







Perceptions of health and ecosystem risks from free-roaming domestic animals in Mediterranean wetlands: One health perspective

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Abstract

Background and Aim: Free-roaming domestic animals (FRDAs) impact ecosystems and public health. The perception of the ecological and health risks posed by FRDAs can vary depending on individual, cultural, and social factors. In this study, we assessed the perception of ecological and health risks associated with FRDAs in the Bатуco wetland (Chile) from a One Health perspective.

Materials and Methods: This descriptive and analytical cross-sectional study was conducted using a questionnaire administered to 399 respondents. A Chi-square test, generalized linear models, and correlations were carried out to assess whether respondents' status (resident or tourist), gender, age, and educational level explained their perception of risks and views on control and management actions for FRDAs. These data were used to propose interventions based on the One Health approach.

Results: Residents exhibited greater awareness of the presence of FRDAs in the Bатуco wetland but had a lower perception of ecological risks and control and management actions than tourists. In contrast to men, women showed a higher level of knowledge regarding ecological and health risks and identified significantly more control and management actions. However, overall knowledge of ecological and health risks is limited across all groups.

Conclusion: The results emphasize the need to implement community engagement and educational programs for residents and tourists using a One Health approach that promotes participation from both men and women to reduce gender gaps in ecological and health risk awareness associated with FRDAs.

Keywords: Ecological risk, free-roaming domestic animals, health risk, one health, urban wetland.

Introduction

Domestic animals are those that have undergone domestication, either through natural or artificial selection, resulting from prolonged interactions with humans. This category includes companion animals, such as dogs and cats, as well as productive animals, such as cows, horses, sheep, chickens, and pigs [1]. Domestication has induced significant and heritable changes in these animals, including alterations in cognition and behavior [2], gut microbiota [3, 4], and gene expression [5]. Moreover, domestication has had profound implications for human society, facilitating the development of agriculture and the use of animals for food, transportation, and companionship [6]. Domestic animals have received essential

provisions from humans, including water, food, shelter, and protection, thereby establishing mutually beneficial co-dependence [7]. Responsible ownership of domestic animals ensures a mutually beneficial relationship between humans and domestic animals, prioritizing their welfare, happiness, and overall quality of life [8]. It involves meeting individuals' physical, behavioral, and psychological needs to promote optimal health, welfare, and well-being [9, 10]. This includes providing appropriate nutrition, veterinary care, socialization, exercise, and suitable living conditions. Compliance with legal requirements, responsible breeding practices, proactive disease prevention, and behavior training that reduce conflicts and ensure the safety of both animals and humans are also integral aspects of responsible ownership [8].

Responsible ownership extends beyond animal welfare, as it has significant implications for ecosystems and public health. Domestic animals that roam freely due to inadequate or absent responsible ownership can significantly disrupt ecosystems and pose health risks [11, 12]. For instance, domestic carnivores may compete with native species for food and habitats,

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increasing their predation of wildlife [11, 13, 14]. These interactions can also lead to stress, disruption of breeding patterns, and reduced reproductive success in wild populations [11, 15]. Free-roaming domestic animals (FRDAs) may interbreed with wild populations, leading to genetic pollution and loss of genetic diversity in native species [16–18].

In addition, FRDAs can contribute to the introduction and spread of invasive species, which can harm native wildlife and ecosystems [19, 20]. FRDAs can also damage vegetation and soil through overgrazing and trampling, leading to erosion, biodiversity loss, and ecosystem structure alterations [21, 22]. Moreover, FRDAs have significant health impacts. For instance, uncontrolled defecation and urination by FRDAs can contaminate water sources with pathogens and pollutants, posing risks to both human and animal health [23, 24]. FRDAs can also act as reservoirs or carriers of various infectious diseases, including zoonotic diseases that can be transmitted to wild animals and humans [25–27]. Examples include rabies [28], leptospirosis [29], toxoplasmosis [30], and tick-borne diseases [31].

Moreover, FRDAs in resource-limited areas or those lacking adequate veterinary care may be subjected to inappropriate or excessive antibiotic use, which can contribute to developing and spreading antimicrobial resistance (AMR) in bacterial populations [32, 33]. FRDAs also can come into contact with environmental reservoirs of AMR, leading to colonization or infection by AMR organisms and facilitating their spread [34–36]. In addition, FRDAs can act as reservoirs or vectors for AMR organisms and transmit resistant strains to humans. This transmission poses a significant risk to public health, limiting the effectiveness of antimicrobial treatment and complicating the management of infections [36, 37]. On the other hand, FRDAs can cause conflicts between humans, such as property damage, aggression toward people or other animals, and nuisance behaviors, leading to potential risks to public safety and well-being [38, 39]. For instance, the challenges of reducing animal-vehicle collisions, including those involving free-roaming livestock, highlight the importance of minimizing the free-roaming of domestic animals to prevent such incidents [40]. The presence of FRDAs in certain areas can vary according to different factors. For example, FRDAs are often more common in urban and peri-urban areas where enforcement of animal control measures, such as leash laws and confinement regulations, may be limited [21]. Urban areas with high population density and inadequate animal management infrastructure may face challenges in controlling the movement of domestic animals [41]. Communities with limited access to veterinary services, low-income households, or areas with economic constraints may have a higher prevalence of FRDAs due to the lack of proper veterinary care, including sterilization, leading to uncontrolled breeding and increased FRDAs [42]. In rural

and agricultural regions, the presence of FRDAs can be influenced by the traditional practice of allowing animals to roam freely for grazing or other purposes [43]. Cultural attitudes and historical practices can also contribute to the prevalence of FRDAs. Some regions have cultural norms or traditions that tolerate or even encourage the presence of FRDAs [13]. Thus, individual, contextual, and cultural variations can significantly impact perceptions of health and ecological risks associated with FRDAs [44].

