Multifactorial drivers of house-soiling behaviour in domestic cats (*Felis catus*): effects of social environment, management, care and health

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Running title: The impact of cat care on house-soiling behaviour in cats

Abstract

House-soiling (characterised by defecation and/or urination outside the litter box) is one of the most common behaviour issues in cats worldwide, leading to drastic results such as increased relinquishment rates, impaired human-animal interactions, and even leading to euthanasia. This study examined the multifactorial determinants of house-soiling by evaluating how cat-owner management and care practices, social environment, behavioural indicators, and household features influence outcomes. Data provided by 421 cat owners were analysed using multivariable logistic regression and six formative indices (Litter Box Management, Social Conflict, Environmental Stress, External Stimuli, Feeding Practices, and Health). The number of cats in the household emerged as a key risk factor, with homes containing more than three cats showing a substantial increase in the odds of house-soiling behaviour. This behaviour was associated with social conflict among cohabiting cats, cumulative environmental stressors, and territorial pressures from neighbouring outdoor cats. Although a composite litter box management index was not predictive, specific deficiencies, such as undersized litter boxes, infrequent cleaning, and urine-only elimination, were strong individual predictors. In our results, feeding practices and a general health index showed fewer associations, whereas specific urinary and gastrointestinal conditions were more strongly associated. Overall, the findings indicate that house-soiling behaviour represents a complex behavioural signal arising from the interaction of social tension, external territorial challenges, and various failures in litter box management. Effective intervention, therefore, requires a multifaceted approach that integrates environmental modifications to reduce social conflict and external stressors with careful optimisation of litter box management quality, including size, number, cleanliness, and location.

Keywords: felines, owner, urine, inappropriate elimination, periuria, undesired behaviour, welfare

Introduction

The domestic cat (*Felis catus*) is one of the most common companion animals worldwide, with its popularity increasing annually and an estimated 174 million cats living in households in the United States alone (American Veterinary Medical Association, 2025; Islam and Towell, 2013; Menor-Campos et al., 2025; Worldostats, 2025). In Brazil, the most recent survey reports more than 30 million cats and commonly having multiple individuals per household (ABINPET, 2024). As a result, interest in this feline behaviour has grown, particularly to improve management when animals exhibit behaviours considered problematic by their owners (Bradshaw, 2018; Delgado et al., 2024; Link and Moody, 2025; Menor-Campos et al., 2024; Worldostats, 2025).

House-soiling, which includes territorial marking (typically urine spraying, but occasionally involving faeces, e.g. middening) and the elimination of faeces and urine in inappropriate places (e.g. defecating and urinating outside the litter box) is one of the most frequently reported problems, followed by aggressiveness towards owners or other animals (Carney et al., 2014; Ramos, 2019; Ramos et al., 2020). Owner-reported studies indicate that these types of behavioural problems are highly prevalent, accounting for 30–40% complaint cases in specific populations from Brazil (Porto Alegre) and Iran (Tehran) (de Albuquerque and Soares, 2019; Tamimi et al., 2015). Soiling is also consistently identified as a major reason for the relinquishment to shelters, representing approximately 25–40% of cat surrenders in some populations. Although their relative importance varies across regions and study contexts, and it may also lead to mistreatment, or even euthanasia of cats (Alberthsen et al., 2016; Albuquerque et al.,

2021; Barrios et al., 2025b; Boonhoh et al., 2025; Buller and Ballantyne, 2020; Fatjó et al., 2006; Jensen et al., 2020; Kisley et al., 2024; Powell et al., 2023).

Terminology has evolved from “inappropriate elimination” to emphasise that the behaviour is not inherently inappropriate; instead, urination or defecation outside the litter box is better viewed as an indicator of mismatches in the feline environment, emotional dysregulation, or physical health, requiring a multifactorial approach to assessment and treatment (Heath, 2019).

The causes of house-soiling are diverse and may include separation anxiety during owner absences, stress, environmental and social changes (e.g. moving house and the arrival of new cats), social conflicts in multi-cat households, and lack of suitable elimination sites that meet the behavioural and environmental needs of the cats (Carney et al., 2014; Schäfer et al., 2021). House-soiling can also arise from medical conditions, such as hyperthyroidism, kidney disease, and arthritis, among others (Atkinson, 2022; Carney et al., 2014). Consequently, the causes of house-soiling in cats should be investigated both clinically and behaviourally, recognising their potential multifactorial nature.

In addition to intrinsic factors associated with health status, extrinsic factors such as litter box management may contribute to house-soiling behaviour. Substrate type and grain size, box design (e.g. covered vs. uncovered), number and placement of boxes, substrate depth, cleaning frequency, and box location within the home are environmental conditions that can trigger these behaviours in domestic cats (Iwabuchi-Inoue et al., 2025; Turner and Bateson, 2017). Previous studies have shown that cats exhibit clear preferences for specific litter characteristics: fine-grained, unscented substrates and sufficient substrate depth (typically ≥5 cm) facilitating appropriate elimination behaviour

(Carney et al., 2014; Grigg et al., 2013; Herron et al., 2021; Horwitz and Mills, 2021; Horwitz, 2019; Villeneuve-Beugnet and Beugnet, 2018).

Similarly, the number and spatial distribution of litter boxes are critical, particularly in multi-cat households, where insufficient availability or clustering of trays may increase competition and avoidance (Ellis et al., 2017; Herron et al., 2021; Neilson, 2004; Tateo et al., 2023). Inadequate cleaning frequency and poor hygiene can further contribute to aversion, leading to elimination outside the litter box (Cooper, 1997; Herron, 2010). In addition, litter box placement in high-traffic, noisy, or otherwise stressful areas, or near feeding and resting sites, may reduce usage and promote house-soiling (Herron et al., 2021). Collectively, these findings suggest that suboptimal litter box husbandry, across multiple dimensions, may act as a key driver of house-soiling behaviour.

Litter box placement can further hinder appropriate use when trays are located in hidden or remote areas, near water and food bowls, or close to noisy appliances, passageways, or high-foot-traffic areas that may licit fear or stress (Herron et al., 2021). Owner adherence to litter box recommendations is variable and often limited by space, aesthetics, and household routines (Barcelos et al., 2018; Cooper, 1997; Herron et al., 2021; Stella and Croney, 2016).

The owner-cat relationship may also influence house-soiling (Hirsch et al., 2022; Menor-Campos et al., 2025). Positive bonds can improve the quality of life and reduce stress, thereby lowering the risk of abnormal behaviours (Franck et al., 2022; Riggio et al., 2022). In contrast, negative relationships or poor management may increase stress and behavioural problems, including house-soiling and aggression (Amat and Manteca, 2019; Franck et al., 2022; Grigg and Kogan, 2019; O'Hanley et al., 2021). However, existing studies do not necessarily present conflicting results, but rather address different, though related, aspects of the owner–cat relationship. While some studies report no direct

association between the strength of the owner–cat bond and house-soiling (Franck et al., 2022; Riggio et al., 2022), others suggest that strong attachment may increase the risk of separation-related problems (Amat and Manteca, 2019; Grigg and Kogan, 2019; O'Hanley et al., 2021), and that owner absence may be associated with house-soiling behaviour (Amat and Manteca, 2019; Franck et al., 2022; Grigg and Kogan, 2019; O'Hanley et al., 2021) Carney et al., 2014; Schäfer et al., 2021).

House-soiling is sometimes associated with behavioural issues in cats, including aggression, excessive grooming, anxiety, and fear-related responses, particularly when expressed at high frequency or intensity or in inappropriate contexts, potentially reflecting underlying stress linked to inadequate environments or poor social relationships (Amat et al., 2016; Mills et al., 2014). Such behaviours may reflect underlying stress linked to inadequate environments or poor social relationships and may be associated with altered or strained social interactions with conspecifics, particularly with unfamiliar or outdoor cats (Elzerman et al., 2020; Finka, 2022; Levine et al., 2005).

Given the evidence linking litter box characteristics and management to elimination behaviour, studies evaluating how cats' husbandry practices and health status influence house-soiling behaviour and whether there are associations between house-soiling and other behavioural issues are therefore essential to identify effective strategies for reducing or eliminating this problem and improving feline welfare. Thus, this study aims to evaluate whether house-soiling behaviour in cats is related to litter tray husbandry and health-related factors, and to assess whether other behavioural issues, such as aggressiveness, separation-related problems, compulsive behaviours, and conflicts between cats (both within the household and involving neighbouring outdoor cats), are associated with house-soiling. We predicted that house-soiling is related to suboptimal litter tray husbandry, with higher frequencies of the behaviour occurring in

households that provide a lower number of trays than cats, small trays, inappropriate substrates, busy tray locations, substrate depth below 5-10 cm, low cleaning frequency, trays concentrated in a single area of the home, and near cats' feeding areas. We also predicted that health-related factors would be associated with increased house-soiling behaviour. We further predict that house-soiling is associated with other behavioural issues, including conflicts between cats, prolonged owner absence, aggressiveness towards humans; anxiety; compulsive behaviours (e.g., excessive grooming, food compulsivity); fears and phobias, difficulties in inter-cat adaptation and competition from cats present in surrounding the environment (i.e. roaming cats outside of the house).

