significantly less likely to agree. Cat owners stated that they opposed stray cats being trapped and impounded because the cats would eventually be euthanized. However, the vast majority of respondents (84%) disagreed strongly or moderately with no intervention for the stray cat population. With regard to cat licensing, cat owners were significantly more likely to be opposed to licensing than nonowners. Most cat licensing programs mandate microchipping as a condition of licensing; however, cat owners were no more likely than noncat owners to believe that microchipping is an effective means of locating a lost cat. Sixty-eight percent of all respondents strongly or moderately agreed that they were concerned about the survival of threatened species, and 65% strongly or moderately agreed that they were concerned about water pollution. Greater concern about water pollution was expressed by residents from Los Osos, compared with the other communities, which may have reflected the ongoing controversy over the construction of a sewage treatment plant close to residential housing. Cat owners were not asked whether they would be willing to change how their cats were managed (eg, by confining their cats indoors) to protect wildlife from predation. In the Texas[50] study about attitudes towards feral cats on campus, employees were equally divided over whether it is more important to protect wildlife than feral cats. A much earlier study[45] found that pet owners were more con-

cerned about environmental air pollution, but the present survey found that cat owners were significantly less likely to be concerned about water pollution than were nonowners. This finding suggested that cat owners may be less motivated to protect water quality by changing the way they dispose of cat feces. Further investigation into the attitudes of cat owners toward threatened wildlife, their perceptions about the impact of their cats on water quality, and factors that would motivate them to manage cats differently is needed.

The communities of Cayucos, Los Osos, and Morro Bay comprise only approximately 12,000 households, but owned and feral cats defecating outside contributed an estimated 107.6 tonnes (105.9 tons) of feces to the environment each year in an area of 11.5 miles^2 (29.4 km^2). Forty percent of the estimated annual fecal tonnage deposited outside came from owned cats in Los Osos and 28% from feral cats. Density of fecal loading was highest in Cayucos (63 kg/hectare) and Los Osos (36 kg/hectare). This finding correlated with estimated cat densities that were 2 to 3 times in Los Osos and Cayucos than Morro Bay and with the fact that Cayucos is a smaller, more densely populated community. These findings implied that more emphasis should be placed on encouraging cat owners to keep their cats inside and collect cat feces in litter boxes. Notwithstanding efforts to reduce fecal contamination by pets, the high number of feral cats in the United States suggests that reducing the amount of pet waste in the environment is likely to remain a daunting problem.

a. Minitab Release, version 14, Minitab Inc, State College, Pa.
b. Model I400/I500, Ohaus Corp, Pine Brook, NJ.
c. SAS, version 9.1, SAS Institute Inc, Cary, NC.
d. @RISK for Excel, Palisade Corp, Ithaca, NY.

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