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Welfare of feral cats and potential influencing factors

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ABSTRACT

The aim of the study was to investigate the habitat, characteristics, and the health status of cat colonies under supervision of a trap-neuter-return program, the distance of the cats maintained with respect to their caregivers as a measure of the animals' fear of or confidence in humans, and relationships between these factors with regard to animal welfare. Thirteen managed cat colonies in different urban habitats were visited twice (1st and 2nd visit) by a team of two observers. The assessment of health and other welfare parameters was based on direct observation at the feeding sites, caregiver inquiry, and photo analysis. Potential associations between the parameters were analyzed at an individual level (e.g., injuries related to sex and neuter status) or at group level (e.g., percentage of animals with impaired health). Interobserver reliability was high for all indicators. Most cats were in a good state of health, and most were already neutered. The lower the percentage of clean feeding places, the higher was the percentage of thin animals (1st/2nd visit: $r_s = -0.72/-0.58$, $P = 0.01/0.04$) and the percentage of cats showing apathetic behavior (1st/2nd visit: $r_s = -0.54/-0.58$, $P = 0.06/0.04$). The larger the group size, the higher was the percentage of cats with hair coat deviations (1st/2nd visit: $r_s = -0.73/-0.79$, $P = 0.01/<0.01$). There were also some associations between sex/neuter status and health. Intact males were most likely to be injured, whereas no injuries were observed in females. The results suggest that feeding site characteristics, such as group size and cleanliness of feeding places, as well as sex and neuter status can have an impact on the health status and thus welfare of colony cats. If caregivers offered diluted milk or treats, a higher percentage of cats approached to close proximity (1st/2nd visit: diluted milk: $P = 0.02/0.01$; treats: $P = 0.04/0.04$). The offering of treats likely strengthened the animal-human relationship. Indicators such as the percentage of very thin animals, cats showing altered, apathetic behavior, cats with hair coat deviations, injuries, as well as the percentage of animals approaching within close proximity to their caregiver seem to be useful indicators for the welfare surveillance of cats in managed colonies in terms of validity, because we found associations with environmental factors, the care provided to the cats, or cat colony characteristics.

Introduction

Feral cats (*Felis silvestris catus;* sensu Slater, 2007) exist worldwide and may give rise to a variety of problems, depending on the size, habitat, and health status of the colony. Problems are related to public health and zoonotic diseases, transmission of diseases, and parasites to the owned cat population, public annoyance, predation of birds and reptiles, disruption of ecosystems, as well as the health and overall welfare of the feral cats (Fitzgerald and Turner, 2000; Hiby et al., 2014; Robertson, 2008; Slater, 2007). Although it has drawbacks, trap-neuter-return/release (TNR) is still the established method of population control in Europe, the United States, and many other countries (Hiby et al., 2014; Levy and Crawford, 2004; Natoli et al., 2006; Remfry, 1996; Slater, 2007).

Although the negative effects of overpopulation are most obvious (Gunther et al., 2015; Nutter et al., 2004), other influencing factors may also be crucial for the welfare of free-roaming cats. Basic requirements for feral cats to stay in good health and enjoy a good quality of life are access to appropriate food resources, safe sleeping places and retreats, daily care, as well as medical treatment, if needed (Remfry, 1996). Four main criteria (good feeding, good housing, good health, appropriate behavior), and 12

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subcriteria (e.g., absence of prolonged hunger, thermal comfort, absence of injuries, good human-animal relationship) have been put forward by Botreau et al. (2007) for the overall assessment of welfare in farm animals; nearly all of them can be applied to assess the welfare of domestic cats in managed colonies. A combination of environment-based and animal-based indicators is required to assess the welfare of animals at group level. The indicators should be reliable (repeatable between observers and over time), valid, and feasible (Knierim and Winckler, 2009).

Most measures used for welfare assessment in domestic cats refer to body condition and/or infectious diseases. Consistent increases in body weight, body condition score (BCS), and falciform fat pad were found in feral cats 1 year after neutering (Scott et al., 2002). Gunther et al. (2018) found that neutering of free-roaming cats was associated with a higher proportion of obese cats and decreased morbidity. Very thin animals must be recognized as undernourished, chronically ill, and/or chronically stressed (Baumgartner et al., 2014; Tanaka et al., 2012). Regarding indicators potentially useful for welfare assessment in shelter cats, Arhant et al. (2015) found two health measures, percentage of very thin cats and percentage of cats with poor coat condition (including easily visible wounds) to meet the criteria of test-retest reliability, inter-rater reliability, and also validity. The percentage of very thin cats was negatively related to the proportion of pens with hiding places for all cats, and positively related to the proportion of pens with fewer resting places than cats (Arhant et al., 2015). These findings confirm links between animal- and resource-based parameters, which might also be relevant to feral cats.

Several authors have investigated associations between clinical signs of upper respiratory tract infection (URI), pathogens, and environmental factors. They identified age (<12 months), large groups, confined space, stress, and mixing of cats from different sources as risk factors for URI in pet and shelter cats (Bannasch and Foley, 2005; Binns et al., 2000; Tanaka et al., 2012). In feral cats, there are indications that reduced colony size and improved hygiene at feeding sites might be beneficial for animal health (Kalz et al., 2000).

Another indicator that should be included in welfare assessment is the animal-human relationship, that is, the animals' perception of humans, as it considerably affects their behavior and welfare. It is reflected in the animals' approach and avoidance reactions, including the distance kept to humans (Waiblinger et al., 2006). Petting and speaking in a gentle voice to shelter cats can reduce anxiety and fear responses, lead to better mucosal immunity and reduce the incidence of URI (Gourkow et al., 2014). In addition, a relationship was found between improved physical condition of shelter cats and regular petting by caregivers (Arhant et al., 2015).

The aim of the present study was to assess colony and feeding site characteristics of cat colonies supervised in the context of a TNR program, the health status of the cats, as well as the distance kept to caregivers as a measure of the animal-human relationship. To investigate potential impacts on animal welfare, we examined possible associations of sex/neuter status, feeding site characteristics, and care provided by caregivers with selected health parameters and with the animals' distance toward their caregivers.