Material and Methods

Ethics Statement

The study was approved by two Research Ethics committees: the Ethics Committee of the Universidade Federal de Ouro Preto (UFOP) via the Plataforma Brasil (approval CAAE 70785223.0.0000.5150) and the Ethics Committee of the University of Salford, UK (reference number 7199). The online questionnaire was designed and administered to ensure participants' complete anonymity/confidentiality. All participants were informed about the study objectives (i.e., an information sheet was provided), enabling them to decide whether to participate, and to withdraw from answering the questionnaire at any time. Informed Consent Forms (ICF) were presented electronically prior to data collection. All results were anonymised.

Data Collection

An online questionnaire (Google Forms™) was administered to pet cat owners across Brazil and the United Kingdom, with a small number of additional responses from

Portugal and Germany (Supplementary Material 1). Although respondents were primarily based in Brazil, litter box management practices assessed in this study are grounded in species-specific behavioural needs and internationally recognised guidelines, and responses were therefore analysed as a single dataset, after statistical confirmation of no significant differences (see Statistical Analyses below) by country of residence (Carney et al., 2014; Ellis et al., 2017, 2013; Neilson, 2004; Rochlitz, 2005). This methodology was chosen for two main reasons: 1) Online questionnaires are a fast and secure method for data collection, enabling the simultaneous recruitment of many respondents (Khan, 2024; Wyatt, 2000), and 2) Research involving cat owners is commonly conducted via online surveys (Buffington, 2002; Machado et al., 2020; Oliveira et al., 2023; Rochlitz, 2005; Sandøe et al., 2018). Data collected included owner sociodemographic details, cat characteristics, information on the owner-cat relationship, health-related information based on owner-reported conditions. and specific details regarding litter tray husbandry. All variables were obtained through owner responses to the online questionnaire. The questionnaire items, including those assessing the owner–cat relationship, were developed based on previously published studies on cat husbandry (Barcelos et al., 2018; Cooper, 1997; de Albuquerque and Soares, 2019; Machado et al., 2020; Tatlock et al., 2017). The survey was available in Portuguese and English.

House-soiling behaviour was operationalised based on owner responses to a structured set of questionnaire items (Part 6; see Supplementary Material S1), which specifically assessed elimination outside the litter box. Respondents reported the type of elimination (urine, faeces, or both), posture during urination (horizontal/squatting vs vertical/spraying), and the location of elimination (e.g. objects, fabrics, walls, doors, windows, near the litter box, or at household boundaries). These variables were used

both to define the presence of house-soiling (inclusion criterion) and to characterise distinct elimination patterns, including those consistent with marking behaviour (e.g. vertical spraying at boundary locations) versus inappropriate toileting.

The Informed Consent Form (ICF) for this study was presented to participants electronically at the beginning of the questionnaire. Instructions for completion were provided on the first screen the respondent viewed. Respondents were required to accept the ICF terms before proceeding to the questionnaire items. All invitations to participate were distributed individually, ensuring that no respondent could view another respondent's details.

The questionnaire was widely disseminated via the most popular social media and communication platforms, including Facebook™, WhatsApp™, Telegram™, Instagram™, and X™. Participation criteria were: Respondents were required to be over 18 years of age, residing in Brazil or the UK (with secondary acceptance of responses from Portugal and Germany) and owning at least one cat exhibiting house-soiling behaviour. For households with multiple cats, responses were based on the cat that had been displaying this behaviour for the longest period, as house-soiling in multi-cat households is not driven by social imitation but is instead associated with shared environmental stressors, olfactory cues, and resource-related competition (Amat et al., 2009; Ellis et al., 2017; Herron and Buffington, 2010; Neilson, 2004). To ensure analytical precision, questionnaires with ambiguous responses or completed by individuals under 18 years of age were discarded and permanently deleted. Ambiguous responses included, for example, contradictory answers across related questions (e.g. reporting both the presence and absence of house-soiling) or the selection of non-informative options (e.g. “I don’t know” or “not applicable”) in key variables required for the analyses.

Statistical analysis

All statistical analyses were conducted in R version 4.5.1 (R Core Team, 2025). Data manipulation and visualisation were performed using the tidyverse package (Wickham et al., 2019). Frequencies and proportions were calculated for categorical variables on owners (age, sex, education, residence type, number of cats) and cats (sex, age, neuter status). Composite infographics were created using ggplot2 (Wickham, 2016) and patchwork (Pedersen, 2025) to illustrate the sample's sociodemographic profile.

To explore associations between litter tray management practices and house-soiling characteristics, an MCA (Multiple Correspondence Analysis) was performed using FactoMineR (Lê et al., 2008). Visualisation and interpretation of the MCA results (scree plot, variable factor map, biplots) were aided by factoextra (Kassambara and Mundt, 2020). Only categories with a representation quality ($\cos^2$) ≥ 0.2 were retained for visual clarity.

Although respondents were primarily based in Brazil, preliminary analyses were conducted to evaluate whether country of residence contributed meaningful variation to the key explanatory variables or outcome measures. Differences in the Litter Box Management Index across countries were assessed using a Kruskal–Wallis test. In addition, country of residence was evaluated as a covariate in logistic regression models predicting house-soiling behaviour, and model fit was compared using likelihood ratio tests. These analyses indicated no statistically significant differences in litter box management adequacy across countries (Kruskal–Wallis test: $\chi^2 = 7.04$, df = 3, p = 0.071), and inclusion of country of residence as a covariate did not improve model fit nor materially alter the association between litter box management adequacy and house-soiling (likelihood ratio test: Δdeviance = 2.95, df = 3, p = 0.399). This approach ensured that analyses were driven by variation in husbandry quality rather than by

geographic grouping. Given the substantial imbalance in sample sizes across countries and the absence of evidence for country-level effects, all subsequent analyses were conducted using the pooled dataset, without distinguishing between nationalities.

Household income was explored as an ordinal variable to assess whether socioeconomic factors influenced litter box management or house-soiling outcomes. Differences in the Litter Box Management Index (as explained later in the text) across income categories were assessed using a Kruskal–Wallis test, and income was subsequently evaluated as a covariate in multivariable logistic regression models predicting spraying behaviour.

Associations between house-soiling and key factors (number of cats, residence type, neuter status, sex, age, breed, and outdoor access), as well as owner-reported health problems (urinary, digestive, or other diseases) and feeding-related variables (who feeds the cat, type of food, food arrangement, frequency/distribution of bowls, and distance between litter box and food/water), were tested. Pearson's Chi-square test was used when all expected frequencies were ≥ 5; otherwise, Fisher's Exact test with Monte Carlo simulation (10,000 replicates) was applied. Effect sizes were calculated using Cramér's V via the *questionr* package (Barnier et al., 2025).

Additional descriptive and exploratory analyses were conducted to characterise owner responses to house-soiling and to explore their association with elimination patterns. Owner-reported reactions upon encountering house-soiling (e.g., no reaction, verbal reprimands or noise-making behaviours, cleaning at the time of the event, or punitive responses) and prior help-seeking behaviour (e.g., behavioural consultation with veterinarians or other professionals) were summarised using absolute and relative frequencies. Associations between these owner response variables and patterns of house-soiling were evaluated using contingency tables. Pearson's Chi-square test was applied when all expected cell counts were ≥ 5; when this assumption was violated,

Fisher's Exact test with Monte Carlo simulation (10,000 replicates) was used to obtain robust p-values. These analyses were considered exploratory and were intended to describe behavioural response patterns and their distribution across house-soiling presentations, as well as to identify potential associations between variables.

Feeding variables were further evaluated using multivariable logistic regression models (GLM) with binomial error distribution, adjusting for core covariates (number of cats, residence type, neutering status, and outdoor access). Similarly, a Health Index summarising the presence of urinary, digestive, and other diseases was analysed using a GLM with the same covariates (described below). Variables with only one observed level were excluded to avoid complete separation. Odds Ratios (OR) with 95% Confidence Intervals (CI) were calculated, and model fit and discriminative ability were assessed using the Hosmer–Lemeshow goodness-of-fit test (ResourceSelection package) and the Area Under the ROC Curve (AUC; pROC package) (Robin et al., 2011), respectively. This approach allowed us to assess the independent contributions of feeding practices, general household and animal-level factors, and health status to the probability of house-soiling, while controlling for potential confounders.