Understanding how people perceive the risks of FRDAs is crucial for developing effective strategies to mitigate their negative impacts on health and ecosystems. In this regard, the World Health Organization and other international organizations have recognized the importance of adopting a One Health approach to address the impacts of FRDAs [45]. The One Health approach emphasizes the interconnectedness of human, animal, and environmental health and promotes collaborative efforts across disciplines and sectors [46].

In this study, we aimed to assess perceptions and level of knowledge regarding the risks posed to the ecosystem and health by FRDAs in the Batuco wetland, a peri-urban area located in central Chile (3° 11' 4 5.08" S, 70° 49' 50.4" W), to provide further insights for designing and implementing targeted educational and awareness campaigns focused on mitigating the adverse impacts of FRDAs on the ecosystem and health in the Batuco wetland and its surrounding communities.

Materials and Methods

Ethical approval and Informed consent

The General Management of Liaison with the Environment and Communications at Universidad de Las Américas supported the questionnaire and informed consent. Verbal consent from each respondent was obtained before the commencement of the study.

Study period and location

The study was conducted in June 2022 in Batuco wetland. The Batuco wetland, located in a semi-arid region in central Chile, provides a crucial habitat for a diverse range of plant and animal species, including migratory birds and endemic flora [47, 48]. Wetland encompasses various habitats, such as marshes, lagoons, and reed beds, which contribute to its rich biodiversity [47]. The Batuco wetland is an important stopover and breeding ground for numerous bird species, including waterfowl, herons, and shorebirds [49]. During their migration journeys, these avian populations rely on the wetland's resources for feeding, resting, and nesting. The presence of these birds not only enhances the wetland's ecological value but also attracts birdwatchers and nature enthusiasts from around the world [50]. In addition to its ecological significance, the Batuco wetlands provide several ecosystem services that benefit local communities. It helps

regulate water flow, reduces flooding risk, and maintains water quality. The wetlands also support groundwater recharge and act as natural filters, enhancing water purification processes [50]. Furthermore, it serves as a recreational area, offering opportunities for ecotourism, education, and research [50]. Despite its health and ecological importance, the Batuco wetland faces various threats, including urbanization, agricultural expansion, improper waste disposal, invasive plant species, and FRDAs, all of which pose significant challenges to its integrity [50].

Survey design

We designed a semi-structured questionnaire, which was piloted with students and faculty members from the Faculty of Veterinary Medicine and Agronomy at the University of Las Américas. During this phase, the initial version of the survey was administered to a specific group of respondents to identify and address any potential issues regarding the clarity, relevance, and comprehensiveness of the questions. Feedback was collected and evaluated, leading to necessary adjustments to ensure the survey's validity and reliability for the main study. The finalized questionnaire was administered in person to 399 individuals from the Batuco wetland. By that time, the Chilean government had lifted all sanitary restrictions related to COVID-19 in both open and closed spaces [51]. The sample size was estimated using the formula:

$$n = Z^2 \times p \times (1-p)/E^2;$$

where n is the sample size, Z is the critical value for the confidence level (1.96 for a 95% confidence level), p is the expected proportion of the characteristic in the population (we used 0.5 as a conservative estimate), and E is the tolerated margin of error (0.10 for exploratory studies) [52].

This calculation resulted in a minimum sample size of 384 individuals. The inclusion criteria specified individuals aged 18 years and above, possessing full autonomy in their mental faculties, and who provided informed consent for the survey's objectives and the use of their data. The questionnaire included seven questions about the respondents' background information, such as age and gender identity, and 10 questions about the risk perception of health and ecosystems associated with FRDAs in the Batuco wetland. The questionnaire covered topics such as potential habitat degradation, introduction of invasive species, water contamination, and transmission of zoonotic diseases. In addition, this study explored respondents' opinions on various actions that could be taken to mitigate the adverse effects of FRDAs on the ecosystem and public health.

Statistical analysis

Pie charts and bar plots were used to visualize the responder's information. Chi-square tests were employed to determine whether there were

significant variations in responses based on the respondents' status (resident or tourist), gender, age category, and source of information on Batuco wetland. Subsequently, the qualitative variables from the survey were subjected to categorization to obtain four quantitative variables representing: (1) perception of FRDAs in the Batuco wetland; (2) knowledge about the ecological risks posed by FRDAs; (3) knowledge about the health risks to humans and other animals caused by FRDAs; and (4) knowledge about actions to reduce the effects of FRDAs. A value of 0 was assigned when respondents did not perceive the presence of FRDAs in the Batuco wetland, did not recognize their associated risks, or did not suggest or select measures to mitigate these risks. Conversely, a value of 1 was assigned when respondents acknowledged the presence of FRDAs and their associated risks. In addition, each identified FRDA species, risk factor, and proposed mitigation action was assigned a score of 1 point. This method facilitated the conversion of textual data from the survey into quantifiable scores reflecting respondents' perceptions, risk awareness, and proposed mitigation actions regarding FRDAs in the Batuco wetland. For questions utilizing a rating scale (such as "very much agree", "agree", "neutral", "disagreement", and "very much disagreement"), a 6-point Likert scale was used. In this scale, a value of 6 was assigned to the "very much agree" option, 1 to the "very much disagree" option, and 0 for missing responses. These points were summarized in the variable knowledge about actions to reduce the effects of FRDAs.

