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Management practices of dog and cat owners in France (pet traveling, animal contact rates and medical monitoring): Impacts on the introduction and the spread of directly transmitted infectious pet diseases

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Abstract

A number of owner practices among the pet dog and cat population can influence the dynamics of directly transmitted infectious dog and cat diseases, including zoonotic ones. To better depict these management practices, which include pet traveling, contact rates with other companion animals and their medical monitoring (which herein includes prevention aspects), we surveyed 2,122 dog- and/or cat-owning French households through an anonymous online questionnaire. Trips with dogs within the European Union (EU) were frequent, while cats travelled less frequently within the EU and both cats and dogs travelled less frequently outside the EU. Recurrent illegal trips with dogs and cats (non-compliant with regulatory measures) were observed in a context of non-systematic pet border controls. We found that a large proportion of dogs are taken for walks in metropolitan France, with frequent intraspecific contacts (1.4 contacts/day on average), but only a minority (1.4%) of dogs were allowed to roam freely. On the other hand, 59.7% of cat owners allowed their cats to roam freely. We classified pet owners according to different profiles, some of which may be considered 'at risk' for directly transmitted infectious pet diseases. Indeed, one dog owner profile and one cat owner profile depict 'spreaders' of pet diseases (high connectivity with other individuals, little medical monitoring but no traveling) and another dog owner profile describes a potential 'introducer' and 'spreader' of pet diseases (foreign travel, high connectivity with other individuals, and intermediate medical monitoring). While these 'at risk' profiles represent only a minority of French pet owners, they should be better characterized to reinforce targeted prevention designed to minimize the risk of (re)introduction and (re)emergence of directly transmitted infectious dog and cat diseases in France, especially when considering zoonoses with a significant potential impact, such as rabies.

KEYWORDS

cat, dog, infectious disease, rabies, spread, travel

1 | INTRODUCTION

France is characterized by a large pet cat and dog population, estimated at 6,950,000 dogs and 13,500,000 cats, with 43% of French households owning at least one dog or one cat (FEDIAF, 2018; FACCO, 2018). The way owners manage their pets greatly influences their movements over short and long distances (including abroad), and the frequency and number of intra- and interspecies contacts, which are drivers of the emergence and circulation of directly transmitted infectious diseases in these populations (Stull et al., 2019). 'Directly transmitted diseases' refers here to diseases that are transmitted by contacts (including bites) or close proximity (airborne or droplets transmission). Dog and cat translocations could be of great importance to the incursion of such infectious agents, which can be zoonotic and thus have public health implications (e.g. rabies or canine influenza), or non-zoonotic (e.g. canine distemper, parvovirus infections of dogs and cats or upper respiratory tract infections of cats) (Anderson et al., 2019; Aziz et al., 2018; Polak, 2019; Stull et al., 2019). In France, non-commercial importations of dogs and cats can be traced through microchip registration (I-CAD, 2017) but the extent of travel by dogs and cats accompanying their owners for temporary translocations is largely unknown, despite its probable frequency. Both importations and temporary translocations appear to contribute to the risk of introducing disease, as highlighted by the example of rabies, which is a notifiable disease in France. Indeed, there have been ten importations of rabies-infected dogs or cats into France and two cases of rabies following the return of French dogs travelling abroad (French Ministry of Agriculture & Food, 2020; Hamelin et al., 2016; Ribadeau-Dumas et al., 2016) since the acquisition of France's rabies-free status in 2001. For many years, rabies-free countries or territories used to impose a strict quarantine period for the pets coming from infected countries (Great Britain Advisory Group on Quarantine, 1998). This quarantine confinement proved to be efficient in combating the introduction of rabies, but was unsatisfactory in terms of animal health (raising physical and behavioural issues) and also for the owners (for psychological and cost reasons) (Rochlitz et al., 1998). The risk of introducing infectious diseases can also be effectively reduced by implementing appropriate mitigation measures such as vaccination when available, blood testing, or through the use of preventive anti-infective treatments (Anderson et al., 2019), which are now tending to replace or alleviate quarantine. However, such preventive measures are not always correctly applied, as illustrated by the cases of imported rabies mentioned above, none of which complied with European regulations regarding rabies vaccination and/or serological testing (Ribadeau-Dumas et al., 2016).

When a directly transmitted infectious disease is present in a population, whether it is new to that population or pre-existing, its subsequent spread is largely influenced by contacts between individuals. In pet dog populations, these contacts may occur during dog walks or when dogs are roaming freely. Data about contact patterns among free-roaming dog populations in various contexts are becoming more numerous thanks to the use of geolocation systems such as Global Positioning System (GPS) devices (Brookes et al., 2018; Dürr & Ward, 2014; Hudson et al., 2019; Laager et al., 2018; Meek, 1999; Molloy et al., 2017; Sparkes et al., 2014). Dog-walking habits have been extensively studied in a public health perspective related to physical activity (Christian et al., 2013; Westgarth et al., 2014). Data on contacts between dogs or between dogs and other species during dog walks remain sparse, but those that are available highlight frequent interactions and possibly high connectivity between individuals in pet dog populations (Hidano et al., 2012; Kwan et al., 2019; Westgarth et al., 2009). In cat populations, contacts between individuals are difficult to trace since they mainly occur during unsupervised roaming. The opportunity given to cats to have unsupervised access to the outdoors, allowing them to roam freely, varies greatly between regions of the world, from 12.5% in the USA to 95% in New Zealand (Freiwald et al., 2014; Tan et al., 2020). Moreover, contact rates between cats when they are roaming freely depend on social organization, which is linked to resource availability (Turner & Bateson, 2014). Very few studies assess such contact data and are based only on use of animal-borne cameras (Bruce et al., 2019; Loyd et al., 2013). In France, both data on outdoor access and opportunities given to dogs and cats to roam freely, and data about dog walks are either scarce or unavailable. To prevent or limit circulation of directly transmitted contagious diseases in the dog and cat populations, and prevent the introduction of diseases, mitigation measures—and the extent to which they are implemented—are of importance since they can decrease the receptivity of an animal population to specific diseases and thus the prevalence level of these same diseases.

In France and other high development index countries with large pet populations, data about traveling with dogs and cats, and management practices affecting the potential spread of directly transmitted contagious diseases, are sparse and do not allow a general overview. This study was designed to (a) describe foreign travel practices of French dog and cat owners with their animals, and pet management practices in relation to inter- and intraspecific contact rates; (b) identify different dog and cat owner profiles regarding practices associated with the potential for introducing and spreading directly transmitted infectious diseases in France; and (c) evaluate the possible impacts of these owner profiles on both animal and public health.

2 | MATERIALS AND METHODS

2.1 | Target population and sample size

This study targeted households currently owning at least one dog or cat and represented by a respondent in mainland France over 18 years of age. The sample size for pet owners was evaluated based on the lowest proportion expected to respond, which was assumed to be the proportion of dog and cat owners having travelled outside the European Union (EU) with their animal(s) in the previous five years. The value of this parameter was hypothesized to be around

1% for dogs and cats with a minimum desired precision of ± 1% with a confidence level of 95%, leading to a minimum sample size of 381 dog owners and 381 cat owners (Sergeant, 2020).

2.2 | Questionnaire design and distribution

An online questionnaire using the Sphinx™ platform was designed to collect data about dog and cat owners' trips with their animals along with their pet management practices, which affect the potential for spreading directly transmitted contagious diseases. We collected data on travel practices included the frequency of foreign trips (in the EU and outside the EU) and country of destination for non-EU countries; time spent abroad; the possibility of contacts with other dogs or cats; and compliance with regulatory travel requirements (rabies vaccination, serology tests). We will refer to these items as 'travel practices' in the rest of this text. We also investigated the occurrence and nature of animal border controls.