Animals, materials, and methods

Feeding sites, animals, and caregivers

The feeding sites were preselected by the animal protection organization FOUR PAWS, Austria, based on the following criteria: feeding of the colony by the same caregiver for at least 6 months, agreement of caregivers to interviews and observations during regular feeding times, and free access to the feeding site. Thirteen of approximately 100 feeding sites involved in the Viennese TNR program met these criteria. This TNR program has been supported by the municipality since 2006, between 2013 and 2017 in cooperation with the animal protection organization FOUR PAWS, Austria. During this time, all healthy cats brought to a veterinary clinic for neutering were also microchipped, vaccinated against FPV, FCV, and FHV-1, dewormed and treated against ectoparasites as necessary. The selected thirteen feeding sites were situated in marginal districts of Vienna. All feeding sites provided access to trees and/or bushes. Ten were situated in or near a garden, six near a forest, and two in a park. Because not all cats showed up regularly during feeding times, all feeding sites were visited twice.

According to caregivers, between one and 30 (mean 11.4 ± SD 9.4, median 9) cats came to the feeding sites. Overall, 148 animals were reported by the caregivers, of which 115 animals were observed. The main caregiver, that is, the person who looked after the cats, fed them at least once a day on weekdays, offered them sleeping places, and in some cases, took care that they were treated medically and also neutered, was partly (in 53.9%) supported by an assisting caregiver. The assisting caregiver kept in touch with the main caregiver and covered for her/him during absence. The main caregivers had been feeding cat colonies for 8.4 ± 12.7 (median 2.8) years on average. 82.6% of them were female.

Data collection

The 13 feeding sites were visited twice within one to 43 (20 ± 14) days by a team of two observers between March and May 2014. Caregivers were contacted by telephone at least 1 week before each visit. Data collection was performed using a combination of direct observation (with the naked eye or with field glasses) and caregiver interviews. In addition, photographs were taken for later verification of cat identity. The observers attended the feeding site 15 minutes before the regular feeding time. Assessment of the cats' health was finished after all animals had finished eating and no further cat showed up for another 15 minutes. After the feeding and the observation of the cats, the interview took place and the observers recorded the characteristics of the feeding site. During the second visit, the procedure of data collection was similar, but interviews were limited to any changes that might have occurred since the first visit.

Data recorded

Information on the number, age, sex, and neuter status of the cats was collected by caregiver interviews. The following animal-based indicators were investigated by means of direct observation of individual cats: sickness behavior, body condition score (BCS), hair coat, injuries, ocular discharge and/or signs of an upper respiratory tract infection (OD/URI), salivation, lameness, lack of body parts, as well as the smallest distance kept to caregivers. Definitions and scores of health parameters are provided in Table 1. In addition to direct observation, the parameters BCS, hair coat, injuries, OD/URI symptoms, and salivation were checked by evaluation of photos taken during the observation. To enable recognition at the second visit, each cat was identified by breed, color, age, sex, neuter status, and unique characteristics such as a broken tail or uncommon eye color. The smallest distance that each cat kept to the respective caregiver was estimated and rated as ≤ 0.5 m (including body contact), > 0.5 − ≤ 3 m or > 3 m.

The following environmental parameters were obtained from caregiver interviews: number and gender of caregivers, number of years involved in care, number of feedings per day (including weekends), possible problems with passers-by, access of dogs without or on leash. The numbers of feeding places (bowls and

Table 1
Description of investigated health parameters

Indicators	Scores and definitions
Sickness behavior (Baumgartner et al., 2014)	0: Normal bearing, no obvious deviation from normal behavior (kittens "agile and attentive", adults "calm and attentive"); animal is interested in environment and food, shows interactions with other cats 1: Altered, apathetic behavior: animal appears weak, faint, sleepy or drowsy; activity, food and/or water intake may be reduced 2: Somnolent or comatose behavior
Nutritional status (BCS) (mod. from Kienzle 2005)	1: Very thin: bone contours clearly visible (ribs, hip bone, lumbar vertebrae), reduced muscle mass, obvious waist behind the ribs 2: Normal nutritional status or slightly underweight or slightly overweight: bone contours not visible, normal muscle mass, round body shape, waist visible behind the ribs 3: Very fat or obese: visible fat depots at thorax, abdomen and spine, waist poorly discernible
Hair coat and injuries (mod. from Arhant et al., 2015)	0: Healthy hair coat: smooth, shining hair coat or physiological winter hair coat, no hairless areas or injuries visible 1: Hair coat deviations: bare, hairless areas or unkempt or scrubby or matted hair coat 2: Visible injuries
Ocular discharge and symptoms of URI (mod. from Ibarrola et al., 2005)—OD/URI	0: No symptoms: no visible ocular or nasal discharge, no discharge remains or incrustation, no sneezing or coughing 1: Light symptoms: visible serous ocular and/or nasal discharge or discharge remains, and/or sneezing or coughing 2: Moderate to severe symptoms: moderate or severe dyspnea, and/or purulent discharge, and/or conglutination, or incrustation
Salivation (mod. from Arhant et al., 2015)	0: No visible salivation, no salivation remains in hair coat near mouth 1: Visible salivation and/or salivation remains in hair coat near mouth
Lameness	0: Normal posture: animal puts equal weight on each of the four legs and shows species-specific locomotion (slight abnormalities included) 1: Moderately lame: gait is clearly impaired, weight may be taken off one or more limbs when standing or moving 2: Severely lame: inability or extreme reluctance to bear weight on one or more limbs may be reluctant to rise (if lying) or move (if standing)
Lack of body parts	0: No body parts missing 1: Lack of body parts such as eye, part of ear, leg, paw or tail