Six formative indices were constructed by summing dichotomised items to measure latent constructs relevant to the hypothesised causal pathways for house-soiling (see Table 1 for a summary of index composition, scoring, and interpretation). Composite indices were constructed using an unweighted additive approach, with equal contribution of all components, to preserve interpretability and avoid imposing *a priori* assumptions about the relative importance of individual variables (Nardo et al., 2005; OECD, 2008; Van Der Borg et al., 2015).

a) Litter Box Management Index: this index assessed adherence to best-practice recommendations for litter tray provision and maintenance (Ellis et al., 2017; Herron et al., 2021). It comprised five binary criteria, as detailed in Table 1.

b) Social Conflict Index: Social conflict was operationalised as the presence of owner-reported aggression directed by cats towards other cats. This index was derived from a multi-response behavioural question ("Does your cat exhibit any of the behavioural issues listed below?"), which contained standardised response categories. Given the questionnaire's structure, aggression toward conspecifics was the only direct and unambiguous indicator of intraspecific social conflict available. All response options explicitly referring to aggression towards other cats, including repeated or intensity-coded selections, were collapsed into a single binary variable (0 = absent, 1 = present). Behavioural items referring to aggression towards people, fear-related responses, or non-social behaviours were excluded. The resulting index represents a formatively defined measure of overt inter-cat social conflict.

c) Environmental Stress Index: The Environmental Stress Index was constructed as a formative, additive measure based on the presence of owner-reported environmental conditions potentially associated with reduced environmental predictability and control. The index comprised nine binary indicators derived from structured questionnaire items (Table 1). Items directly related to inter-cat social conflict or litter-tray management were deliberately excluded. Although some items overlapped conceptually with the External Stimuli Index (e.g., outdoor access and recent adaptation), their inclusion here reflects their role in reducing environmental predictability and perceived control, rather than their territorial significance.

d) External Stimuli Index: The External Stimuli Index was constructed as a formative composite reflecting external (outdoor) territorial pressure, which is considered the

primary ethological trigger for house-soiling in domestic cats (Buffington et al., 2014). The index consisted of the unweighted sum of four binary indicators (0/1), each representing the presence of a distinct external territorial stimulus, as described in Table 1. The index was intentionally restricted to factors external to the household's social structure, excluding enrichment-related variables and litter-box management factors to isolate external territorial challenges. Variables shared with the Environmental Stress Index were reinterpreted here specifically as indicators of territorial challenge, reflecting their ethological relevance to house-soiling rather than general environmental instability.

e) Feeding Practices Index (Food Management Index): The index was created by summing four dichotomised feeding-related items (Table 1). Each item was coded as 0 = non-optimal/absent and 1 = optimal/present, yielding an index ranging from 0 to 4, with higher values indicating more structured and controlled feeding practices.

f) Health Problems Index (Composite Health Index): This index was constructed as a formative measure reflecting the cumulative presence of relevant health issues potentially associated with house-soiling (Table 1). The index was analysed as an ordinal predictor in logistic regression models to evaluate its association with house-soiling.

Table 1: Description of the six formative indices constructed to assess predictors of house-soiling (i.e., defecation and urination) in pet domestic cats (*Felis catus*).

Index Name	Conceptual Focus	Component Variables	Scoring and Interpretation
Litter Box Management Index	Adherence to best-practice recommendations for litter tray provision and maintenance.	1. Number of trays ≥ (number of cats + 1) 2. Cleaning frequency ≥ 6 times/week 3. No use of scented cleaning products 4. Tray size rated as adequate for the cat 5. Substrate type among owner-reported preferred options (e.g., fine clay)	Sum score (0–5). Higher scores indicate closer adherence to recommended practices.
Social Conflict Index	Overt aggression between cohabiting cats indicates intraspecific social tension.	Owner-reported aggression directed towards other cat(s) in the household.	Binary (0/1). 1 = presence of reported inter-cat aggression.

Index Name	Conceptual Focus	Component Variables	Scoring and Interpretation
Environmental Stress Index	Cumulative exposure to conditions associated with reduced environmental predictability and control.	1. Limited environmental enrichment (absence of toys, scratching posts, hiding places, or vertical spaces) 2. Low frequency of owner–cat play (< once daily) 3. Left alone ≥ 6 hours/day 4. Outdoor access 5. Presence of unfamiliar cats in the surroundings 6. Ongoing introduction/adaptation to new cats	Sum score (0–9). Higher scores indicate greater exposure to potential environmental stressors.
External Stimuli Index	Territorial pressure originating from	1. Presence of non-resident cats in the outdoor house	Sum score (0–4). Higher scores indicate greater

Index Name	Conceptual Focus	Component Variables	Scoring and Interpretation
	outside the household.	vicinity 2. Cat has outdoor access 3. Ongoing adaptation to a new environment or recently introduced cats 4. house-soiling occurs at boundary locations (e.g., near doors, windows)	cumulative exposure to outdoor territorial stimuli.
Feeding Practices Index	Structure and control in daily feeding management.	1. Feeding is performed on a regular schedule 2. Provision of optimal food type (mixed or wet food) 3. Food bowls distributed across different locations	Sum score (0–4). Higher scores indicate more structured and controlled feeding practices.

Index Name	Conceptual Focus	Component Variables	Scoring and Interpretation
		4. Feeding provided primarily by the owner	
Health Problems Index	Cumulative presence of owner-reported health issues potentially linked to elimination behaviour.	1. Reported urinary problems (e.g., Urinary Tract Infection, gall bladder or kidney stones) 2. Reported digestive problems (e.g., constipation, diarrhoea) 3. Reported other health problems (any other disease)	Sum score (0–3). Higher scores indicate a greater burden of reported health issues.

The predictive validity of each index was initially assessed using simple binary logistic regression (GLM) models with house-soiling as the outcome. For indices composed of multiple formative items, internal sensitivity was evaluated using a leave-one-out procedure, in which each component was sequentially removed to assess its influence on the index's estimated effect. For indices exhibiting complete separation, this pattern

was interpreted as evidence of a necessary condition rather than a statistical artefact, and internal sensitivity analyses were considered non-informative. To ensure that household or animal-level characteristics did not confound index effects, multicollinearity between each index and core control variables (number of cats, residence type, neuter status, and outdoor access) was assessed using the Variance Inflation Factor (VIF) (car package) (Fox and Weisberg, 2019).

Binary logistic regression models (generalised linear models with binomial error distribution) were fitted to assess the effects of each index and key household- and animal-level covariates on the probability of house-soiling. A base control model (M0) included the number of cats in the household, type of residence, neuter status, and outdoor access. Nested models (M1), in which each index was added separately to the base model, were compared to M0 using likelihood ratio tests and the Akaike Information Criterion (AIC). Model performance was primarily assessed by changes in deviance, AIC, and discriminative ability, quantified using the Area Under the Receiver Operating Characteristic Curve (AUC; pROC package) (Robin et al., 2011). The Hosmer–Lemeshow goodness-of-fit test (ResourceSelection package) was applied as an exploratory measure of calibration, acknowledging its limitations in the presence of data separation and moderate sample sizes. Results are reported as Odds Ratios (OR) with 95% Confidence Intervals (CI). Model summaries were generated using the broom package (Robinson et al., 2025). Instances of complete separation, in which a predictor perfectly discriminated the outcome, were explicitly identified and interpreted as biologically meaningful patterns rather than statistical artefacts, in accordance with established recommendations for logistic regression (Heinze and Schemper, 2002). A directed acyclic graph illustrating the hypothesised causal structure underlying house-

soiling, integrating the tested indices and key modulators, was developed using the DiagrammeR package (Iannone and Roy, 2025).

Results

A total of 421 valid questionnaires were analysed, with most respondents residing in Brazil (n = 394, 93.6%). Smaller samples were obtained from the United Kingdom (n = 24, 5.7%), Portugal (n = 2, 0.5%), and Germany (n = 1, 0.2%).