Dog-walking habits (frequency, duration) and the occurrence of contacts between dogs and between dogs and cats were also recorded. Information was also collected on the opportunity given to dogs to roam freely (with no supervision). For cats, the possibility of outdoor access with or without contacts with other animals was recorded. When the cat had outdoor access without supervision, the owners were asked to specify how many hours a day the cat spent outside. Intra-household contacts between pets were also investigated. We will refer to these items as 'management practices in relation to the potential for spreading contagious dog and/or cat diseases' in the rest of this text. This expression and the previous one ('travel practices') will also be referred to together as 'management practices associated with contagious dog and/or cat disease dynamics'.

In the case of households owning more than one dog or more than one cat, the data collected related to the animal that had been owned for the longest time and aimed to depict management at household level, assuming that management would be very similar for all other dogs or cats in the same household.

Various demographic variables were collected per household, focusing on pets: number of dogs and cats, length of ownership, frequency of veterinary consultations, identification (microchip or tattoo) of the animal, rabies vaccination and serology testing following rabies vaccination. Demographic variables concerning the respondent and his/her household were also collected: number of persons in the household, socio-professional category, age, gender and zip code.

For further details, please refer to the English version of the online questionnaire (Supplementary Material 1). All the questions were mandatory and presented as multiple-choice questions or had to be answered with quantitative values. The questionnaire was pretested by a set of 24 people representing households belonging to the target population. Minor adjustments were made to improve the comprehension of some questions. The questionnaire was then broadcast on several social media (Facebook™, Twitter™, LinkedIn™, and Instagram™) between October 2019 and April 2020. All the questionnaires remained anonymous (no personal data allowed identification of the respondent), and all the participants were fully informed of the purpose of the study and agreed to the terms of the survey before starting.

2.3 | Data post-stratification

Since the questionnaire was based on voluntary responses following publication on social media, it is prone to sampling bias. To take into account this bias and improve the efficiency of estimators, the collected data were post-stratified (Lumley, 2011; Valliant, 1993), that is, the observations were weighted according to the known totals of each relevant stratum of the target population using the Horvitz-Thompson estimator (Horvitz & Thompson, 1952). The auxiliary variables used to define the strata for post-stratification were the number of people composing the household and the socio-professional category of the household (INSEE, 2016, 2018, presented in Appendix 1), and we assumed that the structure of the dog and cat owner population was similar to the structure of the whole population. These auxiliary variables were chosen since it was hypothesized that pet travel and management habits are defined at the household level.

2.4 | Descriptive analyses

Descriptive analyses were performed on post-stratified data (raw counts are provided in Appendix 2 for transparency, but are not directly interpretable given the post-stratification performed). Results are presented in the form of proportions or means with their 95% confidence intervals (95%CI). Variance estimates take into account the post-stratification process and follow the procedure described by Valliant (1993). Aberrant data were treated as missing values (e.g. quantitative values exceeding a maximum, selection of incompatible answers in multiple-choice questions) for descriptive statistics and were imputed only for classification methods (refer below for more details). Some variables were recoded: to evaluate the mean annual time spent abroad by one traveling animal, the number of trips over the five last years was multiplied by the mean duration of one stay and then divided by five for animals owned for at least five years, or by the number of years of ownership for animals owned for less than five years. The variable 'illegal travel' was defined based on the country of destination and the animal's status for rabies vaccination and serologic testing according to European regulations (Regulation (EU) No 576/2013). To calculate the mean daily time taken for dog walking, the daily number of walks was multiplied by the mean time of one walk. Since the number of walks was recorded as a qualitative value, the categories referring to an interval were converted into a mean from the interval's minimum and maximum limits (e.g. if the category '3 or 4 times a week' was selected, a quantitative value of 3.5/7 was used for the daily number of walks). The time spent outside the cats was defined based on the quantitative value provided by owners of indoor–outdoor cats; 0 was attributed for cats not allowed to go outside (or with outside access not allowing contacts with other animals), and 24 hr was indicated for cats living only outside. To evaluate the density of the area where the pet owners and their animals were living, we used the zip code and national statistics about French cities. High-density municipalities were defined as cities with at least 50,000 inhabitants living in one area with a density ≥1,500 inhabitants/km^2. Intermediate density municipalities were defined as cities where at least 50% of their inhabitants were living in areas with a density ≥300 inhabitants/km^2 (and not corresponding to the previous definition). Low or very low density municipalities were defined as cities where less than 50% of their inhabitants were living in areas with a density ≥300 inhabitants/km^2 (INSEE, 2019).

Descriptive analyses were performed using R version 3.6.1 (R Core Team, 2019) and the 'survey' package (Lumley, 2011).

2.4.1 | Scoring systems

To provide a global view of the potential that owners' management of their pets could have on the introduction and spread of directly transmitted infectious dog and cat diseases, three scores were defined: (a) An 'Introduction' score reflecting the potential for introducing a contagious disease into France considering owners' travel habits with their dogs or cats, (b) a 'Spread' score reflecting the potential for contagious dog and cat diseases to spread considering owners' management practices with inter- and intraspecific contacts in France and (c) a 'Health awareness' score reflecting medical monitoring of pets by their owners (which includes prevention aspects). This third score was added because health management practices can help mitigate the introduction and spread of diseases. Table 1 presents how the scores for dogs and cats were developed. All of them lay between 0 and 1, and different weights were given to the variables in the 'Introduction' and 'Spread' scores to take into account the hypothesized impact of these variables on the potential for introduction or spread of infectious diseases. Travels outside the EU, for example, were hypothesized to have more impact on the potential for introducing an infectious disease given the fact that dogs and cats could be exposed to pathogens not found in the EU. Similarly, the fact that dogs and cats could roam freely was hypothesized to have more impact on the potential for spreading contagious diseases compared to supervised contacts among dogs, or intra-household dog and cat contacts (very limited spread).

2.4.2 | Classification method to identify dog and cat owner profiles, and method used to compare these profiles

To study the similarity between respondents and the relationships between variables, a multiple correspondence analysis (MCA) was performed separately for dogs and cats since the two species are not managed in the same way. By representing them in a lower Euclidian multidimensional space, MCA enabled us to better synthesize information, including ten active variables for dogs (frequency of veterinary visits, length of ownership, number of dogs owned, identification, rabies vaccination, ownership of cats, trips in and outside the EU, possibility of pets roaming freely, dog walking), nine active variables for cats (frequency of veterinary visits, length of ownership, number of cats owned, identification, rabies vaccination, ownership of dogs, trips in and outside the EU, possibility of unsupervised access to the outside) and five illustrative variables for both dogs and cats (density of the area of residence, number of people in the household, sex, age, socio-professional category of the respondent). In order to identify owner clusters or profiles, a hierarchical cluster analysis (HCA) was also performed using Ward's method followed by a *k*-mean consolidation (Husson et al., 2017). A v-test (test values) was performed for each variable to assess its over- or under-representation in each cluster, as described by Husson et al. (2017). Before the MCA, missing values were imputed to avoid representing categories not containing any values. The imputation followed the regularized iterative MCA algorithm as described by Josse et al. (2012), so that the imputed values did not influence classification. Once the owner profiles had been identified through the HCA, their post-stratified scores were compared using Wilcoxon-Mann-Whitney tests with a Bonferroni correction for multiple tests (Bland & Altman, 1995). The level of significance (α) was set to 5%. MCA and HCA were performed using the 'factomineR' and 'missMDA' R packages (Josse & Husson, 2016; Lê et al., 2008).