watering places within a radius of three meters) were recorded, as well as the estimated distance between feeding places and the closest retreat. Also, the type of food, freshness and cleanliness of food and water, cleanliness of bowls and watering and feeding places, frost protection, roofing, fencing and accessibility for the caregivers' or unfamiliar dogs were assessed. Because a fence did not necessarily impede dogs from entering the feeding sites, it was recorded separately if unfamiliar dogs could enter them. For artificial sleeping places, the number, type (e.g., feral cat villa), insulation and additional insulation materials (e.g., straw), roofing, impeded accessibility for passers-by and their dogs, risk of injury, and the total area as well as insulated area were recorded. Because the fencing of sleeping and feeding sites was not always identical, it was recorded separately. In addition to the sleeping places, the three retreats (i.e., hiding places that were not designed as sleeping places) in closest proximity to the feeding site were documented according to number, type, accessibility, risk of injury, and fencing, as well as their minimal distance to the feeding and sleeping places. Possible risks or problems such as main streets or dangerous rubbish were recorded if within a radius of 100 m.

Data analysis

The collected data were entered into MS Excel (Microsoft Office, 2010; Redmond, WA, USA). An additional dichotomous variable "health status" (overall good health vs. impaired health, irrespective of the severity of symptoms) was created from the parameters sickness behavior, BCS, hair coat and injuries, OD/URI symptoms, salivation, and lameness. An overall health parameter might be useful for welfare assessment when single health conditions rarely occur. Yet, the possibility of introducing a bias in the results should not be neglected because of multiple testing of the same health indicators.

For data analysis at group level (cat colony, feeding site), percentages of animals with a certain score on an indicator were calculated in relation to the assessable animals at each visit. Some cats were observed but could not be evaluated with respect to every single indicator (due to light conditions, speed of movement, or distance). To avoid a distortion of data, every indicator was related only to those animals that could be evaluated with respect to this particular indicator. During the first visit, for one feeding site, the percentage of animals with impaired health could not be evaluated except for sickness behavior, BCS, and lameness due to bad light conditions, resulting in $N = 12$. Variable sample sizes regarding individual animal data are caused by some missing data, for example, concerning sex or neuter status.

Environmental parameters, such as the number of animals per feeding place, or the total and insulated resting area per animal, were calculated for each feeding site based on the overall number of cats in a particular colony as declared by the caregivers. Owing to the fact that some feeding sites comprised more than one feeding and watering place, the percentages of clean feeding and watering places and the percentages of feeding places with fresh food or water were calculated. Food and water were categorized as fresh if it was provided during the visit.

Data were analyzed and presented at an individual and at group level using the statistical software package IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, N.Y., USA). Data obtained during the first and second visit were analyzed separately. Interobserver reliability of health parameters was assessed based on paired recordings of the same individual cats by two observers (first and last author) using the Kappa coefficient. Agreement between observers was high for all health indicators, and also for the cats' distance kept to caregivers (Kappa coefficients 0.66 to 1.0, $P < 0.001$; Table S1 in supplementary material). The data presented in this article are those that were recorded by the first author.

Some parameters were only analyzed using descriptive statistics but excluded from later analyses because no or only little variation was found between feeding sites (e.g., freshness of the provided food). The relationship between nominal data was investigated using crosstabs and chi-square tests (e.g., differences in the overall health status of individuals related to their sex and neuter status). Standardized residuals were calculated to help identify cells with meaningful differences (standardized residuals $|>1|$). Because most of the data did not fit a normal distribution (according to Shapiro-Wilks tests), nonparametric tests were used. The relationship

Table 2
Overview of age classes and sex/neuter status of observed cats in percentage according to caregivers at the 1st and 2nd visit (N = 13 feeding sites)

Age, sex, neuter status	1st visit					2nd visit				
	Mean	Med	SD	Min	Max	Mean	Med	SD	Min	Max
Age class[a]										
Juvenile	27.5	20.0	32.94	0.0	100	24.9	22.2	29.32	0.0	100
Adult	72.5	80.0	32.94	0.0	100	73.5	77.8	30.67	0.0	100
Kittens	0.0	0.0	0.00	0.0	0.0	1.5	0.0	5.55	0.0	20.0
Sex/neuter status										
Female intact	9.6	0.0	28.02	0.0	100	13.1	0.0	28.32	0.0	100
Female neutered	61.5	60.0	33.72	0.0	100	50.5	36.2	36.20	0.0	100
Male intact	3.5	0.0	7.70	0.0	25.0	6.9	0.0	8.51	0.0	25.0
Male neutered	20.0	25.0	22.18	0.0	66.7	20.7	12.5	21.13	0.0	57.1

[a] Kittens: age ≤ 8 weeks; juvenile: age > 8 weeks - ≤ 12 months; adult: > 12 months.

between environmental parameters (e.g., size of insulated sleeping area, frequency of feeding) and animal-based parameters, such as the percentage of animals with certain health problems, was analyzed by means of Spearman rank correlations. Differences between groups (e.g., health status of colonies at feeding sites with/without artificial sleeping places) were analyzed using Mann-Whitney U tests. Spearman correlation coefficients below 0.4 are referred to as low correlations, 0.4–0.7 as moderate, above 0.7 as high (Martin and Bateson, 1993). Differences and correlations with $P < 0.05$ are referred to as significant, with $0.05 \leq P \leq 0.1$ as a trend. Owing to the explorative nature of this study, no correction was done for multiple testing. Thus, especially trends must be interpreted with caution. Trends are mentioned in the article because the small sample size likely resulted in a low statistical power.

Results

Cat population, health status, and distance to caregiver

Regarding the 115 observed animals, sex and neuter status could be determined of 108 and 99 cats, respectively. Overall, 46.5% of the cats were neutered females, 10.1% intact females, 32.3% neutered males, and 11.1% intact males. Between one and 16 cats were observed at each feeding site (1st visit: 6.2 ± 5.6, median 4; 2nd visit: 7.0 ± 5.1, median 7). Age classes and percentages of sex and neuter status of the observed colonies are depicted in Table 2. Details about the observed cat population and the proportion of observed cats per visit are given in the supplementary material (Tables S2 and S3).