General linear models with a Poisson error distribution and log function were used to test whether: (1) the perception of FRDAs in Batuco wetland; (2) the perception of ecological risks caused by FRDAs; (3) the perception of risks to both human and other domestic animal health caused by FRDAs; and (4) knowledge about actions to reduce the effects caused by FRDAs are predicted by respondents' characteristics. To this end, separate models were fitted with the aforementioned variables as response variables. The predictors included were status (resident or tourist) and gender, based on previous Chi-square tests, which indicated that these variables significantly influenced respondents' opinions (see above). Finally, Spearman's correlation was employed to assess potential correlations among the four quantitative variables. All analyses were conducted using the R Base, Tidyverse [53], and lme4 [54] packages in the R Studio environment [55].

Results

Descriptive analyses of the study population

Age categories, gender, status (resident or tourist), and the source of information where responders learned about Batuco wetland were adequately represented among the total respondents (Figures-1a-d), allowing for subsequent statistical analyses. Regarding

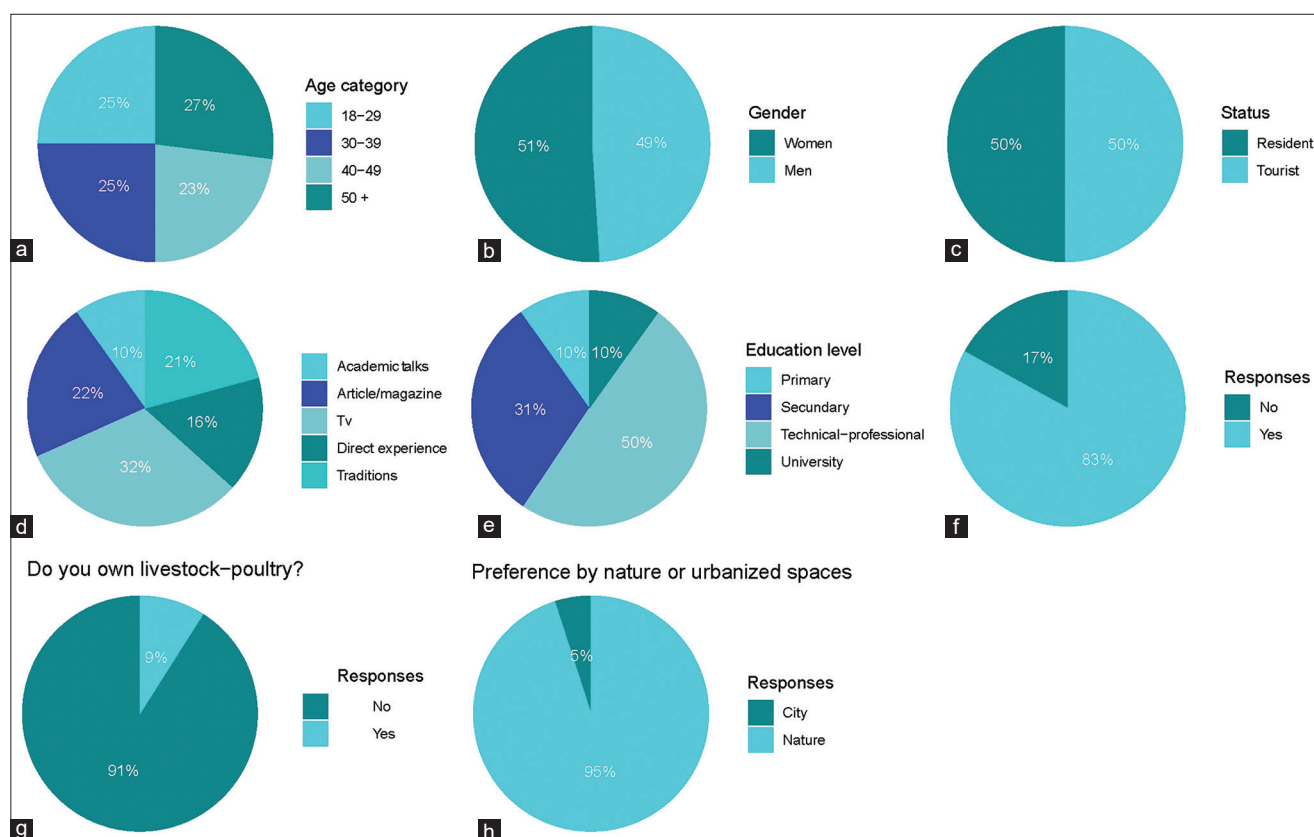


Figure-1: The figure shows the characteristics of the study population. (a) age categories, (b) gender distribution, (c) status (resident or tourist), (d) information source where learned about the Batuoco wetland, (e) Education level, (f) whether they owned pets (dogs and/or cats), (g) whether they owned livestock-poultry and (h) Their preference regarding nature or urbanized spaces.