3 | RESULTS

3.1 | Participation and characteristics of the participating households

2,384 questionnaires were completed and 2,122 met the inclusion criteria (34 concerned residents outside mainland France, 14 concerned respondents that did not meet age criteria and 214 did not own a dog or cat, and were thus excluded for these analyses). Among the 2,122 households owning a pet, and before the post-stratification process, 48.0% were composed of three or more people, 33.2% of two people and 18.8% of only one person. The density of the area of residence was high for 47.2% of the households, intermediate for 31.9%, and low or very low for 20.9%. Ninety percent of household representatives were women. As for the socio-professional category, 22.5% belonged to high socio-professional categories (artisans, retailers or company directors, corporate executives or intellectual professions), 34.5% to low socio-professional categories (workers, employees, farmers), 4.1% were retired, 11.6% were unemployed or studying and the other 27.1% worked in veterinary professions (veterinarians

TABLE 1 Construction of the 'Introduction', 'Spread', and 'Health awareness' scores for dog and cat owners

Score (*target species*)	Variable	Coding	Weight
'Introduction' score *For dogs and cats*	Annual time spent abroad in the EU	Continuous variable: No travel = 0/≥1 trip(s): 1st quartile = 0.25; 2nd quartile = 0.5; 3rd quartile = 0.75; 4th quartile = 1	1/7
	Annual time spent abroad outside the EU	Continuous variable: No travel = 0/≥1 trip(s): 1st quartile = 0.25; 2nd quartile = 0.5; 3rd quartile = 0.75; 4th quartile = 1	2/7
	Possibility of contacts with dogs and cats abroad in the EU	Dichotomous variables: Yes = 1/No = 0	1/7
	Possibility of contacts with dogs and cats abroad outside the EU	Dichotomous variables: Yes = 1/No = 0	2/7
	Illegal trip(s) (not compliant with rabies vaccination and serology requirements)	Dichotomous variables: No = 0/Yes = 1	1/7
'Spread' score *For dogs*	Mean number of daily contacts with other dogs (intra-species contacts)	Continuous variable: No contacts = 0/≥1 contact(s): 1st quartile = 0.25; 2nd quartile = 0.5; 3rd quartile = 0.75; 4th quartile = 1	1/4.5
	Mean number of daily contacts with cats (inter-species contacts)	Continuous variable: No contacts = 0/≥1 contact(s): 1st quartile = 0.25; 2nd quartile = 0.5; 3rd quartile = 0.75; 4th quartile = 1	1/4.5
	Possibility of contacts with other dogs and cats in the household (if present)	Dichotomous variables: Yes = 1/No = 0	0.5/4.5
	Possibility of roaming freely (unsupervised)	Dichotomous variables: Yes = 1/No = 0	2/4.5
'Spread' score *For cats*	Possibility of contacts with other dogs and cats in the household (if present)	Dichotomous variables: Yes = 1/No = 0	0.5/1.5
	Mean time spent each day outside (unsupervised)	Continuous variable: No unsupervised access to the outside = 0/ Unsupervised access to the outside: 1st quartile = 0.25; 2nd quartile = 0.5; 3rd quartile = 0.75; 4th quartile = 1	1/1.5
'Health awareness' score *For dogs and cats*	Identification (microchip or tattoo)	Dichotomous variables: Yes = 1/No = 0	1/3
	Frequency of veterinary visits	Ordinal variable: Less than once every two years = 0/Once every two years = 0.5/Once a year or more = 1	1/3
	Rabies vaccination (with regular boosters)	Dichotomous variables: Yes = 1/No = 0	1/3

and other animal heath related professions). Nonetheless, for the following results, observations were weighted (during the post-stratification process) to match the French population structure provided in Appendix 1.

3.2 | General characteristics of pet dogs and cats

Among dog and cat owners, and after the post-stratification process, 29.5% $[26.1; 33.0]_{95\%CI}$ only owned dogs, 40.2% $[36.3; 44.2]_{95\%CI}$ only owned cats and 30.4% $[26.9; 34.1]_{95\%CI}$ owned both dogs and cats. Descriptive statistics for the general characteristics of pet dogs and cats are presented in Table 2 (non-weighted statistics and raw counts are also available in Appendix 2).

These results highlighted more frequent veterinary visits and a higher proportion of identified and rabies-vaccinated animals for dogs than cats.

3.3 | Travel practices of dog and cat owners with their pets

In addition to general characteristics, we extracted from our questionnaire information on travel practices (Table 3). These

TABLE 2 General characteristics of pet dogs and cats

	Dog owners (*N* = 1,343) [95%CI]	Cat owners (*N* = 1,463) [95%CI]
Mean number of animals owned[a]	1.5 [1.4; 1.7]	2.0 [1.7; 2.2]
Mean length of ownership (years)	6.0 [5.6; 6.5]	7.4 [7.0; 7.9]
Frequency of veterinary visits (%)		
<1 time a year	4.1 [2.7; 6.3]	20.5 [17,4; 24.0]
1–2 times a year	56.7 [51.7; 61.5]	66.2 [61.7; 70.3]
>2 times a year	39.2 [34.4; 44.2]	13.3 [10.4; 16.9]
Identification (%)		
Microchip	91.4 [88.2;93.7]	59.0 [54.2; 63.7]
Tattoo	7.5 [5.2; 10,6]	22.0 [18.0; 26.5]
Doesn't know	0.2 [0.1; 0.5]	6,3 [4.8; 8.4]
No	0.9 [0.5; 1.7]	12.7 [9.7; 16.3]
Rabies vaccination (with regular boosters) (%)		
Yes	73.7 [69.0; 77,8]	34.4 [30.0; 39.1]
Doesn't know	3.7 [2.3; 5.8]	6.9 [5.2; 9.0]
No	22.7 [18.7; 27.1]	58.7 [54.0; 63.3]

Note: '*N*' provided for each column corresponds to the number of observations available to produce the statistics.

Abbreviation: CI, confidence interval.

[a]One observation was excluded (aberrant value) for this variable among cat owners.

TABLE 3 Travel habits of dog and cat owners with their pets

	Dog owners [95%CI]	Cat owners [95%CI]
Proportion of owners having travelled at least once with their pets in the past five years (%) (*N* = 1,340 for dogs, *N* = 1,460 for cats)		
In the EU	21.2 [17.3; 25.7]	2.5 [1.4; 4.3]
Outside the EU[a]	0.5 [0.2;1.2]	0.6 [0.3; 1.3]
Mean annual time spent abroad (days)		
In the EU (*N* = 269 for dogs, *N* = 50 for cats)	7.2 [5.6; 8.7]	35.9 [10.7; 61.0]
Outside the EU (*N* = 13 for dogs, *N* = 9 for cats)	68.1 [1.6; 134,6]	75.9 [19.4; 132.3]
Proportion of pets having contacts with other dogs or cats during trips abroad (%)		
In the EU (*N* = 265 for dogs, *N* = 50 for cats)	56.0 [43.7; 67.5]	21.8 [9.3; 43.1]
Outside the EU (*N* = 13 for dogs, *N* = 9 for cats)	64.6 [25,1; 90,9]	61.6 [25.1; 88.4]
Proportion of illegal (non-compliant) trips (%)		
In the EU (*N* = 265 for dogs, *N* = 48 for cats)	3.4 [1.5;6.6]	12.2 [2.3; 32.7]
Outside the EU (*N* = 13 for dogs, *N* = 9 for cats)	22.3 [0.9; 72.3]	0.1 [0.0; 0.5]
Trips including border control (%)		
In the EU (*N* = 269 for dogs, *N* = 50 for cats)	8.6 [3.7; 18.7]	16.5 [6.2; 37.4]
Outside the EU (*N* = 13 for dogs, *N* = 9 for cats)	77.6 [35.3; 95.6]	52.8 [18.7; 84.4]

Note: '*N*' provided for each column corresponds to the number of observations available to produce the statistics.

Abbreviation: CI, confidence interval.

[a]Destinations outside the EU mentioned by dog owners: North America (9), North Africa (2), Eastern Europe (1), Latin America (3), Middle East (1). Destinations outside the EU mentioned by cat owners: North America (5), North Africa (3), Eastern Europe (2), Latin America (1), Asia (1), Middle East (1).

results indicated more frequent travel within the EU for dogs than for cats. Trips outside the EU remained rare for both species. Stays outside the EU were longer than stays within the EU for both dogs and cats. Furthermore, stays within the EU appeared to be longer for cats than for dogs. These results also highlighted frequent contacts with other dogs and /or cats in the country of destination. We also showed some occurrence of trips that did not comply with the regulatory framework and non-systematic border controls, especially when traveling within the EU. Non-weighted statistics and raw counts for travel habits are available in Appendix 2.