Descriptive statistics for the health parameters and the smallest distance kept to caregivers at colony level are given in Table 3. On average, one-fifth of the cats observed in each colony showed an impaired health status at both visits. On neither of the two visits, somnolent, comatose, obese or severely lame cats or cats with missing body parts other than the tail were observed. Regarding the distance kept to humans, on average, one-quarter of the cats came very close (≤0.5 m) to their caregiver during the first, about 30% during the second visit.

Feeding sites and care

Caregivers fed the cats one to three times per day (mean 2.0 ± SD 0.7) and renewed the drinking water up to three times (1.2 ± 0.9). At two feeding sites drinking water was not offered by the

Table 3
Overview of health status and smallest distance cats kept to caregivers in percentage of animals per feeding site at the 1st and 2nd visit (N = 13 feeding sites, except for *N = 12 feeding sites at the 1st visit)

Indicators	1st visit					2nd visit				
	Mean	Med	SD	Min	Max	Mean	Med	SD	Min	Max
Sickness behavior										
Normal	97.4	100	5.83	80.0	100	98.2	100	6.40	76.9	100
Altered, apathetic	2.6	0.0	5.83	0.0	20.0	1.8	0.0	6.40	0.0	23.1
Nutritional status–body condition score (BCS)										
Normal	98.3	100	4.51	84.6	100	98.8	100	4.27	84.6	100
Very thin	1.7	0.0	4.51	0.0	15.4	1.2	0.0	4.27	0.0	15.4
Hair coat and injuries*										
Healthy hair coat	95.8	100	7.78	80.0	100	92.8	100	10.42	69.2	100
Hair coat deviations	3.1	0.0	5.97	0.0	16.7	4.4	0.0	8.09	0.0	23.1
Visible injuries	1.2	0.0	2.69	0.0	7.1	2.8	0.0	4.73	0.0	14.3
Ocular discharge/upper respiratory tract infection (OD/URI) symptoms*										
None	88.0	100	28.39	0.0	100	81.4	100	29.20	0.0	100
Light	12.0	0.0	28.39	0.0	100	17.1	0.0	29.64	0.0	100
Moderate–severe	0.0	0.0	0.00	0.0	0.0	1.5	0.0	5.55	0.0	20.0
Salivation*										
Visible	2.7	0.0	7.32	0.00	25.0	1.0	0.0	3.47	0.0	12.5
Lameness										
Normal posture	100	100	0.00	100	100	99.5	100	1.73	93.8	100
Moderately lame	0.0	0.0	0.00	0.0	0.0	0.5	0.0	1.73	0.0	6.3
Lack of body parts*										
Missing tail	2.7	0.0	7.36	0.0	25.0	1.6	0.0	4.19	0.0	14.3
Overall health status*										
Impaired health	17.9	5.0	28.63	0.0	100	22.6	14.3	29.05	0.0	100
Smallest distance to caregiver										
≤ 0.5 m	26.2	25.0	26.12	0.0	66.7	29.7	22.2	32.40	0.0	100
> 0.5–≤ 3 m	34.9	33.3	37.50	0.0	100	37.2	33.3	33.16	0.0	100
> 3 m	38.9	30.8	40.42	0.0	100	33.1	14.3	39.06	0.0	100

caregivers, but water was naturally accessible (e.g., from ponds). Both dry and canned food was offered at 84.6% of the feeding sites; at one feeding site either dry or canned food was offered per feeding. 38.5% of the caregivers offered diluted, at some feeding sites lactose-free milk, 30.8% offered cat milk, and 76.9% offered treats. Between one and four (2.3 ± 1.9) feeding places were documented at each feeding site. Up to 24 (6.0 ± 6.4) cats shared one feeding place. The reported number of cats per feeding site and the number of cats per feeding place was correlated ($r_s = 0.79$; $P = 0.001$, N = 13). Each feeding site had between two and 16 (6.5 ± 4.9) food bowls, and between zero and four (1.4 ± 1.0) water bowls. Up to eight (2.0 ± 2.0) cats shared one feeding bowl, and up to 24 (9.6 ± 7.9) cats shared one water bowl. At 76.9% (10) of the feeding sites, all the feeding places and food bowls were clean. At 90.9% (10) of the 11 feeding sites where drinking water was offered, water bowls and water were clean. Seven (53.8%) of the 13 feeding sites were fenced. At eight of the 13 feeding sites, between one and 40 (5.3 ± 11.0) artificial sleeping places were offered with a total area between 0.3 and 10.1 (3.1 ± 3.1) m^2, corresponding to a calculated area between 0.1 and 1.0 (0.4 ± 0.3) m^2 per animal. At seven feeding sites, the sleeping huts or boxes were insulated, with an insulated area per animal between 0.1 and 1.0 (0.3 ± 0.3) m^2. Considering all feeding sites, the insulated area per animal ranged between zero and 1.0 (0.2 ± 0.3) m^2. Twelve different kinds of sleeping places were distinguished, the most common being Styrofoam boxes (56.5%), modified cat carriers (18.8%), and wooden huts partly insulated with Styrofoam (11.6%). The floor of all sleeping places was covered with additional material, most frequently with straw or hay (75.0%), blankets (62.5%), and/or Styrofoam (25.0%). On five of the eight feeding sites with artificial sleeping places, all sleeping places were fenced and not accessible for passers-by (and their dogs).

In addition to the sleeping places, a variety of natural and artificial retreats were permanently accessible to the cats (e.g., hedges, abandoned greenhouses). The smallest distance of a retreat to the nearest feeding site was 0–7 (2.3 ± 2.9) m. The smallest distance of a retreat to the nearest sleeping site was 0–13 (1.9 ± 4.5) m. The caregiver's dog had access to 38.5% (5) of the feeding sites, whereas unfamiliar dogs could access 53.8% (7) of the feeding sites. 76.9% (10) of the feeding sites were located near a main street. At 38.5% (5) of the feeding sites, there was a high risk of injury due to dangerous rubbish such as broken glass, barbed wire, or sharp wire.