educational level, to mitigate potential biases from the disproportionate representation of secondary education (29%; $n = 115$) and technical-professional education (49%; $n = 196$) compared to the sparsely represented group of individuals without formal education ($n = 3$), respondents were categorized into primary, secondary, technical-professional, and university levels. The category of students without formal education was excluded from the analysis (Figure-1e). Despite re-categorizing educational levels, the variable exhibited significant underrepresentation in the two categories (10% primary and 10% university). Consequently, random sub-sampling was employed in subsequent analyses to address this limitation. In cases where obtaining a minimum of 10 responses per category was not feasible, the decision was made to exclude that specific response variable from further analyses to mitigate potential biases arising from underrepresented opinions. Similarly, 83% ($n = 324$; Figure-1f) of the respondents were identified as pet owners, compared to only 9% ($n = 36$; Figure-1g) who were identified as livestock (including poultry) owners. In addition, 95% of the respondents ($n = 380$; Figure-1h) preferred natural environments over urban settings. Given the impracticality of random sub-sampling for the underrepresented categories of these variables due to their limited representation, the decision was made to exclude these variables from subsequent analyses.

Perceptions of FRDA in the Batuoco wetland

The results revealed that 73% of the respondents ($n = 292$) believed that FRDAs existed within the Batuoco wetland and its environs (Figure-2a). Variation in opinions was observed based on respondents' status as either residents or tourists ($\chi^2 = 73.24$, $df = 1$, $p < 2.2e^{-16}$). Specifically, residents more frequently expressed that they believe FRDAs are presented in the Batuoco wetland than tourists (Figure-2b). In terms of the prevalence of FRDAs, dogs (25%), cows (20%), and horses (19%) were the most commonly observed animals within the Batuoco wetland and its surroundings (Figure-2c). Factors such as gender ($\chi^2 = 0.62$, $df = 1$, $p = 0.43$), age categories ($\chi^2 = 3.43$, $df = 1$, $p = 0.32$), and source of information from which respondents learned about Batuoco ($\chi^2 = 0.62$, $df = 1$, $p = 0.24$) did not emerge as statistically significant determinants of respondents' viewpoints.

Perception of the ecological risks caused by FRDAs in the Batuoco wetland

About 81% of the respondents ($n = 322$) believed that FRDAs within the Batuoco wetland were responsible for causing some form of harm (Figure-3a). Tourists more frequently expressed the belief that FRDAs cause harm in the Batuoco wetland than residents ($\chi^2 = 7.92$, $df = 1$, $p = 0.01$; Figure-3b). Neither gender ($\chi^2 = 1.66$, $df = 1$, $p = 0.19$), age categories ($\chi^2 = 6.45$, $df = 1$, $p = 0.09$) nor source of information