3.4 | Dog-walking habits, dog contact rates with other pets and prevalence of free-roaming dogs and cats

Among dog owners, 77.1% $[72.7; 80.9]_{95\%CI}$ walked their dogs. The mean daily time of these walks was 94.2 min $[84.0; 104.3]_{95\%CI}$. Dogs had a mean number of 1.4 $[1.1; 1.6]_{95\%CI}$ daily contacts with other dogs not belonging to the household, and a mean number of 0.08 $[0.06; 0.12]_{95\%CI}$ daily contacts with cats not belonging to the household. Furthermore, 1.4% $[0.1; 2.3]_{95\%CI}$ of dog owners declared that their dog(s) could roam freely. In households owning more than one dog or cat, 82.6% $[76.8; 87.2]_{95\%CI}$ of the dogs had contacts with other dogs or cats in the household.

Among cat owners, 59.7% $[55.0; 64.2]_{95\%CI}$ let their cat(s) go outside (unsupervised, with the possibility of contacts with other animals). The mean daily time spent outside by such cats was 9.4 hr $[8.4; 10.4]_{95\%CI}$. In households owning more than one cat or dog, 97.2%

[94.3; 98.6]$_{95\%CI}$ of the cats had contacts with other cats or dogs in the household.

Non-weighted statistics and raw counts for these management habits are available in Appendix 2.

3.5 | Profiles of dog and cat owners in terms of management habits with an impact on the dynamics of directly transmitted infectious dog and cat diseases

An HCA was performed on the first five dimensions of MCA for both dog and cat owners. These dimensions explained 52.2% of the variance in dog owner classification and 56.9% of the variance in cat owner classification. HCA results are presented in Table 4 for dog owners and in Table 5 for cat owners. For dog owners, the first profile (cluster 1) was characterized by two young owners living in a household in a high-density (urban) area. They usually owned one dog, which they had owned for less than 2 years with close medical monitoring (frequent veterinary consultations, animal identified and vaccinated against rabies). These owners did not travel with their dogs, walked them but did not let them roam freely. The second profile (cluster 2) was very similar to the first one with respect to the dog management practices being evaluated. When compared to the previous cluster, this one corresponded to owners possessing a dog for a longer time and was not specifically characterized by the young age of the respondent, by the high-density area of residence, or by not traveling in the EU. The third profile (cluster 3) was characterized by older owners living in a household of three or more people. They owned more than one dog (for more than 6 years) and at least one cat. Their dogs underwent frequent veterinary visits and were identified, they travelled with them in the EU (but not outside the EU). They neither walked their dogs nor let them roam freely. The fourth profile (cluster 4) was more ill-defined. The owners were mainly living in low or very low-density (rural) areas. They owned dog(s) that were not frequently brought to the veterinarian. They travelled with their dog(s) outside the EU, did not walk it/them but let it/them roam freely. The last profile (cluster 5) was characterized by owners living in a household of three or more people in low or very low-density areas, and not belonging to high socio-professional categories. They owned more than one dog (for more than 6 years) and at least one cat. Their dogs had little medical monitoring (no frequent veterinary visits, no or uncertain identification, no or uncertain vaccination against rabies). They did not travel in the EU with their dogs and did not walk them.

Three profiles (or clusters) were identified among cat owners. The first one (cluster 1) was characterized by owners living in a household composed of three or more people located in an intermediate, low, or very low-density area and belonging to low socio-professional categories. They owned more than one cat (for more than 6 years) and at least one dog. Their cats had little medical monitoring (no frequent veterinary visits, no or uncertain identification, no or uncertain vaccination against rabies). They did not travel with their cat and gave them unsupervised access to the outside. Cluster 2 was characterized by owners living in households composed of two people located in high-density (urban) areas and belonging to high socio-professional categories. They owned one cat and no dog. Their cat had closer medical monitoring (frequent veterinary visits, identified and vaccinated against rabies) and they had owned it for between 0 and 6 years. They did not travel with their cat and allowed it outside. Cluster 3 was characterized by owners living alone or in households composed of two people. They lived in high-density areas and belonged to veterinary professions. Their cat(s) was/were identified and vaccinated against rabies. They travelled with their cat(s) (in the EU and outside the EU) but did not allow it/them outside.

For the following comparisons, we decided to consider clusters 1 and 2 of dog owners as only one cluster (renamed 'cluster 1–2') since it seemed to correspond to the same profile of owners but at a different time of their dog ownership (initial cluster 2 owners had their dog for a longer time and the cluster is thus less defined by the absence of travel within the EU since such events had time to occur). For dog owners, clusters 1–2 represented 54.8% [49.7; 59.7]$_{95\%CI}$ of dog owners; cluster 3, 38.8% [33.9; 44.0]$_{95\%CI}$; cluster 4, 1.8% [1.2; 2.8]$_{95\%CI}$ and cluster 5, 4.5% [3.0; 6.6]$_{95\%CI}$. For cat owners, cluster 1 represented 27.5% [23.7; 31.7]$_{95\%CI}$; cluster 2, 69.5% [65.2; 73.5]$_{95\%CI}$, and cluster 3, 3.0% [1.8; 4.8]$_{95\%CI}$. Boxplots for 'Introduction', 'Spread', and 'Health awareness' scores with two-by-two comparison tests between clusters are presented in Figure 1 and the detail of mean score values and comparison test *p*-values is available in Appendix 3.

4 | DISCUSSION

We surveyed 2,122 dog and cat owners on their dog and/or cat management practices (including travel habits with their pets) in relation to the dynamics of directly transmitted infectious dog and cat diseases, indicating that sample size objectives were met.

Despite the valuable information that this study provided, there were some limitations. First, the framework proposed here relied on a convenience sample based on volunteer enrolling through social media and was thus prone to sample bias. We nonetheless took this bias into account through post-stratification. Such a process could not replace probabilistic sampling but was an alternative to obtain more representative values in a context where random sampling was not possible, since no list of dog and cat owners was available. Quota sampling (a non-probabilistic version of stratified sampling) could also have been implemented and has in fact already been used in another recent online survey (Julien et al., 2020), but the advantage of post-stratification lies in the opportunity it provides to choose which variables are used for the weighting of analysed data. In this case, it was important, for example, to include the socio-professional category 'veterinary profession' in order to appropriately weight this over-represented category in our sample (which could have been missed with the quota sampling method). However, this process

TABLE 4 Dog owners' hierarchical cluster analysis results

	v-test value				
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Active variables					
Veterinary visits					
<1/year	−5.6	−6.5	−7.1	**2.1**	**19.1**
1–2/year	−5.2	**3.6**	**5.2**		−7.9
>2/year	**7.5**		−2.6		−6.6
Identification					
Yes	**3.1**	**3.1**	**3.6**		−10.4
No or Doesn't know	−3.1	−3.1	−3.6		**10.4**
Rabies vaccination					
Yes	**2.6**	**3.3**			−9.4
No or Doesn't know	−2.6	−3.3			**9.4**
Number of dogs owned					
1	**14.7**	**2.4**	−14.0		−2.1
>1	−14.7	−2.4	**14.0**		**2.1**
Cat owned					
Yes	−4.5		**3.8**		**2.4**
No	**4.5**		−3.8		−2.4
Length of ownership (years)					
0–2	**32.4**	−17.3	−16.2		−3.3
3–6	−15.7	**34.4**	−15.9		−2.1
>6	−18.0	−20.9	**29.1**		**4.8**
Travel abroad in the EU					
Yes	−3.3		**3.4**		−3.7
No	**3.3**		−3.2		**3.3**
Travel abroad outside the EU					
Yes	−2.5	−2.4	−2.9	**9.1**	
No	**2.1**	**2.0**	**3.3**	−8.7	
Dog walks					
Yes	**5.2**	**7.8**	−9.2	−2.8	−2.3
No	−5.2	−7.8	**9.2**	**2.8**	**2.3**
Possibility of roaming freely					
Yes	−4.2	−4.1	−4.8	**15.4**	
No	**4.2**	**4.1**	**4.8**	−15.4	
Illustrative variables					
Socio-professional category (SPC)					
Low SPC				−2.0	
High SPC					−2.2
Retired					
No work activity					
Veterinary profession					
Number of people in the household					
1			−2.6		
2	**2.7**	**2.9**	−4.3		
≥3	−3.5	−4.0	**5.9**		**2.7**