Influence of sex and neuter status on the incidence of injuries and health status

A significant association between recorded injuries and sex/neuter status of cats was only found for the second visit (1st/2nd visit: $\chi^2 = 5.20/8.51$, $df = 3$, $P = 0.16/0.04$, N = 67/73). No injured females, regardless whether intact or neutered, were observed during either visit. During the second visit, significantly more intact males showed injuries than could be expected by chance, according

Table 4
Relationships between group size, number of cats per feeding place, and health indicators during the 1st and 2nd visit (N = 13 feeding sites, except for *N = 12 during the 1st visit)

Health indicators	1st visit		2nd visit	
	Group size	Cats/feeding place	Group size	Cats/feeding place
% altered, apathetic behavior				
r_s	**0.74**	**0.74**	0.39	0.47
P	**<0.01**	**<0.01**	0.19	0.11
% very thin				
r_s	*0.51*	**0.63**	0.39	0.47
P	*0.08*	**0.02**	0.19	0.11
% with healthy hair coat*				
r_s	**−0.74**	**−0.77**	**−0.84**	**−0.72**
P	**0.01**	**<0.01**	**<0.01**	**0.01**
% with hair coat deviations*				
r_s	**0.73**	**0.76**	**0.79**	**0.75**
P	**0.01**	**<0.01**	**<0.01**	**<0.01**
% with visible injuries*				
r_s	**0.65**	*0.57*	**0.73**	**0.60**
P	**0.02**	*0.05*	**<0.01**	**0.03**
% no OD/URI symptoms*				
r_s	−0.34	−0.31	−0.23	−0.11
P	0.28	0.33	0.45	0.72
% light OD/URI symptoms*				
r_s	0.34	0.31	0.13	0.05
P	0.28	0.33	0.67	0.86
% moderate-severe OD/URI symptoms*				
r_s	No cats with mod.-severe symptoms		0.23	0.16
P			0.44	0.61
% visible salivation*				
r_s	0.33	0.03	0.04	−0.16
P	0.30	0.92	0.90	0.61
% moderately lame				
r_s	No lame cats observed		0.31	0.39
P			0.30	0.19
% missing tail*				
r_s	0.31	0.23	0.33	0.26
P	0.32	0.47	0.27	0.38
% impaired health*				
r_s	0.38	0.23	0.39	0.22
P	0.23	0.47	0.19	0.48

If data contained only scores for two levels of an indicator with potentially three levels, only the results for one level are given to not present the results in duplicate. r_s = Spearman correlation coefficient. Significant results ($P \leq 0.05$) are given in bold font, trends ($P \leq 0.1$) in italics.

to expected frequencies and standardized residuals (Table S4 in supplementary material).

A significant association between the overall health and sex/neuter status of cats was only found for the second visit (1st/2nd visit: $\chi^2 = 3.28/11.77$, $df = 3$, $P = 0.35/0.01$, N = 67/73). The health of intact females was more likely to be impaired, whereas neutered females were more likely to show good health at the second visit. Also, more tomcats had an impaired health than expected by chance (Table S5 in supplementary material).

Correlations between cat colony, feeding site characteristics, and health status

Correlations between cat colony, feeding site characteristics, and health parameters are depicted in Tables 4 and 5. For instance, during both visits, the percentage of very thin cats was significantly lower at feeding sites with a higher percentage of clean feeding places. The percentage of animals with hair coat deviations was significantly higher at feeding sites with a larger group size and higher number of cats per feeding place. During both visits, there was a trend for a moderate positive correlation between the size of the insulated sleeping area per cat and the percentage of cats with impaired health. With regard to a general effect of the presence or absence of artificial sleeping places, no differences in BCS, OD/URI symptoms, injuries, or overall health status were detected (Mann-Whitney U tests: $Z = -1.36$ to -0.23, $P = 0.18–0.82$, N = 12–13; Table S6 in supplementary material).

Influence of different risks and hazards on the incidence of injuries

Table 6 gives an overview about differences in the percentage of injured animals in relation to risks and hazards. No difference in the percentage of injured cats was found between feeding sites with or without a risk of injury due to dangerous rubbish. During both visits, the percentage of injured animals did not differ significantly between feeding sites with or without fences (impeding access of passers-by and their dogs) around the feeding places. At the second visit, a trend ($P = 0.05$) toward a higher percentage of injured cats was found when sleeping places were accessible for passers-by and their dogs. In case of inaccessible sleeping places, no injured animals were recorded during either visit. If sleeping places were accessible for passers-by and their dogs, on average, 2.4% were injured during the first and 4.9% during the second visit.

The distance between the feeding place or the sleeping place and the nearest retreat was not significantly correlated with the percentage of injured animals (distance feeding place to retreat: 1st/2nd visit: $r_s = 0.26/-0.17$, $P = 0.42/0.52$, N = 12/13; distance sleeping place to retreat: 1st/2nd visit: $r_s = 0.38/0.14$, $P = 0.35/0.75$, both N = 8).