A summary of the sociodemographic profile of the respondents and characteristics of their cats with house-soiling behaviour is presented in Figure 1. Respondents were predominantly female (n = 386, 91.7%) and fell within the adult age groups of 25–44 years (n = 272, 68.7%) and 45–64 years (n = 79, 19.9%). Most respondents completed further education, with 38.5% (n = 162) holding a complete higher education degree and 26.6% (n = 112) holding a postgraduate certificate. The sample was evenly distributed between houses (n = 211, 50.1%) and flat/apartments (n = 203, 48.2%); only seven respondents lived on farms (1.7%). The number of cats per household varied considerably, with two-cat households being the most common (n = 146, 34.7%), followed by single-cat (n = 75, 17.8%) and three-cat households (n = 54, 12.8%). Among cat owners, the majority (n = 385, 91.4%) reported 1-5 years of ownership experience, whereas only 4.5% (n = 19) reported more than 5 years of experience. In terms of income, half of the sample (n = 213, 50.6%) reported earning between 1 and 5 times the minimum wage in their country of residence, followed by 26.8% earning 6–10 times the minimum wage (n = 113), 12.8% earning more than 10 times the minimum wage (n = 54), and 9.3% earning up to 1 minimum wage (n = 39). A small proportion of respondents (n = 2, 0.5%) did not answer this question. The Litter Box Management Index differed significantly across income categories (Kruskal–Wallis: $\chi^2 = 25.45$, df = 4, $p < 0.001$), indicating a modest income-related gradient in litter box management

practices, with lower median scores observed among respondents reporting the lowest income levels. Nevertheless, income did not contribute independently to the prediction of house-soiling behaviour, as its inclusion as a covariate did not improve model fit nor alter the association between litter box management adequacy and house-soiling behaviour (likelihood ratio test: Δdeviance = 1.93, df = 4, p = 0.748).

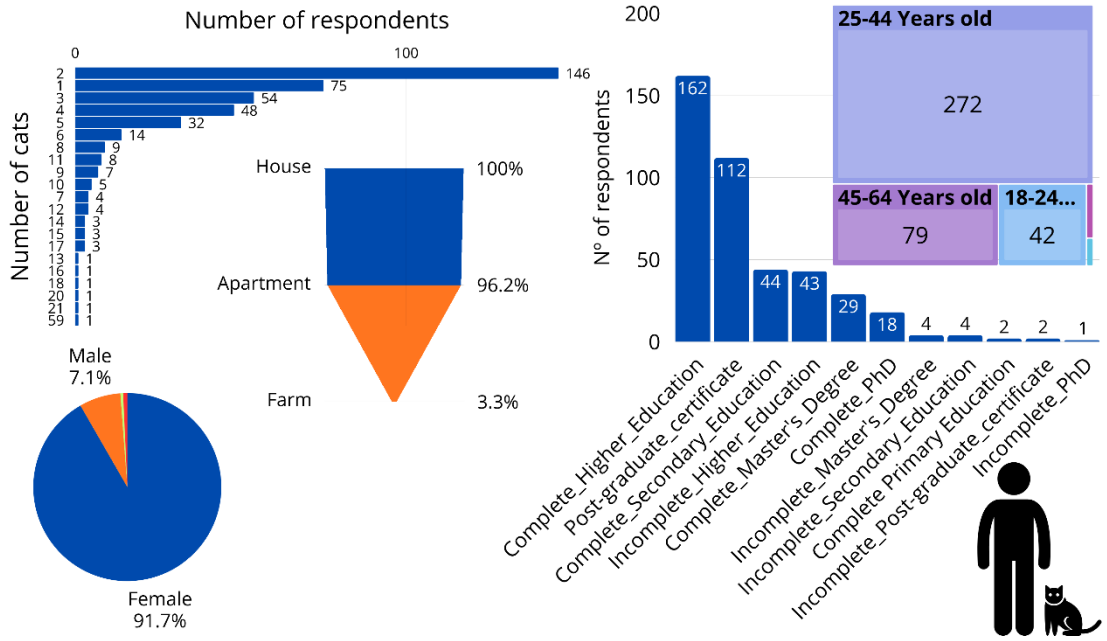


Figure 1: Sociodemographic profile of owners of pet cats exhibiting house-soiling behaviour. The figure summarises respondent age, gender, education level, household type, number of cats per household, ownership experience, and income category.

The sample comprised 421 cats exhibiting house-soiling (Figure 2). Slightly more than half were female (n = 241; 57.5%), with the remainder male (n = 179; 42.5%). Most cats (n = 26262.2%) were classified as 'Young adults' (7 months to 6 years), while 20% (n = 84) were 'Adult mature' (7–10 years). Most were neutered (n = 386; 91.7%). Regarding breed, 90.0% of cats (n = 379) were mixed-breed (non-pedigree), with

Persian (n = 13; 3.1%) and British Shorthair (n = 11; 2.6%) being the most reported pedigree breeds.

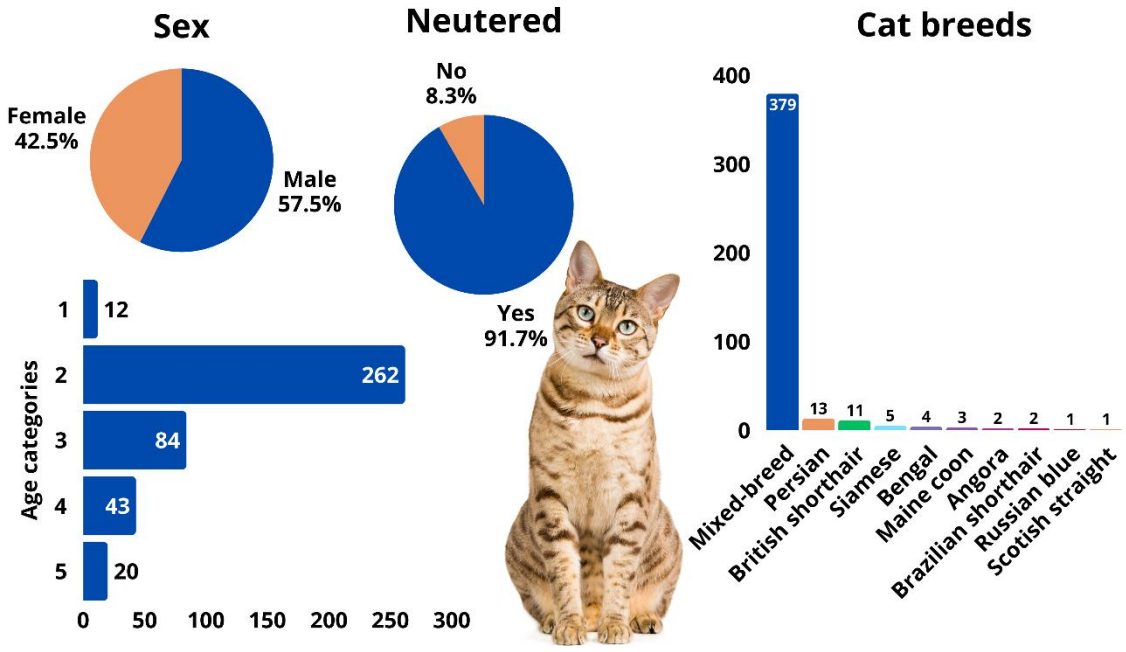


Figure 2: Demographic and biological characteristics of pet cats exhibiting inappropriate elimination behaviour, including sex, age category, neuter status, and breed distribution.

Overall, house-soiling behaviour in the sample was primarily characterised by urine-only elimination (59.6%), followed by combined urine and faeces (23.5%) and faeces-only elimination (16.9%). Regarding elimination posture, horizontal elimination (squatting) predominated (67.2%), whereas vertical elimination (spraying) was reported in 31.8% of cases. Elimination sites were most frequently reported on various objects (20.9%) and fabrics on the floor (20.0%), followed by locations near the litter box (14.0%) and specific vertical or boundary-associated areas (e.g., wall corners and doors), as well as resting areas such as the owner's bed (7.1%). These patterns are consistent with the coexistence of both marking and inappropriate elimination behaviours.

MCA analysis showed relationships between litter box management practices and house-soiling characteristics in domestic cats. The first two dimensions accounted for 6.79% of the total variance (Dimension 1: 3.71%; Dimension 2: 3.09%). Dimension 1 was associated with owners of a few cats and moderate litter box use, contrasting limited-resource households (negative pole) with multi-cat households (positive pole). Dimension 2 captured extreme cases of overcrowding, with substantial contributions from variables such as 15 cats sharing litter boxes (25.33%). Analysis of well-represented categories ($\cos^2 \geq 0.2$) revealed that house-soiling was associated with overcrowding and excessive resource sharing. In contrast, appropriate management, characterised by sufficiently sized and covered boxes in low-traffic areas, was associated with a reduced risk. Three owner profiles were identified: single-cat owners with low risk, multi-cat owners with insufficient resources and elevated risk, and extreme overcrowding cases (e.g., 15+ cats) with the highest likelihood of house-soiling.