(Continues)

TABLE 4 (Continued)

	v-test value				
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Age of the respondent (years)					
18–29	**4.4**		−5.7		
30–39					
40–49			**2.17**	−2.0	
50–59	−3.6				
≥60			**2.3**		
Gender of the respondent					
Woman					
Man					
Density of area of residence					
High	**3.2**				
Intermediate					
Low and Very Low	−4.2			**2.8**	**3.0**

Note: Only variable categories that are significantly over- or under-represented ($p < .05$) are shown. A negative v-test value indicates an under-representation of the category in the cluster and a positive v-test value (shown in bold) indicates an over-representation of the category in the cluster.

could not ensure representativeness within the strata of the population (used for post-stratification) since it remained a non-probabilistic sampling method and caution is needed in interpreting these results. Beyond sampling bias, the quality of data collected through online questionnaires has been questioned regarding measurement bias, but it has been shown that this type of questionnaire is not overly affected by such bias (Van Gelder et al., 2010). Nonetheless, this kind of bias could not be excluded in our study, particularly for the number of contacts between dogs, the duration of dog walks or for the time spent outside by cats, which may be difficult for owners to remember. Moreover, among all the disease prevention measures available, we only assessed the rabies vaccination in order to minimize measurement bias, since this particular vaccination is recorded in pet passports (which is not necessarily the case for other vaccinations) and thus easily identifiable by the owners. Similarly, we did not assess anti-parasitic nor anti-infective treatments since the questionnaire would have had to be much longer in order to collect a sufficiently high quality of data to be able in particular to evaluate the concordance between traveling and the administration of such treatment. In addition, the 'Health awareness' score (Table 1) was designed to obtain the owners' general awareness of medical issues by collecting relevant but not exhaustive pieces of information. We did not seek to find out whether the dogs and cats were neutered since the study focused on owner management practices affecting the potential to introduce and spread infectious diseases, but this variable could have been of interest for free-roaming cat interactions. However, contact rates could not have been assessed with such a questionnaire for cats roaming freely. The problem is the same for dogs roaming freely even if the proportion of dogs having this opportunity was very limited in our study. Such investigations would require other tools, such as GPS devices (Brookes et al., 2018; Bruce et al., 2019; Dürr & Ward, 2014; Hudson et al., 2019; Laager et al., 2018; Loyd et al., 2013; Meek, 1999; Molloy et al., 2017; Sparkes et al., 2014).

The characteristics of owners who responded before post-stratification highlighted a slight over-representation of households composed of three people or more (48.0% in our sample versus 31.5% in France) and an under-representation of households composed of one person (18.8% in our sample versus 35.7% in France). High socio-professional categories were under-represented (22.5% in our sample versus 31.8% in France), as were households composed of retired people (4.1% in our sample versus 29.2% in France). Households represented by people without an activity (including students) were over-represented (11.6% in our sample versus 6.2% in France), as were households composed of people whose job was linked to the veterinary field (27.1% in our sample versus 0.2% in France). These discrepancies—and primarily the strong over-representation of households linked to veterinary professions—emphasize the advantages of post-stratification, as stated above, which was conducted to properly weight the observations of this non-probabilistic sample to match the composition of the French population (Appendix 1). Nevertheless, care should be taken when analysing these comparisons as they were based on the assumption that the structure of the dog and cat owning population is the same as that of the general population.

After the post-stratification process, the characteristics of the pet dogs and cats were similar to those observed in other studies conducted in France, although not directly comparable since the variables were not collected using the same methodology (e.g. in other studies, vaccinations were evaluated without any focus on a specific disease). This study confirms the closer medical monitoring of dogs (vaccination, veterinary visits) than cats, as previously observed (Bussiéras, 2013;

TABLE 5 Cat owners' hierarchical cluster analysis results

	v-test value		
	Cluster 1	Cluster 2	Cluster 3
Active variables			
Veterinary visits			
<1/year	**30.4**	−29.5	
1–2/year	−22.3	**21.1**	
>2/year	−6.7	**6.3**	
Identification			
Yes	−23.3	**21.9**	**2.9**
No or Doesn't know	**23.3**	−21.9	−2.9
Rabies vaccination			
Yes	−16.4	**11.1**	**8.5**
No or Doesn't know	**16.4**	−11.1	−8.5
Number of cats owned			
1	−2.0	**2.3**	
>1	**2.1**	−2.3	
Dog owned			
Yes	**4.0**	−3.5	
No	−4.0	**3.5**	
Length of ownership			
0–2	−9.0	**9.7**	−2.4
3–6	−2.9	**2.0**	
>6	**9.5**	−9.2	
Travel abroad in the EU			
Yes	−5.7	−10.4	**19.6**
No	**5.8**	**9.5**	−19.1
Travel abroad outside the EU			
Yes	−2.00	−4.0	**7.4**
No	**2.4**	**2.8**	−6.7
Unsupervised access to the outside			
Yes	**3.3**	−2.3	−2.2
No	−3.3	**2.3**	**2.2**
Illustrative variables			
Socio-professional category (SPC)			
Low SPC	**2.5**	−2.1	
High SPC	−2.3	**2.5**	
Retired			
No work activity			
Veterinary profession	−2.0		**2.0**
Number of people in the household			
1			
2	−2.9	**2.0**	
≥3	**4.3**	−3.3	−2.1
Age of the respondent (years)			
18–29			
30–39			
40–49			
50–59			
≥60			
Gender of the respondent			
Woman			
Man			
Density of area of residence			
High	−4.2	**3.2**	**2.2**
Intermediate	**2.0**		
Low and Very Low	**2.9**		−2.1

(Continues)

Note: Only variable categories that are significantly over- or under-represented ($p < .05$) are shown. A negative v-test value indicates an under-representation of the category in the cluster and a positive v-test value (shown in bold) indicates an over-representation of the category in the cluster.

Ipsos/SantéVet, 2019). Better medical monitoring of dogs was also observed in other high development index countries such as the USA and Italy (Freiwald et al., 2014; Slater et al., 2008b). A similar frequency of veterinary visits for cats was noticed in New Zealand (Johnston et al., 2017) but appeared to be lower in Italy (Carvelli et al., 2016; Slater et al., 2008b). A similarly high frequency of veterinary visits for dogs was observed in Italy (Slater et al., 2008b).