Table 5
Relationship between feeding site characteristics and health parameters during the 1st and 2nd visit (N = 13 feeding sites, except for *N = 12 during the 1st visit)

Health indicators	1st visit			2nd visit		
	Feedings/day	% Clean feeding places	Insulated sleeping area/cat	Feedings/day	% Clean feeding places	Insulated sleeping area/cat
% altered, apathetic behavior						
r_s	0.00	−0.54	0.08	0.00	−0.58	−0.28
P	1.00	*0.06*	0.78	1.00	**0.04**	0.35
% very thin						
r_s	0.00	−0.72	−0.06	0.00	−0.58	−0.28
P	1.00	**0.01**	0.83	1.00	**0.04**	0.35
% with healthy hair coat*						
r_s	−0.09	0.59	−0.02	−0.19	0.30	0.04
P	0.77	*0.05*	0.95	0.53	0.32	0.89
% with hair coat deviations*						
r_s	0.09	−0.57	0.07	0.00	−0.40	0.09
P	0.77	*0.05*	0.84	1.00	0.17	0.77
% with visible injuries*						
r_s	0.07	−0.25	0.04	0.30	−0.28	−0.08
P	0.82	0.43	0.90	0.33	0.36	0.80
% no OD/URI symptoms*						
r_s	−0.13	0.24	−0.36	0.13	0.15	−0.52
P	0.68	0.46	0.24	0.67	0.63	*0.07*
% light OD/URI symptoms*						
r_s	0.13	−0.24	0.36	−0.16	−0.24	0.48
P	0.68	0.46	0.24	0.61	0.43	*0.10*
% moderate-severe OD/URI symptoms*						
r_s	No cats with mod.-severe symptoms			0.00	0.16	0.08
P				1.00	0.61	0.79
% visible salivation*						
r_s	0.07	0.25	0.40	0.00	0.16	0.24
P	0.82	0.42	0.20	1.00	0.61	0.42
% moderately lame						
r_s	No lame cats observed			0.00	−0.42	0.16
P				1.00	0.15	0.60
% missing tail*						
r_s	0.43	−0.13	−0.16	0.34	−0.16	−0.11
P	0.17	0.68	0.62	0.26	0.60	0.71
% impaired health*						
r_s	0.15	−0.13	0.56	−0.03	−0.17	0.55
P	0.64	0.69	*0.06*	0.92	0.57	*0.05*

If data contained only scores for two levels of an indicator with potentially three levels, only the results for one level are given to not present the results in duplicate. r_s = Spearman correlation coefficient. Significant results ($P \leq 0.05$) are given in bold font, trends ($P \leq 0.1$) in italics.

Table 6
Percentages of injured cats related to the presence or absence of risks and hazards during the 1st and 2nd visit (N = 12 feeding sites during the 1st and N = 13 during the 2nd visit, except for "[a]")

Injured cats (%)	1st visit						2nd visit					
	Mean	Med	Min	Max	N	Z/P	Mean	Med	Min	Max	N	Z/P
Risk of injury at the feeding site (e.g., presence of barbed wire, broken glass)												
No	1.0	0.0	0.0	7.1	7	−0.13/0.90	2.8	0.0	0.0	14.3	8	−0.18/0.86
Yes	1.3	0.0	0.0	6.7	5		2.8	0.0	0.0	7.7	5	
All feeding places fenced and thus not accessible for passers-by and their dogs												
No	2.3	0.0	0.0	7.1	6	−1.48/0.14	3.7	3.1	0.0	8.3	6	−1.05/0.30
Yes	0.0	0.0	0.0	0.0	6		2.0	0.0	0.0	14.3	7	
All artificial sleeping places fenced and thus not accessible for passers-by and their dogs[a]												
No	2.4	0.0	0.0	7.1	3	−1.29/0.20	4.9	6.3	0.0	8.3	3	−1.95/*0.05*
Yes	0.0	0.0	0.0	0.0	5		0.0	0.0	0.0	0.0	5	

Z/P: test statistics of Mann-Whitney U test. Trends ($P \leq 0.1$) are given in italics.
[a] Artificial sleeping places only provided on eight feeding sites.

Associations with the distance kept to caregivers

During both visits, there was a trend for a higher percentage of cats approaching ≤ 0.5 m at feeding sites with a higher percentage of very thin animals (≤0.5 m: 1st/2nd visit: $r_s = 0.52/0.48$, $P = 0.07/0.10$, both N = 13; for > 0.5 − ≤ 3 m or > 3 m: $P > 0.1$; Table S7 in supplementary material). No significant correlation was found between the percentage of cats approaching very close (≤0.5 m), within > 0.5 to ≤ 3 m, or > 3 m and OD/URI symptoms or the observed cats' general health status (Table S7 in supplementary material). There were no significant correlations between the percentage of cats approaching very closely (≤0.5 m) and group size of the colony (1st/2nd visit: $r_s = 0.38/0.40$, $P = 0.20/0.18$, both N = 13) or the number of feedings per day (1st/2nd visit: $r_s = 0.33/0.47$, $P = 0.28/0.11$, both N = 13). Also, for the percentage of animals approaching within 3 m or staying outside a perimeter of 3 m, no significant correlations were found with the size of the colony or the frequency of feeding ($r_s = -0.41$ to 0.03, $P = 0.17–0.92$, N = 13).

During both visits, a significantly higher percentage of cats approached very close to the caregiver if offered diluted milk or treats (Table 7). No significant differences in the percentage of animals approaching within 0.5 m were found between feeding sites providing cat milk or not. No significant differences in the percentages of animals approaching > 0.5 − ≤ 3 m or > 3 m were found between colonies where cats were offered diluted milk, treats, or cat milk, or not (Table S8 in supplementary material).

Discussion

In this study, feral cat colonies under supervision of a TNR program were visited to assess cat colony and feeding site characteristics, the health status of the cats, and their distance kept to the caregivers as an indicator for the animal-human relationship. Most observed cats appeared to be in good health, and there are some indications for relationships between environmental factors, including care, and health parameters as well as the distance kept to the caregivers.