Table 2 summarises the associations between demographic and environmental factors and the occurrence of house-soiling. The number of cats in the household was strongly associated with the behaviour, with increasing risk in households containing three or more cats. The type of residence was also relevant, with a higher prevalence in houses compared to flats or apartments. In addition, sex was significantly associated with house-soiling, with males showing a markedly higher prevalence of spraying behaviour than females. In contrast, neuter status, outdoor access, age category, and breed were not significantly associated with house-soiling.

Table 2: Bivariate associations between demographic/environmental characteristics and house-soiling in pet domestic cats. All associations were tested using Pearson's Chi-square test (when all expected frequencies ≥ 5) or Fisher's exact test with a Monte Carlo

460 simulation (10,000 replicates) (when all expected frequencies ≤ 5). Effect sizes are
461 reported as Cramér's V.

Factor	Statistical test	p-value	Effect size
Number of cats in the household	$\chi^2(2) = 15.76$	0.00038	0.19
Type of residence	Fisher's exact test	< 0.001	0.25
Neutering status	$\chi^2(1) = 1.08$	0.30	0.06
Outdoor access	$\chi^2(1) = 0.69$	0.41	0.06
Sex	$\chi^2(1) = 23.16$	< 0.001	0.24
Age category	Fisher's exact test	0.18	0.12
Breed	$\chi^2(1) = 0.07$	0.79	0.03

462

463 Bivariate analyses of litter box management practices (Table 3) revealed significant
464 associations between several specific variables and house-soiling. An insufficient
465 number of litter boxes (number of trays ≥ number of cats + 1), excessive sharing of litter

boxes among cats, urine-only elimination (as opposed to faeces or both), elimination on vertical surfaces, and infrequent litter box cleaning (≥ 6 times/week) were all strongly associated with an increased risk of house-soiling (Figure 3). Conversely, less frequent washing of boxes with water was also associated with a higher risk of house-soiling (Figure 3). Other variables, including litter box type, size, location, distance from food and water, use of deodorising products, and whether owners sought veterinary or behavioural consultation for the problem, were not significantly associated with house-soiling in the bivariate analyses (Figure 3).

Table 3: Bivariate associations between litter box management practices and house-soiling in pet domestic cats. All associations were tested using Pearson's Chi-square test (when all expected frequencies ≥ 5) or Fisher's exact test with a Monte Carlo simulation (10,000 replicates). Effect sizes are reported as Cramér's V.

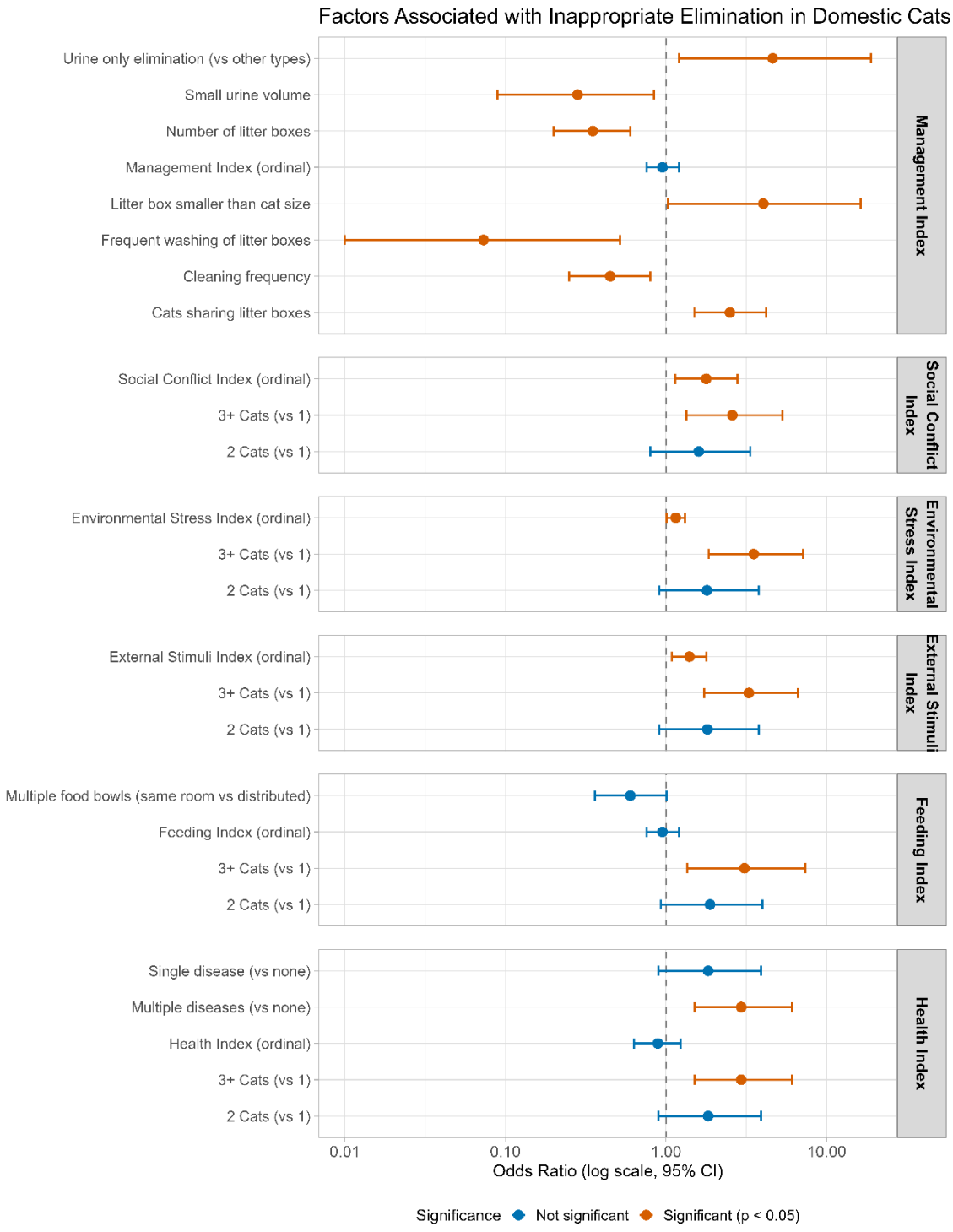
Variable	Statistical test	p-value	Effect size
Number of litter boxes available	Fisher's exact test	< 0.001	0.361
Number of cats sharing litter boxes	Fisher's exact test	< 0.001	0.368
Type of house-soiling	χ^2 = 5.80e-10	< 0.001	0.319
Elimination location (vertical surfaces)	Fisher's exact test	< 0.001	0.492

Variable	Statistical test	p-value	Effect size
Frequency of litter box cleaning	Fisher's exact test	< 0.001	0.243
Frequency of washing boxes with water	Fisher's exact test	0.029	0.172
Litter box location	$\chi^2 = 0.686$	0.686	0.035
Distance from food/water	$\chi^2 = 0.692$	0.692	0.059
Use of deodorising products	$\chi^2 = 0.924$	0.924	0.016
Owners seeking behavioural consultation	Fisher's exact test	0.830	0.064

To evaluate whether these individual factors would demonstrate cumulative effects, we constructed a composite litter box management index operationalised as the cumulative fulfilment of five criteria related to litter box number, cleaning frequency, absence of scented products, box size, and substrate type. Generalised linear modelling indicated that this adequacy index was not significantly associated with house-soiling ($\beta = -0.047 \pm 0.12$ SE, $z = -0.39$, OR = 0.95, 95% CI: 0.76–1.21, $p = 0.698$) (Figure 3). Predictive

performance of the index was modest (AUC = 0.686), and the ordinal representation of the index did not reveal a dose–response relationship ($p > 0.9$), supporting a lack of cumulative effect in this sample. When the number of cats in the household, housing type, neuter status, and level of outdoor access were included as covariates, the adequacy index remained non-significant. In contrast, households with three or more cats retained an increased likelihood of house-soiling compared to single-cat households ($\beta = 1.13 \pm 0.35$ SE, OR = 3.09, 95% CI: 1.59–6.36, $p = 0.001$) (Figure 3). Sensitivity analyses, in which each component criterion was removed from the index, confirmed consistent non-significant effects (all $p > 0.1$). Multicollinearity was negligible (VIFs < 1.06), and model diagnostics indicated adequate fit (Hosmer–Lemeshow test, $p = 0.269$).