To our knowledge, this is the first study assessing dog and cat owners' travel and management practices in relation to their potential for introducing and spreading directly transmitted infectious diseases. In particular, we evaluated the frequency of people's trips abroad accompanied by their dogs and cats, data that are unknown for most countries, and difficult to trace (Anderson et al., 2019; Polak, 2019) considering the diversity of traveling routes (plane, road, boat and train), the absence of systematic border control and the lack of any registration of these cross-border movements. All attempts to quantify such events seem to be limited to new importations (McQuiston et al., 2008) with an emphasis on rescue animals, which are considered at high risk because greatly exposed to infectious diseases in their country of origin (Anderson et al., 2019; Norman et al., 2020; Overgaauw et al., 2020; Stull et al., 2019). However, dogs and cats accompanying their owner during trips should not be neglected since we showed that these events were frequent for a high-income country like France (Table 3), especially within the EU with a substantial annual time spent abroad (mean of 7.2 days/year for dogs that travel and mean of 35.9 days/year for cats that travel) and thus at risk of exposure to infectious diseases. The frequency of travel within the EU was far higher for dogs than for cats. This phenomenon is probably linked to the few regulatory constraints when compared to those applying for travel outside the EU, to the geographic proximity and to the fact that dog owners are prone

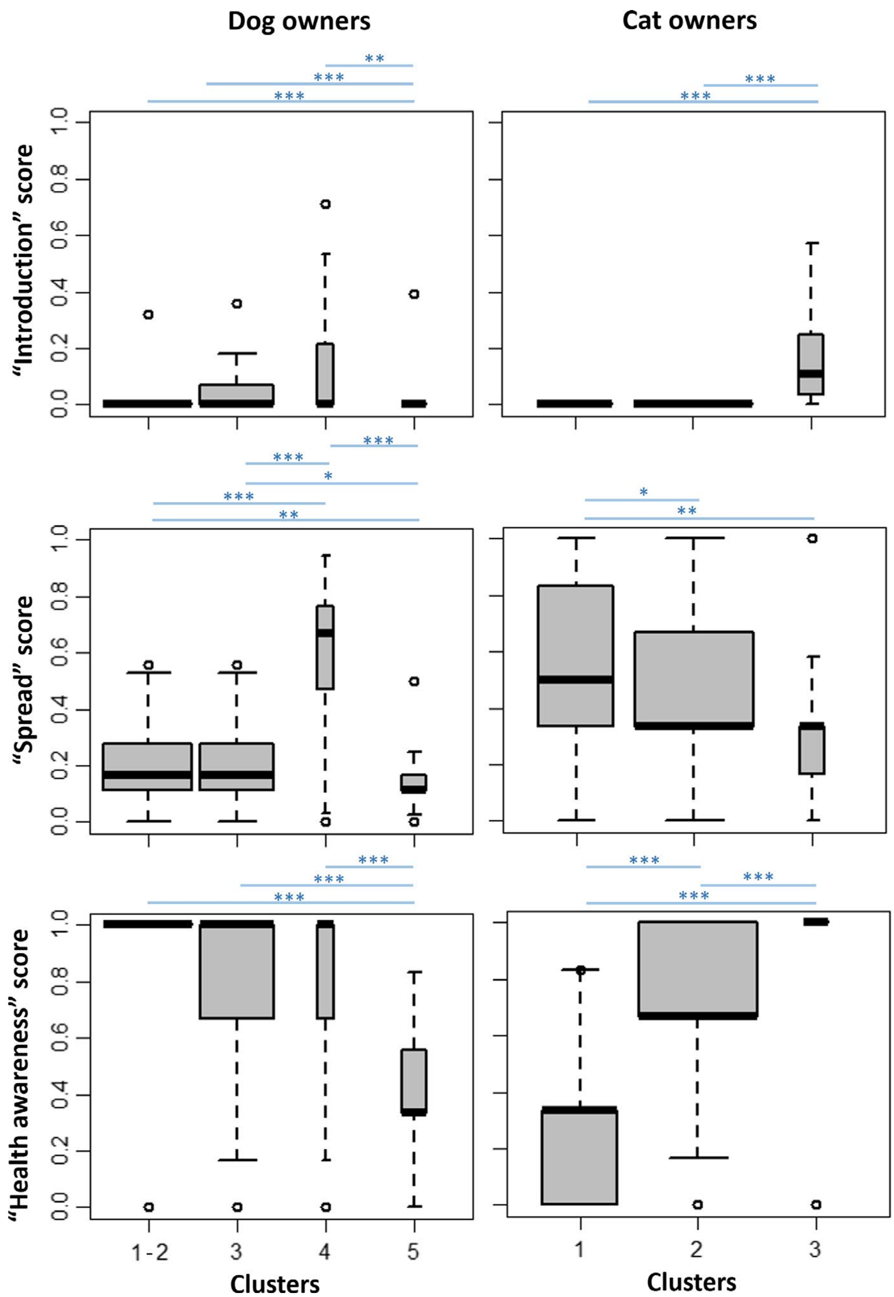

FIGURE 1 'Introduction', 'Spread', and 'Health awareness' scores for the different dog and cat owner profiles. The boxes represent the interquartile range with the median (bold line in the box); whiskers cover 1.5 interquartile ranges beyond the end of the box or the minimum and/or the maximum if closer. Points represent minimum and maximum (if not included in the whiskers). Lines above the plots represent two-by-two comparisons between owner profiles. The absence of a line indicates a non-significant Wilcoxon-Mann-Whitney test after Bonferroni correction. Lines with stars indicate a significant test after Bonferroni correction. *$p < .05$; **$p < .01$; ***$p < .001$

to take their dogs with them when they go on holiday (Ipsos/SantéVet, 2019). Trips within the EU, despite being far less at risk for reintroducing rabies since very few cases are now reported across the EU (Robardet et al., 2019), should not be neglected for dynamics of directly transmitted infectious dog and cat diseases that are distributed unevenly across Europe such as, for example, pathogens associated with the Canine Infectious Respiratory Disease Complex (Day et al., 2020) and the Feline Leukaemia Virus (Studer et al., 2019). Regulatory measures for travel within the EU include identification and vaccination against rabies (Regulation (EU) No 576/2013) but few countries consider the risk posed by other infectious diseases, for which there are rarely specific measures. The frequency of owners traveling with their dogs and cats outside the EU seemed to be far lower (<1% of dog and cat owners had travelled with their pets within the previous five years) and linked to longer stays (Table 3), probably for purposes other than holidays (e.g. for family or work reasons). Longer stays abroad were thus linked to longer exposure times to infectious diseases with a high proportion of traveling dogs and cats having contacts with other dogs and/or cats (64.6% for dogs and 61.6% for cats). Considering the limited number of trips outside the EU, compared to travel within the EU, the probability that such translocations introduce directly transmitted infectious dog and cat diseases is probably low. Nonetheless, specific consideration must be given to rabies because of major public health implications (a fatal zoonosis with economic consequences) and because such events have already been documented in France in 2004 and 2008 (Ribadeau-Dumas et al., 2016). Indeed, there is a substantial flow of travellers (including travellers with their pets) between France and some areas that are enzootic for rabies, such as North Africa (European Commission, 2019). It should be noted that non-compliance with rabies regulations on travel was frequent (Table 3), probably due to a lack of knowledge and awareness. Such non-compliances represent a serious threat when traveling to enzootic areas for rabies since checks by border control officials were far from systematic, as shown by our results (Table 3). These results should encourage to raise awareness about rabies risk among pet owners, especially when traveling abroad. The high frequency of pets in non-compliance with regulatory requirements when traveling should also encourage to increase the number of border controls especially for high risk routes such as roads. Education about the risks posed by live-animal movements should also be reinforced for people in charge of theses controls. Trainings, such as those organized by the European Commission from 2013 to 2020 (European Commission,n.d.), should be prioritized for staff without veterinary background involved in such controls (e.g. custom officers).

Contacts between individuals are also of great importance in understanding the dynamics of directly transmitted contagious diseases in populations. According to our results, many contacts between French dogs can occur during dog walks and probably far fewer during unsupervised roaming, since the proportion of dogs having the opportunity to roam freely was very limited (1.4%). Thus, despite being associated with a poorer health status and infectious diseases, free-roaming dogs (Bradbury & Corlette, 2006; Slater, 2001; Slater et al., 2008a; Sparkes et al., 2014) are probably of minor importance for contagious dog disease circulation in France, contrary to other countries with high development indexes such as Australia or Italy, which appear to have greater free-roaming dog populations (Slater et al., 2008b; Sparkes et al., 2014). The proportion of owners walking their dogs in our study (77.1%) was in the range of values found in other studies that reported values between 64% and 94% (Cutt et al., 2008; Hidano et al., 2012; Kwan et al., 2019; Liao et al., 2018; Oka & Shibata, 2012). Nonetheless, there seems to be diversity in dog-walking habits among the different areas of the world, probably linked to cultural aspects regarding pet management or due to the different methodologies used to assess such data. Our study showed that during their walks, dogs had frequent contacts with other dogs (mean >1 contacts/day with other dogs). Similar results, indicating frequent contacts between dogs, were obtained in Japan but are not directly comparable because of different methodologies (Hidano et al., 2012; Kwan et al., 2019). Moreover, the mean daily dog-walking time of 94.2 min (mean of 659 min/week) in our study appears to be higher than values obtained in other studies, which ranged from 48 to 192 min/week in the USA and Australia (Christian et al., 2013) and from 214 to 453 min/week in Western Asia (Kwan et al., 2019; Liao et al., 2018; Oka & Shibata, 2012). We found that dogs' contacts with cats were far less frequent than contacts with other dogs. However, it should be noted that a large proportion of households (30.4%) own both dogs and cats, facilitating such interspecific contacts. This information is of importance for diseases affecting both dogs and cats (e.g. rabies) as it makes it easier for a disease to spread from one domestic species to another.