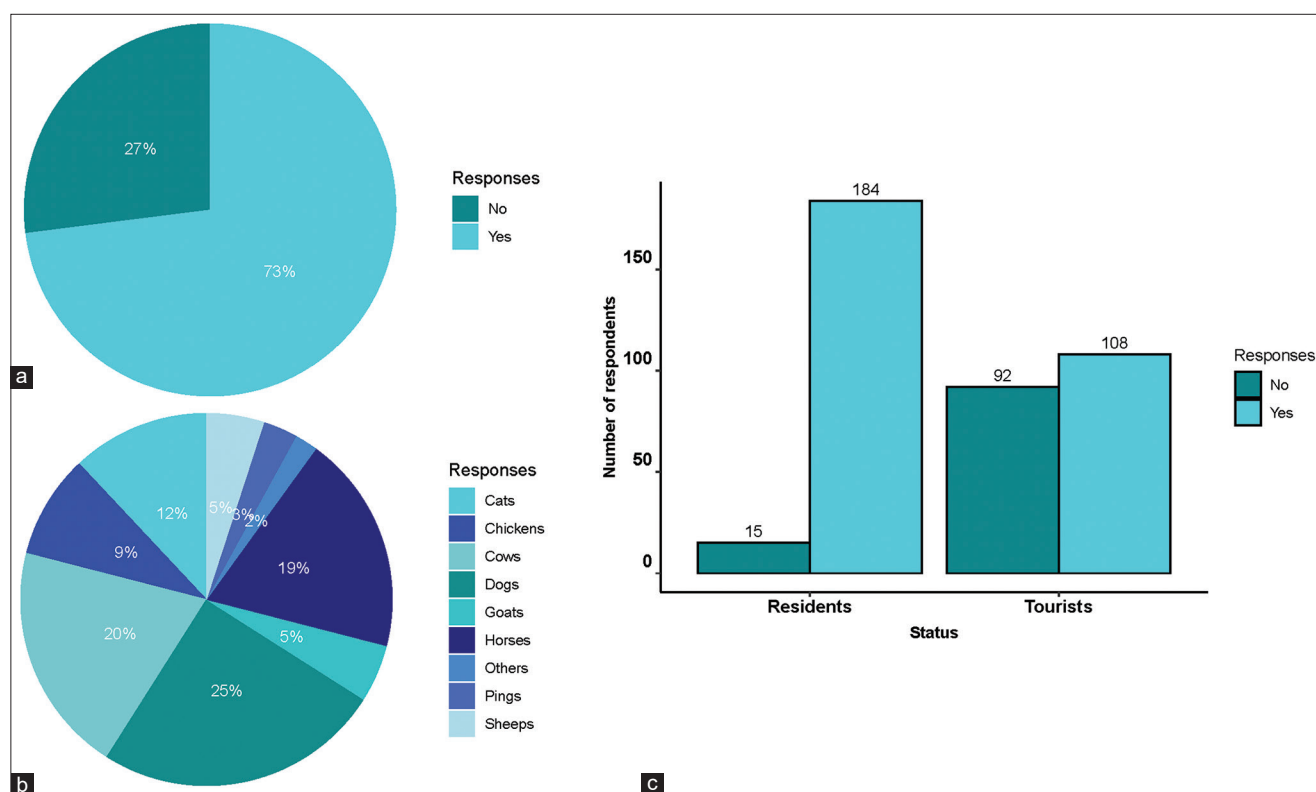


Figure-2: The figure shows the respondents responses regarding their perception of FRDAs in the Batuco Wetland. (a) Do you believe there are FRDAs in the Batuco wetland and its surroundings? (b) Which animals can be seen freely roaming in the wetland? FRDAs=Free-roaming domestic animals and (c) Do you believe there are FRDAs in the Batuco wetland and its surroundings?

on Batuco ($\chi^2 = 0$, $df = 1$, $p = 1$) emerged as statistically significant determinants of respondents' perspectives. When respondents were queried about the specific harms of FRDAs within the Batuco wetland, a majority expressed concerns about their harmful effects on wildlife and the ecosystem (Figure-3c). When giving their opinions freely, respondents also expressed concerns about detrimental effects such as fecal contamination, harm to plant life, disruption to bird populations, and broader ecosystem damage. The issue of dogs attacking people also emerged as a concern, whereas the potential transmission of infections was mentioned less frequently (Figure-3d). Some of these impacts exhibit significant variations according to gender and status. Women were more likely to recognize the threat posed by FRDAs related to fecal contamination and dog attacks on people and other domestic animals than men ($\chi^2 = 19.95$, $df = 1$, $p = 0.02$; Figure- 3e). Tourists were also more likely to acknowledge the ecological negative effects of FRDAs on wildlife, plants, birds, and the ecosystem than residents, and to a lesser extent, the potential transmission of infections to wildlife ($\chi^2 = 35.51$, $df = 1$, $p = 0.13$; Figure-3f). Conversely, residents were more likely to identify effects associated with fecal contamination and dog attacks on people and other domestic animals ($\chi^2 = 116.98$, $df = 1$, $p = 0.001$; Figure-3f). Age categories ($\chi^2 = 35.51$, $df = 1$, $p = 0.13$) and sources of information from which respondents learned about Batuco ($\chi^2 = 35.51$, $df = 1$, $p = 0.13$) did not emerge as

statistically significant determinants of respondents' perspectives.

Perception of health risks caused by FRDA in the Batuco wetland

A significant proportion of the surveyed individuals (91%, $n = 356$) expressed the belief that livestock (including poultry) can transmit diseases to other animals and humans (Figure-4a). This belief was significantly varied based on gender and status. Specifically, women ($\chi^2 = 6.72$, $df = 1$, $p = 0.03$) and tourists ($\chi^2 = 11.66$, $df = 1$, $p = 0.003$) were more likely to express this belief than men (Figure-4b) and residents (Figure-4c). On the other hand, age categories ($\chi^2 = 7.02$, $df = 1$, $p = 0.32$) and source of information about Batuco ($\chi^2 = 12.68$, $df = 1$, $p = 0.24$) were not found to be statistically significant determinants of respondents' perspectives. In response to the question about which diseases can be transmitted by livestock (including poultry) to other animals and humans, 48% of the respondents ($n = 180$) indicated that they were uncertain about the specific diseases that could be transmitted by livestock (including poultry). Meanwhile, 11% ($n = 42$) specified avian influenza as a potential disease (Figure-4d). A few respondents mentioned unspecified conditions caused by parasites, general infections, viral infections, and other diseases. Tourists more frequently reported that livestock (including poultry) could transmit avian influenza than residents ($\chi^2 = 15.74$, $df = 1$, $p = 0.001$; Figure-4e). Factors such as gender ($\chi^2 = 3.75$, $df = 1$,