Given the discrepancy between the significance of individual variables and the non-significance of the composite index, we conducted a refined multivariable logistic regression focusing on the most predictive individual factors. This analysis identified four specific predictors: elimination of urine only versus other types (OR = 4.62, 95% CI [1.21–18.9], $p = 0.028$), litter boxes smaller than the cat's size versus appropriately sized (OR = 4.04, 95% CI [1.03–16.3], $p = 0.046$), frequent washing of litter boxes (scale level 4 versus baseline, OR = 0.073, 95% CI [0.010–0.519], $p = 0.008$), and small urine volume during house-soiling (scale level 3 versus baseline, OR = 0.281, 95% CI [0.089–0.843], $p = 0.026$). Notably, this refined model demonstrated substantially improved discrimination (Area Under the Curve = 0.931, 95% CI [0.906–0.956]) compared to the composite index model (AUC = 0.686) and showed excellent fit (Hosmer–Lemeshow $\chi^2 = 3.17$, df = 8, $p = 0.975$). The model explained 51.2% of the deviance (Null deviance: 519.09 on 414 df, Residual deviance: 253.28 on 319 df).



509

510 **Figure 3:** Adjusted odds ratios (OR) and 95% confidence intervals (CI) for factors
511 associated with house-soiling in pet domestic cats, derived from multivariable logistic
512 regression models. The figure integrates results from six domains: litter box
513 management index, social conflict index, environmental stress index, external stimuli
514 index, feeding practices index, and health index. All models were adjusted for the

number of cats in the household (reference category: one cat), type of residence, neuter status, and outdoor access. Points represent adjusted ORs, and horizontal bars indicate 95% CIs. The vertical dashed line at OR = 1 denotes the null effect. Estimates to the right of this line indicate increased odds of house-soiling behaviour, whereas estimates to the left indicate a protective effect. Statistically significant associations ($p < 0.05$) are shown in orange, while non-significant associations are shown in blue. Facets are ordered from top to bottom according to the conceptual relevance of each index.

Most owners reported minimal or no active response when encountering elimination outside the litter box (house-soiling), with the majority (70.8%) indicating they did not react to the behaviour. A smaller proportion reported drawing the cat's attention through verbal reprimands or noise-making behaviours (27.8%), whereas active cleaning at the time of the event (0.5%) and punitive responses such as spraying water at the cat (1.0%) were rarely reported. Similarly, most respondents (83.4%) had not sought any form of professional behavioural assistance to address the problem. Among those who did, consultation with a veterinary behavioural specialist was the most frequently reported option (7.6%), followed by behavioural consultants (3.8%), pet sitters (1.7%), trainers (0.5%), or more than one type of professional (3.1%). Exploratory analyses revealed a significant association between owner reaction and patterns of house-soiling (Fisher's Exact Test with Monte Carlo simulation, $p = 0.009$), indicating that the distribution of elimination patterns differed according to owner responses. In contrast, no association was detected between having sought behavioural assistance and house-soiling patterns (Fisher's Exact Test with Monte Carlo simulation, $p = 0.836$).

Building on these exploratory findings, generalised linear modelling was employed to evaluate the association between house-soiling and a constructed social conflict index,

while controlling for household demographic variables. The social conflict index, operationalised as the presence of owner-reported aggression directed towards other cats, was significantly associated with house-soiling in a univariate model ($\beta = 0.79 \pm 0.21$ SE, $z = 3.69$, OR = 2.21, 95% CI: 1.45–3.36, $p < 0.001$), indicating more than a twofold increase in the odds of house-soiling in cats exhibiting conspecific aggression (Figure 3). The index's predictive performance was modest (AUC = 0.60) and exhibited a clear dose–response pattern, with the ordinal representation of the index showing a significant linear trend ($p = 0.0002$). When the number of cats in the household was included as a covariate, the effect of social conflict remained significant, albeit attenuated ($\beta = 0.58 \pm 0.23$ SE, $z = 2.54$, OR = 1.78, 95% CI: 1.14–2.78, $p = 0.011$), demonstrating an independent contribution beyond social density alone. Households with three or more cats showed a markedly increased likelihood of house-soiling compared to single-cat households ($\beta = 0.95 \pm 0.35$ SE, OR = 2.59, 95% CI: 1.34–5.31, $p = 0.006$); whereas households, with two cats did not differ significantly from single-cat households ($p = 0.19$) (Figure 3). Model diagnostics indicated no significant multicollinearity among predictors (VIFs < 1.3). Overall, the model's fit improved with the inclusion of both predictors (AIC = 504.9) relative to the conflict-only model (AIC = 510.1).

The Environmental Stress Index, constructed as an additive measure of nine owner-reported environmental stressors, was positively associated with house-soiling. In the univariable model, the index showed a marginal effect ($\beta = 0.103 \pm 0.063$, $z = 1.64$, $p = 0.102$), corresponding to a modest increase in the odds of house-soiling with each additional stressor. When included in a multivariable model controlling for household cat number, the association became statistically significant ($\beta = 0.140 \pm 0.064$, $z = 2.17$, $p = 0.030$), indicating that each additional environmental stressor increased the odds by

approximately 15% (OR = 1.15, 95% CI: 1.01–1.31) (Figure 3). Model fit improved substantially following inclusion of the index (ΔDeviance = 21.04, Δdf = 2; AIC reduced from 524.98 to 510.61). The number of household cats remained a strong independent predictor: homes with three or more cats showed a more than threefold increase in odds of house-soiling (OR = 3.52, 95% CI: 1.85–7.13, $p < 0.001$), whereas two-cat households showed a non-significant trend toward increased risk (OR = 1.80, 95% CI: 0.91–3.77, $p = 0.102$) (Figure 3). Sensitivity analyses indicated that the observed effect was robust: sequential removal of individual stressors from the index (leave-one-out) did not substantially alter the association, and variance inflation factors (GVIF < 1.03) confirmed minimal multicollinearity. Together, these results suggest that environmental stressors contribute additively and independently to the risk of house-soiling, with the number of household cats as the dominant factor.

The external stimuli index, designed to quantify territorial pressure arising from outside the household, showed a clear and statistically robust association with house-soiling. In the univariable logistic regression model, the index was a significant positive predictor of house-soiling ($\beta = 0.33 \pm 0.12$ SE, $z = 2.68$, $p = 0.007$), with each additional external stimulus increasing the odds of house-soiling by approximately 39% (OR = 1.39) (Figure 3). The inclusion of the index significantly improved model fit relative to the null model (ΔDeviance = 7.21; AIC = 520.44). When controlling for the number of cats (social density) within the household, the effect of the external stimuli index remained significant and of similar magnitude ($\beta = 0.33 \pm 0.13$ SE, $z = 2.65$, $p = 0.008$), indicating an independent contribution to the probability of house-soiling. In this multivariable model, households containing three or more cats showed elevated odds of house-soiling compared with single-cat households ($\beta = 1.19 \pm 0.34$ SE, OR ≈ 3.28, $p <$ 0.001), whereas households with two cats showed a non-significant trend toward

increased risk (OR ≈ 1.81, p = 0.10) (Figure 3). Sensitivity analyses using a leave-one-out approach demonstrated that the predictive effect of the index was generally robust to the removal of individual components: excluding any single component still produced significant associations with house-soiling, whereas removing one component yielded a non-significant but directionally consistent effect. Multicollinearity diagnostics confirmed that the index and covariates were not highly correlated (VIFs < 1.3), supporting the stability and independence of the observed effects. Together, these results indicate that external territorial stimuli constitute a continuous and cumulative risk factor for house-soiling, whereas multi-cat living conditions amplify this effect.

Bivariate analyses indicated that most feeding-related variables were not significantly associated with house-soiling (Figure 3). Specifically, who cares for the cat during trips ($\chi^2 = 4.20$, df = 2, p = 0.122), type of food (Fisher's exact p = 0.714), food arrangement (Fisher's exact p = 0.124), and distance from litter box to food/water ($\chi^2 = 1.35$, df = 3, p = 0.718) showed no significant associations. Only the frequency and distribution of food bowls ($\chi^2 = 11.84$, df = 2, p = 0.0027) demonstrated a significant effect, with multiple bowls distributed across different rooms associated with a reduced likelihood of house-soiling. In the multivariable logistic regression model including all feeding variables and covariates (number of cats, type of residence, neuter status, and outdoor access), the number of cats remained the strongest predictor: households with three or more cats had an increased risk of house-soiling (OR ≈ 3.08, p = 0.0013). Among feeding variables, only the distribution of multiple food bowls in the same room showed a trend towards reducing elimination outside the litter box (OR ≈ 0.60, p = 0.053). Other feeding factors, including who feeds the cat, type of food, food arrangement, and proximity of the litter box, were not significant. When a composite feeding index was created, no additional predictive power was observed. Model diagnostics indicated good

615 fit (Hosmer–Lemeshow p = 0.477) and moderate discrimination (AUC = 0.687).
616 Overall, these results suggest that managing the number of cats and the spatial
617 distribution of food bowls is more relevant for preventing house-soiling than the type or
618 timing of feeding.