In terms of cat management practices in relation to the potential for spreading directly transmitted contagious cat diseases, we found a lower proportion of cats having outdoor access than another recent study conducted in France, though the values remained in the same range (59.7% in our study versus 66% in the study of Roussel et al. (2019)). In other parts of the world, the proportion of owners allowing their cats to go outside appears to vary considerably, probably also linked to cultural aspects (Farnworth et al., 2010; Freiwald et al., 2014; Johnston et al., 2017; Slater et al., 2008b; Tan et al., 2020). However, contact rates between cats roaming freely are largely unknown in France and very few studies assessing such data are available. In one study conducted in New Zealand using animal-borne cameras, only three contacts between cats (involving three different cats) were observed after 90 cumulated days of observation of 37 different domestic cats (each observed for 1 to 3 days) (Bruce et al., 2019), whereas in another study conducted in the USA, one-quarter of the cats enrolled had at least one contact with another cat (28 contact events involving 14 different cats during 83 cumulated days of observations) (Loyd et al., 2013). Although contacts between free-roaming cats are not easily traceable, it is clear that such cats run a higher risk for contracting infectious diseases such as feline immunodeficiency virus, feline leukaemia virus, bartonellosis or external and internal parasitic infections (Tan et al., 2020).

Dog and cat owner classification results enabled us to put these data about travel and management practices into perspective by relating them to the potential for spreading directly transmitted contagious dog and cat diseases. Indeed, through the three scores we designed (Table 1) and their inter-profile comparison (Figure 1), we were able to evaluate the potential of each owner profile to be a dog and/or cat disease 'introducer' and/or 'spreader'. Among the various dog owner profiles, the first two (clusters 1–2 and 3)—representing the vast majority of dog owners (93.6%)—did not appear to have much of a potential for either introducing or spreading disease since they did not travel much, had only an intermediate 'Spread' score but, more importantly, owned dogs that were regularly monitored by their veterinarian, indicating a high probability of correctly implementing mitigation measures for such risks of infection. Dog owners belonging to the 5th profile (cluster 5) did not travel with their dog(s) but could play the role of 'spreader' considering the fact they were not well monitored from a medical standpoint. The 4th cluster of dog owners is of particular interest since it could act both as an 'introducer' a 'spreader' of directly transmitted contagious pet diseases. Indeed, this cluster had the highest 'Introduction' score (with trips outside the EU), the highest 'Spread' score, and an intermediate 'Health awareness' score (but not the lowest). The proportion of such dog owners was nonetheless very limited in our study (1.8%) but this profile could still be associated with health alerts following rabies reintroductions as observed in France at least twice, in 2004 and 2008. Indeed, owners illegally brought dogs from countries where rabies is enzootic into France and then exposed many other animals in France to the disease, resulting in some secondary cases (Note de service DGAL/SDSPA/N2008-8104, 2008; Servas et al., 2005). Among cat owners, the first profile (cluster 1, representing 27.5% of cat owners) could act as a 'spreader' of directly transmitted contagious diseases since it was characterized by cats with little medical monitoring that could roam freely (but do not travel). Clusters 2 and 3 concerned cats with closer medical monitoring and lower 'Spread' scores, especially for cluster 3. Only cluster 3 was characterized by owners who travelled with their cats, but their role as 'introducers' is probably very limited since it is the profile with the highest 'Health awareness' score. Compared to dog owners, there does not seem to be a specific high-risk profile which could act as an 'introducer' and 'spreader', though cluster 1 could still act as a 'spreader' of a disease introduced by dogs but affecting both dogs and cats.

This work thus provides useful insights that could shed light on some of the dynamics of directly transmitted infectious diseases in both the dog and cat populations of high development index countries, which closely depend on the way these pets are kept and managed by their owners. Despite pets travelling abroad frequently, especially within the EU, and despite the likelihood that individual pets can be closely connected within the dog and cat populations in keeping with their owners' management practices, very few owners in France were identified as a potentially high-risk 'introducer' or 'spreader' of directly transmitted infectious cat and dog diseases. Such results open up opportunities for other research aiming to investigate the psycho-social determinants involved in owners' choices regarding pet management as previously applied to production animals for biosecurity measure implementation (Garforth, 2015; Mankad, 2016). Such data could be useful for better identifying and characterizing these owners, and for providing suitable targeted prevention advice. Additional data could also be collected to extend this framework and to investigate the role of pets in introducing and spreading diseases with other transmission routes such as vector-borne diseases or diseases with indirect transmission.

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CONFLICT OF INTEREST

None.

ETHICAL APPROVAL

The authors confirm that they have complied with the journal's ethical policies as noted on the journal's author guidelines page. No ethical approval was required as this study does not involve animal subjects and is not considered biomedical research on human beings. Indeed, only fully anonymous declarative data (which do not allow identification of the respondent even when crossing variables) were collected on a voluntary basis, by clicking on a link published on social media. Before starting the questionnaire, all the participants were fully informed as to the study's purpose and agreed on the use of the data they provided. In addition, we are in full compliance with the GDPR (General Data Protection Regulation – Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016, adapted in French regulations by Act no. 2018-493 of 20 June 2018) since no personal data were handled, as previously stated.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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APPENDIX 1

FRENCH POPULATION COUNTS FOR THE STRATA USED IN THE POST-STRATIFICATION OF THE SURVEY (INSEE, 2016, 2018)

Number of people in the household	Socio-professional category	Number of households in France	% of households in France
1	Lower socio-professional category	2,501,941	8.56%
1	Higher socio-professional category	2,434,245	8.33%
1	No activity (including students)	1,178,840	4.03%
1	Retired	4,322,712	14.79%
2	Lower socio-professional category	2,807,985	9.60%
2	Higher socio-professional category	2,647,989	9.06%
2	No activity (including students)	321,766	1.10%
2	Retired	3,761,993	12.87%
>3	Lower socio-professional category	4,269,046	14.60%
>3	Higher socio-professional category	4,195,110	14.35%
>3	No activity (including students)	305,857	1.05%
>3	Retired	442,377	1.51%
1 to >3	Veterinary profession	46,079	0.16%
Total		29,235,939	

APPENDIX 2

QUANTITATIVE RESULTS OF THE SURVEY BEFORE THE POST-STRATIFICATION PROCESS

General characteristics of pet dogs and cats

	Dog owners		Cat owners	
	Counts	% or mean [95%CI]	Counts	% or mean [95%CI]
Mean number of animals owned	*N* = 1,343	1.58 [1.50; 16.65]	*N* = 1,462	1.90 [1.82; 1.99]
Mean possession time (years)	*N* = 1,343	5.61 [5.40; 5.83]	*N* = 1,463	7.11 [6.87; 7.35]
Frequency of veterinary consultations (%)				
<1 time a year	70/1,343	5.2% [4.1; 6.5]	346/1,463	23.7% [21.5; 25.9]
1–2 times a year	749/1,343	55.8% [53.1; 58.4]	921/1,463	63.0% [60.4; 65.4]
>2 times a year	524/1,343	39.0% [36.4; 41.7]	196/1,463	13.4% [11.7; 15.2]
Identification (%)				
Microchip	1,237/1,343	92.1% [90.5; 93.4]	931/1,463	63.6% [61.1; 66.1]
Tattoo	87/1,343	6.5% [5.3; 7.9]	258/1,463	17.6% [15.8; 19.7]
Doesn't know	6/1,343	0.4% [0.2; 1.0]	131/1,463	8.9% [7.6; 10.5]
No	13/1,343	1.0% [0.6; 1.7]	143/1,463	9.8% [8.3; 11.4]
Rabies vaccination (with regular boosters) (%)				
Yes	977/1,343	72.7% [70.3; 75.1]	470/1,463	32.1% [29.7; 34.5]
Doesn't know	56/1,343	4.2% [3.2; 5.4]	126/1,463	8.6% [7.3; 10.1]
No	310/1,343	23.1% [20.9; 25.4]	867/1,463	59.3% [56.7; 61.7]

Abbreviation: CI, confidence interval.