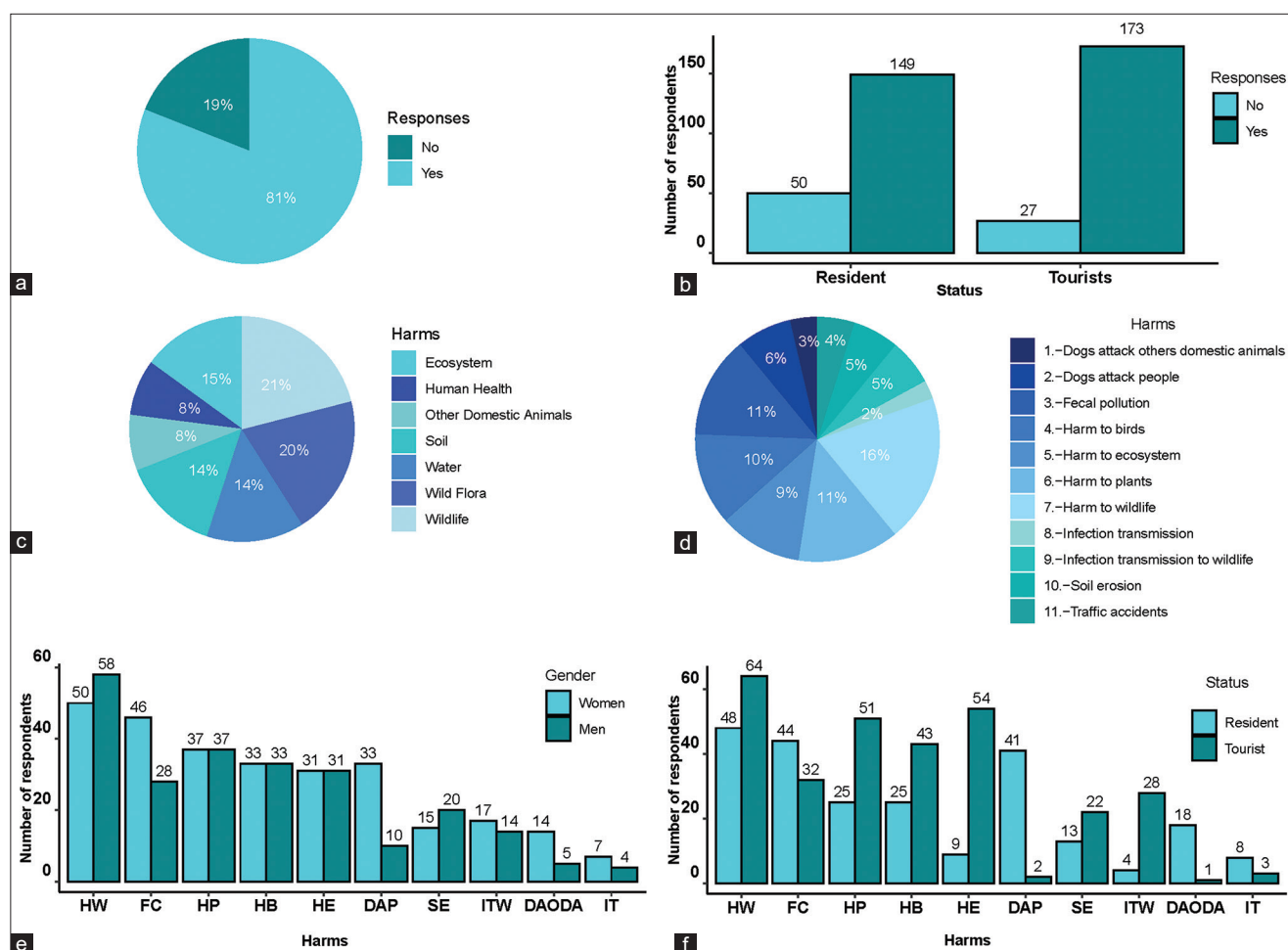


Figure-3: The figure shows the respondents' responses regarding the ecological harm caused by FRDAs in the Batuco Wetland. (a) Do you believe that the FRDAs in the Batuco wetland cause any harm? (b) Do you believe that FRDAs in the Batuco wetland causes any harm? (c) Which harms can be caused by FRDAs in the Batuco wetland? (d) Open opinion: Could you specify what harms are caused by FRDAs? (e) What effects are generated by the FRDAs of domestic animals? (f) What harms are generated by the FRDAs of domestic animals? HW=Harm to wildlife, FC=Fecal contamination, HP=Harm to plants, HB=Harm to birds, HE=Harm to ecosystems; DAP=Dog attack to people, SE=Soil erosion, ITW=Infection transmission to wildlife, DAODA=Dog attacks other domestic animals, IT=Infection transmission, FRDAs=Free-roaming domestic animals.

$p = 0.30$), age categories ($\chi^2 = 13.44$, $df = 1$, $p = 0.15$), and source of information about Batuco ($\chi^2 = 0.05$, $df = 1$, $p = 1$) did not emerge as statistically significant determinants influencing respondents' perspectives. Regarding pets, 82% ($n = 315$) of those surveyed believed that pets (dogs/cats) can transmit diseases to other animals and humans (Figure-5a). Women indicated more frequently than men that pets can transmit diseases to other animals and humans ($\chi^2 = 5.48$, $df = 1$, $p = 0.02$; Figure-5b). Status ($\chi^2 = 3.11$, $df = 1$, $p = 0.06$), age categories ($\chi^2 = 8.32$, $df = 1$, $p = 0.05$), and source of information about Batuco ($\chi^2 = 5.46$, $df = 1$, $p = 0.35$) were not statistically significant determinants of respondents' standpoints.

When asked which diseases can be transmitted by pets to other animals and humans: 21% ($n = 98$) indicated that they did not know which diseases can be transmitted, followed by 21% mentioning rabies ($n = 89$), 10% citing parasites ($n = 46$), and 7% specifying ringworms. Other conditions, such as scabies, fleas, distemper, and toxoplasmosis, were also noted

(Figure-5c). Female respondents showed greater knowledge about diseases that can be transmitted by pets than male respondents ($\chi^2 = 8.77$, $df = 1$, $p = 0.02$; Figure-5d). Factors such as age categories ($\chi^2 = 13.45$, $df = 1$, $p = 0.14$) and sources of information from which respondents learned about Batuco ($\chi^2 = 0.05$, $df = 1$, $p = 1$) did not emerge as statistically significant determinants of respondents' perspectives.