619 Bivariate analyses indicated that most owner-reported individual health variables were
620 not significantly associated with house-soiling (Figure 3). Owner-reported cat health
621 problems were dominated by urinary conditions (42.7%), followed by gastrointestinal
622 conditions (12.6%), allergies (8.4%), respiratory problems (7.0%), and orthopaedic
623 conditions (6.3%), with other conditions reported at lower percentages. Specifically, the
624 frequency of veterinary consultations (Fisher's exact p = 0.084), whether the cat
625 received attention related to elimination problems ($\chi^2 = 0.788$, df = 2, p = 0.674),
626 individual diseases (Fisher's exact p = 0.365), and body condition score (Fisher's exact
627 p = 0.444) showed no significant associations. In contrast, owner-reported health
628 problems categorised as affecting urine (e.g., urinary tract infections, urinary stones,
629 incontinence), faeces (e.g., constipation, diarrhoea, gastrointestinal disorders), or both
630 were strongly associated with house-soiling ($\chi^2 = 42.54$, df = 2, $p < 0.001$). In the
631 multivariable logistic regression model that included the composite health index (sum of
632 urinary, digestive, and other reported diseases) and covariates (number of cats, type of
633 residence, neuter status, and outdoor access), the health index was not a significant
634 predictor (OR ≈ 0.89, p = 0.465). The number of cats remained the strongest predictor:
635 households with three or more cats had an increased risk of house-soiling (OR ≈ 2.94, p
636 = 0.002). Other covariates, including residence type, neuter status, and outdoor access,
637 were not significant. Model diagnostics indicated good fit (Hosmer–Lemeshow p =
638 0.832) and moderate discrimination (AUC = 0.685). Overall, these results suggest that
639 specific urinary or digestive health problems are strongly associated with house-soiling.

In contrast, the cumulative health index does not significantly increase risk, and household composition (number of cats) is a key modulator.

Discussion

This study provides a comprehensive evaluation of factors associated with house-soiling in pet domestic cats, integrating litter box husbandry practices, behavioural indices, environmental stressors, external stimuli, feeding practices, health-related variables, and household social structure. The results partially supported most hypotheses and revealed distinct contributions of social, environmental, and husbandry-related factors to house-soiling. Indices reflecting social conflict, environmental stress, and external stimuli were positively associated with house-soiling, and these associations remained consistent after adjustment for the number of cats in households. In contrast, the general composite litter box husbandry and health indices were not significantly associated with the outcome, although several individual husbandry practices and specific health-related variables showed strong, independent effects. The number of cats in the household emerged as a significant structural risk factor but did not fully account for the influence of behavioural indices, indicating that house-soiling is shaped not only by social density but also by the quality of social interactions and environmental stability and quality. Likewise, sex was significantly associated with house-soiling, with males exhibiting a higher prevalence than females. This pattern may reflect a combination of behavioural, physiological, and anatomical factors, rather than behavioural tendencies alone, particularly given known sex-related differences in the feline urinary tract. Overall, these findings support the interpretation of house-soiling as a multifactorial issue arising from interactions among social stress, environmental challenges, and specific management failures, rather than as a uniform response to a single underlying cause, aligningwith previous frameworks that conceptualise feline elimination problems as

665 stress-related or maladaptive behaviours rather than isolated disorders (Buffington,
666 2011; Carney et al., 2014).

667 The consistent and strong effect of the number of cats in the household highlights multi-
668 cat living conditions as a key structural context in which house-soiling emerges. This
669 effect was driven by differences between single-cat households and those with three or
670 more cats, rather than by extreme cases with very high cat numbers. Urinary problems
671 are significantly more prevalent in multi-cat (21.5%) than in single-cat homes (11.9%),
672 being associated with a threefold increase in the overall risk of periuria, a sixfold
673 increase in marking and twofold increase in latrine behaviour when more than one cat is
674 present (Barcelos et al., 2018; Lawson et al, 2020). Stressors inherent to multi-cat
675 environments, such as competition for resources, social conflict, and reduced or shared
676 access to litter trays, are well-established contributors to elimination problems (Lawson
677 et al., 2020). The interplay between social stress and house-soiling is further
678 underscored by observations that, in multi-cat households, stress can trigger both
679 territorial marking and soiling, often as a coping response to territorial inter-cat tensions
680 (Learn and Horwitz, 2024). The persistence of behavioural index effects after
681 adjustment for cat number indicates that house-soiling cannot be attributed social
682 density alone but appears to be mediated by how the social and environmental
683 challenges are managed. Previous studies have shown that social stress in multi-cat
684 households is often associated with unequal access to essential environmental resources
685 and with inadequate introduction of new cats to resident individuals (Elzerman et al.,
686 2020; Rodan et al., 2024). Within this context, house-soiling may arise from suboptimal
687 environmental conditions, reflecting social tension among cats and serve as an
688 important behavioural indicator of social stress.

The quality and quantity of key resources are crucial to a healthy feline environment (Ellis et al., 2013) and litter box husbandry represents a critical, modifiable variable. This study showed that several individual litter box variables were strongly associated with house-soiling, highlighting the importance of specific aspects of environmental management for elimination behaviour. Litter box size relative to cat´s size, hygiene-related practices, sharing of litter boxes, cleaning frequency, and elimination characteristics all showed robust, independent effects in multivariable models. These findings are consistent with evidence that cats are sensitive to litter box conditions and may avoid sites perceived as aversive, insecure, or competitively constrained (Ellis et al., 2017; Guy et al., 2014; Neilson, 2004). Inadequate box size, poor hygiene, and forced sharing (fewer litter boxes for the cats) have repeatedly been identified as triggers of litter box aversion and elimination outside the box (Carney et al., 2014; Ellis et al., 2017; Neilson, 2003; Tateo et al., 2023). However, when these heterogeneous practices were aggregated into a single equally weighted composite management index, the overall association with house-soiling was attenuated and non-significant. This likely reflects limitations of an unweighted composite index in capturing heterogeneous behavioural effects, particularly when practices differ in relevance or effect magnitude, and is consistent with methodological considerations that such indices may obscure variables with disproportionate influence on the outcome (Van Der Borg et al., 2015). In addition, individual variation in litter box preferences may further contribute to this pattern, as cats differ in their responses to box characteristics such as size, substrate, and whether boxes are covered or uncovered. Indeed, Grigg et al. (2012) found that while most cats showed no preference when boxes were large, clean, and filled with clumping litter, a substantial minority (30%) did exhibit a clear preference, half for covered and half for uncovered boxes. This supports

714 the recommendation of presenting individual cats with multiple litter box types,
715 including both covered and uncovered options. Social dynamics may also play a role, as
716 inter-cat tension can lead to subtle forms of resource competition or blocking behaviour,
717 whereby access to litter boxes is restricted or perceived as unsafe, increasing the
718 importance of box number and spatial distribution (Elzerman et al., 2020; Rodan et al.,
719 2024). Together, these factors may explain why aggregating multiple husbandry
720 variables into a single index reduces explanatory power, as it fails to account for both
721 individual-level preferences and context-dependent social constraints. These results,
722 therefore, suggest that house-soiling may be more sensitive to specific husbandry
723 shortcomings, as well as their interaction with social and individual factors, than to
724 overall husbandry quality as captured by a global index.

725 Two principal dimensions of risk were identified within multi-cat contexts: deficiencies
726 in physical resource management and disturbances in the social environment. Regarding
727 the latter, the social conflict index was one of the strongest predictors of house-soiling,
728 even after controlling for cat number. Rather than reflecting social density alone, this
729 underscores the impact of poor-quality social interactions on feline welfare. Although
730 households with more cats were consistently associated with increased odds of house-
731 soiling (Tomlinson, 2016), the persistence of the social conflict effect indicates that
732 aggressive or antagonistic interactions constitute an independent stressor. These
733 findings are consistent with research showing that social tension, resource competition,
734 and unpredictability in social relationships compromise welfare and increases stress-
735 related behaviours, including house-soiling (Barcelos et al., 2018; Heath, 2019). The
736 observed dose–response relationship for the ordinal social conflict index further
737 suggests that the likelihood of house-soiling increases progressively with higher social
738 stress, supporting a cumulative rather than a threshold-based effect.