The cat colonies differed in several aspects such as colony size, age, and gender distribution of the cats, habitat, and the commitment of the caretakers. Most of the colonies were rather small (less than 10 cats); the largest colony comprised 30 cats. This distribution is comparable with the overall distribution of cat colony sizes in other cities. In Berlin, Kalz et al. (2000) documented 13 feeding sites with up to 12 cats observed per feeding site. Natoli et al. (2006) recorded colony sizes of 4–50 (median 12) cats before and of 2–40 (10) cats after a neutering campaign in the city of Rome. Finkler and Terkel (2010) observed eight feeding sites in the city of Tel Aviv with 13–42 cats each. Artificial sleeping places were documented at eight of the 13 feeding sites, but not all of them were used by the cats, according to the caretakers. Probably the cats attending the feeding sites used another kind of sleeping place, at least in addition to the sleeping places provided; a garden hut, a neighbor's attic, and a badger's set were documented among others. This may explain why no association of the presence or absence of artificial sleeping places with the animals' health was found. The trend for a moderate positive correlation between the insulated sleeping area per cat and the percentage of cats with impaired health might be explained by an association between an increased sleeping area per cat and an increased number of cats sharing the same sleeping place, and hence, an increased infectious pressure. Kalz et al. (2000) found that roaming cats with many social contacts and cats using the same feeding or sleeping places, often had the same infectious diseases or parasites. Another explanation could be that cats with poorer health are more likely to be offered insulated sleeping areas by caregivers.

Apathetic behavior was rarely observed. It is often a general sign of infectious disease and fever (Gregory, 1998; Broom, 2006;

Table 7
Percentages of assessed animals approaching to close proximity (≤0.5 m) for colonies offered or not offered diluted milk, treats, or cat milk, during the 1st and 2nd visit

Provided milk, treats	1st visit						2nd visit					
	Mean	Med	Min	Max	N	Z/P	Mean	Med	Min	Max	N	Z/P
Diluted milk												
No	13.4	0.0	0.0	50.0	8	−2.41/**0.02**	10.2	0.0	0.0	50.0	8	−2.71/**0.01**
Yes	46.7	53.9	25.0	66.7	5		60.8	57.1	37.5	100	5	
Treats												
No	0.0	0.0	0.0	0.0	3	−2.09/**0.04**	0.0	0.0	0.0	0.0	3	−2.09/**0.04**
Yes	34.1	41.7	0.0	66.7	10		38.6	40.2	0.0	100	10	
Cat milk												
No	31.5	33.3	0.0	66.7	9	−1.03/0.30	39.4	42.9	0.0	100	9	−1.43/0.15
Yes	14.3	3.6	0.0	50.0	4		7.8	4.6	0.0	22.2	4	

Z/P: Test statistics of Mann-Whitney U test. Significant results ($P \leq 0.05$) are given in bold font.

Baumgartner et al., 2014), and may also be associated with stress (Stella et al., 2013). During both visits, moderate negative correlations were found between the percentage of cats showing apathetic behavior and the percentage of clean feeding places. Poor hygiene may have increased the risk for diseases.

Nearly all of the observed cats showed an ideal body condition or were slightly overweight or underweight. This might be due to the fact that all caregivers fed their cats regularly, and dry or canned food was permanently available. The percentage of very thin cats was higher at feeding sites with a higher number of cats per feeding place and with a lower percentage of clean feeding places, although the number of very thin cats was generally low. Poor hygiene as well as close contact of cats and increased stress due to competition at feeding places may have increased the risk for the outbreak and transmission of infectious diseases, and hence reduced body weight. In case of an inadequate number of feeding places per feeding site, competition might also hinder thinner and possibly weaker animals from feeding. The percentage of very thin cats appears to be a valid and reliable indicator of animal welfare (Arhant et al., 2015; Baumgartner et al., 2014; Gunther et al., 2018; Tanaka et al., 2012); it also could be reliably assessed in the present study.

On average, less than 20% of the animals of each feeding colony showed ocular discharge and/or signs of upper respiratory disease (OD/URI). Kalz et al. (2000) found a cat flu prevalence of 20% in feral cats in central Berlin. Moderate to severe OD/URI symptoms were only observed in two very young kittens (approximately 3 weeks of age). They were only seen during the second visit. It is well known that kittens are at a higher risk of infectious disease and injury (Gunther et al., 2018; Nutter et al., 2004). Interobserver reliability of OD/URI symptoms was high in the present study, but no significant correlations with feeding site characteristics were found. It has to be considered that the animals were observed but not submitted to clinical examination to verify URI.

Salivation was seldom observed. According to the caregivers, these animals had some kind of dental problem in addition to URI symptoms, and needed veterinary treatment. Dental disease is reported to be the most common disease in owned (Buffington, 2002) and feral cats (Kalz et al., 2000), but it cannot be detected by observation alone. Visible salivation may be associated with conditions such as stomatitis, gingivitis, dental problems, URI, and/or stress. Combined with other health parameters, salivation may be a reliable welfare parameter in cats (Arhant et al., 2015), which is supported by our reliability analysis.

Most animals showed no hair coat deviations. About half of the cats with hair coat deviations showed OD/URI symptoms, some had ectoparasites. We found high correlations between the percentage of animals with hair coat deviations and group size and the number of cats per feeding place. Also, in the shelter context, group size seems to be linked to hair coat condition: A higher number of cats kept in the shelter, a longer duration of stay in the shelter, and a higher proportion of pens with fewer resting areas than cats was related to an increased percentage of cats with poor coat condition (Arhant et al., 2015). Regarding the lack of body parts, only missing parts of the tail were recorded. This was rarely the case. Potential reasons for missing body parts in feral cats might be traffic accidents and injuries from cats, dogs, or wild animals. Similarly, injuries were seldom recorded. Intact males were more likely to be injured. The association between sex/neuter status and injuries was likely only significant during the second visit because two of the injured cats did not appear at the feeding site during the first visit. Owing to their higher tendency to roam and to be aggressive (Finkler et al., 2011; Hart and Barrett, 1973), entire males are at a higher risk of traffic accidents, injuries, bite wounds, and transmission of FIV, FeLV, and FHV infections, as compared with neutered males and females (Finkler et al., 2011; Gunther et al., 2018; Levy and Crawford, 2004; Muriden, 2002; Slater, 2007).