Knowledge of actions to reduce the effects of FRDAs in the Batuco wetland

When asked respondents what actions they think are most suitable for reducing the impact of FRDAs on the ecosystem and human health, 24% ($n = 127$) of respondents indicated responsible ownership, followed by 17% ($n = 88$) suggesting enclosing the wetland area, and 9% ($n = 50$) mentioning education (Figure-5e). Other actions, such as prohibiting pet access, inspections, and increased security, were also mentioned (Figure-5e). The proposed actions varied significantly depending on status, with residents ($\chi^2 = 48.14$, $df = 1$, $p = 0.001$; Figure-5f) more frequently

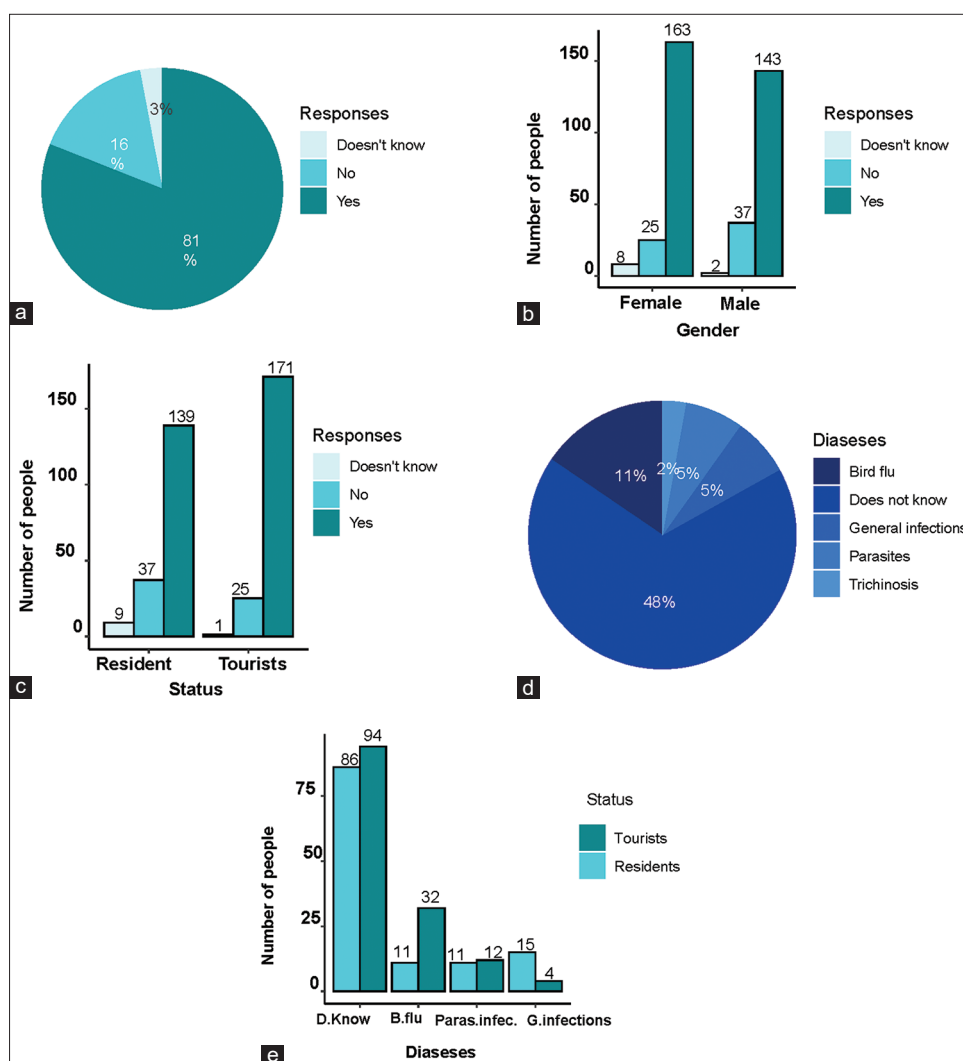


Figure-4: The figure shows the respondents' responses regarding whether livestock can transmit diseases to other animals and humans. (a) Do you believe that livestock can transmit diseases to other animals and humans? (b) Do you believe that livestock can transmit diseases to other domestic animals and humans? (c) Do you believe that livestock can transmit diseases to other animals and humans? (d) Could you specify what diseases can be transmitted by livestock (including poultry) to other animals and humans? and (e) Could you specify what diseases can be transmitted by livestock (including poultry) to other animals and humans?

advocating for responsible ownership, while tourists primarily proposed enclosing the wetland area and education. Age categories ($\chi^2 = 6.61$, $df = 1$, $p = 0.34$), gender ($\chi^2 = 5.15$, $df = 1$, $p = 0.07$), and source of information on Batuco ($\chi^2 = 0.01$, $df = 1$, $p = 1$) were not statistically significant determinants of respondents' standpoints. When respondents were presented with a set of actions aimed at mitigating the negative effects of FRDAs, rated on a scale from "very much agree" to "very much disagree" (Table-1), it was found that over 50% of the respondents strongly agreed with these actions. However, exceptions were observed for the actions "assistance for dogs and cats feeding" and "assistance for livestock and poultry feeding (forage and water)," where only 28.3% and 42.36% of respondents, respectively, strongly agreed (Table-1).