739 Beyond acute social conflict, the chronic accumulation of more subtle environmental
740 stressors was also influential. The environmental stress index showed a modest but
741 statistically significant association with house-soiling after adjustment for social
742 structure. Although the effect size was relatively small, the consistent direction of the
743 association suggests that everyday environmental stressors meaningfully shape
744 elimination behaviour. In domestic cats, repeated exposure to low intensity but
745 persistent challenges, such as changes in routine, household noise, limited
746 environmental control, or frequent disturbances, can promote chronic stress rather than
747 isolated acute responses (Amat et al., 2016; Croney et al., 2023; Stella et al., 2013).
748 Chronic stress reduces behavioural flexibility, increase vigilance, and impair coping
749 capacity, thereby, lowering the threshold for stress-related behavioural problems,
750 including house-soiling (Buffington, 2002; Carlstead et al., 1993; Ellis et al., 2013).
751 This cumulative effect is consistent with the concept of allostatic load, whereby the
752 long-term burden of multiple stressors, contributes to maladaptive behavioural
753 outcomes (Koolhaas et al., 2011; McEwen and Wingfield, 2003). The stability of this
754 association across sensitivity analyses further supports the interpretation that
755 environmental instability contributes independently to elimination problems, in line
756 with previous reports linking environmental unpredictability and inadequate
757 environmental management, to chronic stress, anxiety-related behaviours, and house-
758 soiling in cats (Amat et al., 2016; Barrios et al., 2025a; Stella et al., 2013; Vitale Shreve
759 and Udell, 2017).

760 External territorial pressures constituted another distinct risk factor. The external stimuli
761 index showed a clear, consistent association with house-soiling, supporting the
762 hypothesis that territorial pressure from outside the household plays an important role in
763 elimination behaviour. Visual or olfactory exposure to unfamiliar cats or other animals

near windows, doors, balconies, or shared boundaries may elicit anxiety-driven marking or avoidance behaviours rooted in territorial defence (Amat et al., 2016; Carney et al., 2014; Pryor et al., 2001; Ramos and Mills, 2009). This mechanism is particularly relevant in urban and suburban environments, where proximity between households increases repeated exposure to non-resident animals (Heath and Wilson, 2014). The association remained significant after adjustment for the cat number, indicating that external territorial challenges operate independently of internal social density or compatibility.

The relevance of external stimuli may be amplified in strictly indoors cats, which perceive visual or olfactory cues from potential intruders but lack opportunities for direct investigation, retreat, or spatial avoidance. Under such conditions, urine marking may serve as a compensatory communicative response, allowing cats to signal territorial presence or cope with perceived intrusion and insecurity. This interpretation is supported by the present finding that urine spraying, the elimination behaviour most closely linked to territorial signaling, was the form of house-soiling most frequently reported as problematic by owners. Previous studies similarly link urine spraying to territorial insecurity, anxiety, and environmental stress, particularly in response to perceived external threats rather than litter box-related factors alone (Amat et al., 2016; Horwitz, 2019; Mills et al., 2011; Pryor et al., 2001). Together, these results suggest that house-soiling, especially urine spraying, may reflect an adaptive communicative response to external territorial pressure that becomes maladaptive within the domestic environment.

In contrast to the strong influences of the physical and social environments, other resource-related practices, such as feeding arrangements, showed a more limited direct association. At the composite index level, feeding practices had limited predictive value,

and neither the presence of multiple food bowls nor greater spatial separation between feeding and litter box areas was independently associated with house-soiling in multivariable models. However, households with three or more cats consistently showed increased odds of house-soiling across feeding-related models. This pattern suggests that feeding practices alone may not directly influence elimination behaviour but instead interact with broader social dynamics in multi-cat households. In high-density environments, competition, social tension, or restricted access to preferred feeding locations may elevate overall stress, even when food is adequately available (Ellis et al., 2013; Levine et al., 2005). Thus, feeding-related variables may exert their effects through social relationships and resource competition rather than through feeding configuration *per se*, reinforcing the central role of social structure and inter-cat relationships in shaping house-soiling.

The role of health status paralleled the pattern observed in resource management: specific conditions were relevant, but composite indices were not. While particular health conditions, especially urinary and gastrointestinal disorders, were associated with house-soiling, the composite health index itself was not, consistent with clinical knowledge that elimination problems are more closely related to discrete medical disorders than to overall or owner-reported health status (Buffington, 2011; Carney et al., 2014; Landsberg et al., 2024; Learn and Horwitz, 2024). Cats with multiple concurrent diseases showed markedly higher odds of house-soiling, suggesting that multimorbidity increases behavioural vulnerability. Conditions such as feline lower urinary tract disease, chronic gastrointestinal disturbances, dermatological problems associated with pruritus, and pain-related disorders have been linked to changes in elimination behaviour through discomfort, altered mobility, increased urgency, or negative associations with the litter box (Heath, 2019; Learn and Horwitz, 2024;

814 Neilson, 2004). Multiple concurrent conditions may therefore compound these effects,
815 increasing both physiological stress and behavioural disruption. The association
816 between health-related variables and house-soiling was more pronounced in households
817 with three or more cats, suggesting an interaction among social density, chronic stress,
818 and disease burden. Chronic stress has been implicated in both the exacerbation of
819 existing medical conditions and the emergence of stress-related disorders, particularly
820 those affecting the urinary and gastrointestinal systems (Amat et al., 2016; Buffington,
821 2011; Ellis et al., 2013). These findings emphasise the need for comprehensive, targeted
822 clinical assessments when addressing house-soiling. Veterinarians should prioritise
823 investigation of specific urinary and gastrointestinal disorders, particularly in
824 multimorbidity cases, and actively evaluate chronic stressors related to social density,
825 environmental instability, and husbandry practices. An integrated diagnostic combining
826 medical interventions, (e.g., diagnosis and treatment of underlying medical conditions),
827 environmental and psychological strategies (e.g., optimisation of housing conditions
828 and reduction of chronic stressors), and behavioural interventions (e.g., implementation
829 of behaviour modification and training techniques) is likely to provide more accurate
830 diagnoses and more effective long-term management of house-soiling in cats.

831 Despite the findings, some limitations should be acknowledged. Although responses
832 were obtained from four countries, the sample was overwhelmingly composed of
833 Brazilian respondents and cultural norms, housing characteristics, and management
834 practices may differ elsewhere; therefore, findings should be interpreted primarily
835 within this context, and cross-cultural studies are needed to assess the generalisability.
836 All data were based on owner-reported information, including health status and
837 behaviour, which, while widely used in behavioural research and informative, are
838 subject to recall bias, misinterpretation, and variability in observational accuracy (Ines

et al., 2021; Powell et al., 2023). Future studies incorporating veterinary records, professional behavioural assessments, or direct observations would strengthen causal inference. Additionally, the inclusion criteria required that all cats had already exhibited house-soiling, so analyses address factors associated with variation in risk and severity among affected cats rather than predictors of prevalence in the general cat population. In multi-cat households, responses were based on the individual that had been displaying house-soiling behaviour for the longest period. While this approach was intended to standardise reporting and focus on established cases, it may have influenced owner responses by prioritising more persistent or salient cases, potentially underrepresenting variability in behavioural expression among other cats in the household. Finally, although owner reactions to house-soiling were associated with different elimination patterns, the cross-sectional design does not allow causal conclusions about whether these responses contribute to the onset, persistence, or escalation of the behaviour. Longitudinal or intervention studies are needed to evaluate the directionality and effectiveness of management strategies.

Future research should also explore interactions among indices, investigate temporal relationships between stressors and elimination behaviour, and assess the effectiveness of targeted interventions based on the specific risk factors identified here. Such approaches would further refine prevention and management strategies for house-soiling and enhance feline welfare in multi-cat and complex household environments.

Conclusion

The findings presented here indicate that elimination issues in domestic cats are associated with multiple factors related to environmental management and to both physical and social health. These include the number of cats per household, inadequate litter box quantity and cleanliness, external territorial pressures, internal social tension,

and the presence of urinary or gastrointestinal diseases. The presence of males was also significantly associated with an increased prevalence of house-soiling. This pattern may reflect a combination of behavioural, physiological, and anatomical factors, rather than behavioural tendencies alone, particularly given known sex-related differences in the feline urinary tract.

Comprehensive behavioural and physical assessments are therefore essential to identify the underlying causes of house-soiling in cats. In addition, educational strategies focused on appropriate feline environmental management should be implemented as both preventive and therapeutic measures. Future research based on longitudinal interventions and observational data will be important for refining guidance for cat owners and professionals dealing with feline elimination problems.

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Declarations

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Consent to participate: All participants provided informed consent before completing the online questionnaire. The informed consent form was presented electronically at the beginning of the survey, and only respondents who agreed to the terms could proceed with the questionnaire.

Consent for publication: All authors agreed to the paper's content and its publication in the journal.

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