'*N*' in the 'counts' column corresponds to the number of observations used to produce the mean and its confidence interval.

Travel habits of dog and cat owners with their pets

	Dog owners		Cat owners	
	Counts	% or mean [95%CI]	Counts	% or mean [95%CI]
Proportion of owners having travelled at least once with their pets in the previous five years (%)				
In the EU	269/1,340	20.1% [18.0; 22.3]	50/1,460	3.4% [2.6; 4.5]
Outside the EU	13/1,340	0.9% [0.6; 1.7]	9/1,460	0.6% [0.3; 1.2]
Mean annual time spent abroad (days)				
In the EU	*N* = 269	10.3 [7.54; 13.0]	*N* = 50	65.3 [40.2; 90.3]
Outside the EU	*N* = 13	83.0 [32.0; 134.1]	*N* = 9	78.4 [31.0; 125.7]
Proportion of pets having contact with other dogs or cats during travels abroad (%)				
In the EU	164/265	61.9% [55.9; 67.5]	16/50	32.0% [20.6; 46.0]
Outside the EU	11/13	84.6% [54.9; 96.1]	6/9	66.7% [33.3; 88.9]
Proportion of illegal (non-compliant) journeys (%)				
In the EU	19/265	7.2% [4.4; 11.0]	6/48	12.5% [4.7; 25.2]
Outside the EU	3/13	23.1% [5.0; 53.8]	1/9	11.1% [0.2; 48.3]
% checked during border crossings				
In the EU	18/269	6.7% [4.2; 10.4]	7/50	14.0% [6.8; 26.6]
Outside the EU	9/13	69.2% [40.9; 88.0]	5/9	55.6% [25.1; 82.3]

'*N*' in the 'counts' column corresponds to the number of observations used to produce the mean and its confidence interval.

Management practices of dog and cat owners in relation to the potential for spreading directly transmitted contagious cat and dog diseases

Species	Variable	Counts	% or mean [95%CI]
Dogs	Proportion of owners walking their dogs (%)	1,034/1,343	77.0% [74.7; 79.2]
	Mean daily time spent walking the dog, if applicable (in minutes)	*N* = 1,019	83.2 [79.4; 86.9]
	Mean daily number of contacts with dogs not belonging to the household	*N* = 1,295	1.5 [1.4; 1.7]
	Mean daily number of contacts with cats not belonging to the household	*N* = 1,295	0.2 [0.1; 0.2]
	Proportion of dogs having contacts with other dogs or cats in the same household (%)	709/840	84.4% [81.8; 86.7]
	Proportion of dogs allowed to roam freely (%)	31/1,343	2.3% [1.6; 3.3]
Cats	Proportion of cats allowed to roam freely (%)	872/1.463	59.6% [57.1; 62.1]
	Mean daily time spent outside by the cats (in hours)	*N* = 1,463	10.3 [9.7; 10.8]
	Proportion of cats having contacts with other dogs or cats in the same household (%)	967/1,004	96.3% [94.9; 97.3]

'*N*' in the 'counts' column corresponds to the number of observations used to produce the mean and its confidence interval.

APPENDIX 3

MEANS OF THE 'INTRODUCTION', 'SPREAD', AND 'HEALTH AWARENESS' SCORES FOR DOG AND CAT OWNERS AND FOR EACH CLUSTER AMONG DOG AND CAT OWNERS, ALONG WITH RESULTS OF TWO-BY-TWO COMPARISONS BETWEEN CLUSTERS

Means of the 'Introduction', 'Spread', and 'Health awareness' scores for dog and cat owners and for each cluster among dog and cat owners

	Mean 'Introduction' score [95%CI]	Mean 'Spread' score [95%CI]	Mean 'Health awareness' score [95%CI]
Dogs			
Global	0.04 [0.038; 0.049]	0.19 [0.18; 0.20]	0.90 [0.88; 0.91]
Cluster 1–2	0.030 [0.020; 0.040]	0.19 [0.18; 0.21]	0.93 [0.91; 0.95]
Cluster 3	0.047 [0.034; 0.061]	0.18 [0.16; 0.20]	0.90 [0.88; 0.93]
Cluster 4	0.140 [0.053; 0.227]	0.60 [0.48; 0.71]	0.86 [0.78; 0.94]
Cluster 5	0.003 [0.00; 0.009]	0.14 [0.11; 0.17]	0.45 [0.37; 0.53]
Cats			
Global	0.005 [0.003; 0.008]	0.46 [0.43; 0.49]	0.66 [0.63; 0.68]
Cluster 1	0	0.53 [0.48; 0.57]	0.26 [0.24; 0.29]
Cluster 2	0	0.44 [0.40; 0.47]	0.80 [0.78; 0.82]
Cluster 3	0.18 [0.10; 0.25]	0.34 [0.26; 0.43]	0.93 [0.86; 1]

***p*-values of the two-by-two comparison using Wilcoxon-Mann-Whitney tests after Bonferroni correction for the 'Introduction' score between dog owner clusters**

	Cluster 1–2	Cluster 3	Cluster 4	Cluster 5
Cluster 1–2		0.177	0.129	<0.001
Cluster 3			0.743	<0.001
Cluster 4				0.002
Cluster 5				

***p*-values of the two-by-two comparison using Wilcoxon-Mann-Whitney tests after Bonferroni correction for the 'Spread' score between dog owner clusters**

	Cluster 1–2	Cluster 3	Cluster 4	Cluster 5
Cluster 1–2		1.000	<0.001	0.001
Cluster 3			<0.001	0.027
Cluster 4				<0.001
Cluster 5				

***p*-values of the two-by-two comparison using Wilcoxon-Mann-Whitney tests after Bonferroni correction for the 'Heath awareness' score between dog owner clusters**

	Cluster 1–2	Cluster 3	Cluster 4	Cluster 5
Cluster 1–2		0.745	0.640	<0.001
Cluster 3			1.000	<0.001
Cluster 4				<0.001
Cluster 5				

***p*-values of the two-by-two comparison using Wilcoxon-Mann-Whitney tests after Bonferroni correction for the 'Introduction' score between cat owner clusters**

	Cluster 1	Cluster 2	Cluster 3
Cluster 1		0.904	<0.001
Cluster 2			<0.001
Cluster 3			

***p*-values of the two-by-two comparison using Wilcoxon-Mann-Whitney tests after Bonferroni correction for the 'Spread' score between cat owner clusters**

	Cluster 1	Cluster 2	Cluster 3
Cluster 1		0.005	<0.001
Cluster 2			0.101
Cluster 3			

***p*-values of the two-by-two comparison using Wilcoxon-Mann-Whitney tests after Bonferroni correction for the 'Heath awareness' score between cat owner clusters**

	Cluster 1	Cluster 2	Cluster 3
Cluster 1		<0.001	<0.001
Cluster 2			<0.001
Cluster 3			