Both male and female intact cats appeared to be at a higher risk and neutered females at lower risk of impaired health. This is in accordance with results from Gunther et al. (2018), suggesting that neutering of male and female free-roaming cats has a favorable effect on their health. With regard to females, reproduction may be associated with an increased risk of infectious disease (e.g., endometritis, mastitis) and nutritional deficiencies due to increased energy demands during gestation and lactation (Arnold et al., 2005; Finkler and Terkel, 2010; Kienzle, 2005). In addition, reproduction can exert a high level of stress on female cats; compared with neutered free-ranging females, intact females had higher cortisol levels and showed more agonistic behavior in the feeding context (Bonnani et al., 2007; Finkler and Terkel, 2010).

Concerning possible relationships between environmental hazards and the frequency of injuries, only the accessibility of sleeping places to passers-by (and their dogs) could be identified as a potential risk factor. Attacks by dogs are a well-known source of injury and death in feral cats, especially kittens (Hiby et al., 2014; Kalz et al., 2000; Nutter et al., 2004; Robertson, 2008), but to our knowledge this is the first study to investigate differences in the proportion of injured feral cats in relation to feeding site characteristics. When attacked by a dog, a healthy alert cat will either flee or defend itself; but a sick, injured, sleeping, or dozing cat may not be able to react accordingly. Our result confirms the recommendation issued by animal protection organizations (e.g., Kortis, 2013) to hide (or fence in) both the feeding and sleeping sites of feral cats. Dog-safe fencing seems to be especially important in public locations where dogs are allowed to run without a leash.

On average, 26% and 30% of the cats per feeding site (during the first and second visit, respectively) approached very close ($\leq$0.5 m) to their caregiver. Details about the socialization of particular individuals are unknown, but probably these animals were socialized to humans by their former owners and/or by their caregivers, if they were abandoned during their sensitive period of socialization. Another possibility is that some feral cats were tamed to some extent as adults by their caregivers' efforts (regular feeding, talking in a gentle voice, stroking if possible). The frequency of feeding was not associated with the approach behavior of the cats. This might be due to the fact that all caregivers fed their cats regularly, and dry or canned food was permanently available. Cats approached closer to their caregivers when offered treats and/or diluted milk in addition to the regular feed, but not when offered cat milk. Probably just certain socialized cats accessed this highly appreciated food, which was offered during a limited time span by the caregivers. Caregivers offering treats and/or diluted milk did so regularly, whereas cat milk, which is more expensive, was offered only occasionally. This might explain why no difference with regard to cat milk was found. We assume that repeated positive interactions (feeding, offering treats, gentle talking, stroking) strengthened the social bond between the caregivers and already socialized cats, and may even have generated some degree of trust in formerly unsocialized individuals (Turner 1995). In future studies caregivers should be also interviewed about the duration of time spent with the cats and about the frequency of positive vocal and tactile interactions so that these factors can be related to the cats' approach and avoidance behavior. Emotional, behavioral, and health benefits of gentle stroking and talking (gentling) have been documented for several species (e.g., dogs: Odendaal and Meintjes, 2003; cats: Arhant et al., 2015, Arhant and Troxler, 2017; Gourkow et al., 2014; horses: McBride et al., 2004; calves: Lürzel et al., 2015). It has been shown in laying hens that regular close contact with humans, including feeding small amounts of grain, talking in a gentle voice, and stroking leads to a decrease in avoidance and an increase in

approach reactions toward humans (Graml et al., 2008). More frequent provision of fresh water and more frequent cleaning of food bowls were related to an increased proportion of cats showing contact behavior in shelters (Arhant and Troxler, 2017). In our study, there was a trend toward a moderate positive correlation between the percentage of very thin cats and the percentage of cats approaching very close to their caregiver. All of the very thin cats were ill and/or rather old. Half of them were in a very poor condition and also approached very close to their caregiver. Socialized animals in a poor condition may seek close contact with their caregivers, because being close to their caregiver enables them to pick up the most appealing food. In addition, socialized sick, old, or disabled cats may perceive their caregiver as a "safe haven", in the sense that his/her presence and the feeding, talking, and possibly stroking generate positive emotions and trust (Kotrschal et al., 2014). Another explanation could be that if the caretakers notice very thin animals, they might want to take extra care and try to lure the animals closer, for example, by providing more attractive food.

The fact that the feeding sites were preselected and part of a TNR program might explain why just a small percentage of cats showed health problems. In addition, there may be a bias in the proportion of healthy cats to (severely) injured cats, because the latter are less likely to approach the feeding site in the presence of humans. Because not all cats showed up regularly at feeding times, the number and identity of observed cats varied between the first and second visit; this explains statistical dissimilarities between the two visits. Some weak and moderate correlations were found that did not reach the level of significance. This might have been caused by the sample size of N = 13 and lower. Despite of partly different cats showing up during the visits and despite of the low sample size, similar relationships and patterns were found during the two visits. Owing to the epidemiological approach, the study provides only indications for relationships and allows no causal inference, for which further experimental studies will be necessary.

Conclusions

Especially the indicators percentage of very thin animals, cats showing altered, apathetic behavior, cats with hair coat deviations, injuries, as well as the percentage of animals approaching within close proximity to their caregiver seem to be useful indicators for the welfare surveillance of cats in managed colonies in terms of validity because we found associations with environmental factors, the care provided to the cats, or cat colony characteristics. The results indicate that it is possible to keep feral cats in satisfactorily good health in a suitable urban environment, but colonies need to be well managed and should not comprise many animals; veterinary treatment may be necessary and should be provided.

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Authors' contributions: All authors were involved in the study design and the development of the assessment protocol. E.G. and V.H. were responsible for data collection. E.G. and I.W. performed the statistical analysis. E.G., V.H., and I.W. interpreted the data. E.G. drafted the article. I.W. and V.H. revised the first versions of the article. All authors have revised the article and they all have read and approved the final version.

Ethical considerations

All procedures applied during the course of this study were discussed and approved by the institutional ethics committee in accordance with guidelines for Good Scientific Practice and with national legislation.

Conflicts of interest

The authors declare no conflict of interest. The animal protection organization FOUR PAWS, Austria, preselected the feeding sites according to defined criteria but played no other role in this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jveb.2018.12.012.

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