Modeling the perception, risks, and mitigation actions of FRDAs in the Batuco wetland

These models support the observed trends. First, residents exhibited a notably higher perception of

the presence of FRDAs in the Batuco wetland compared to tourists (Table-2). Second, there is a statistically significant difference in the perception of health risks (Table-2) and ecological risks (Table-2) between women and men, with women expressing a higher level of perception in both categories. Third, tourists perceive ecological risks more acutely than residents (Table-2). Regarding knowledge about actions to mitigate the negative effects of FRDAs, both women and men exhibited significantly higher awareness, as indicated by a greater number of actions listed (Table-2).

Relationships among perception, risk, and mitigation actions associated with FRDAs in the Batuco wetland

The perception of FRDAs in the Batuco wetland showed a low but significant correlation with knowledge about ecological risks ($r = 0.15$; $p = 0.005$) and health risks ($r = 0.14$; $p = 0.003$) caused by these animals. However, there was no significant correlation between the perception of FRDAs and the actions proposed to mitigate their effects in the wetland ($r = 0.014$;

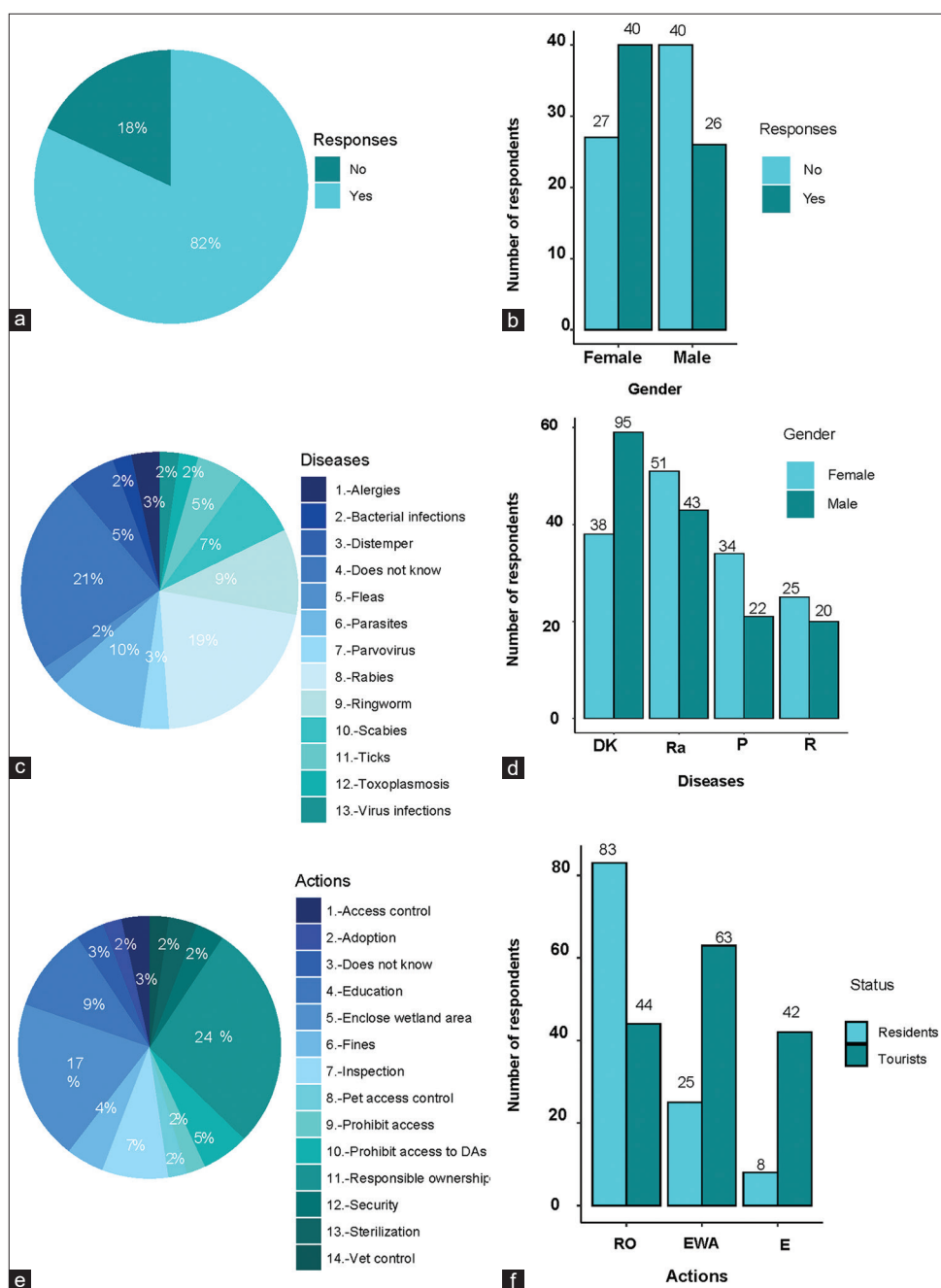


Figure-5: The figure shows the respondents' responses regarding whether pets can transmit diseases to other animals and humans and about actions linked to mitigate the effects of FRDAs in the Batuco wetland. (a) Do you believe that pets can transmit diseases to other animals and humans? (b) Do you believe pets (dogs/cats) can transmit diseases to other animals and humans? (c) Could you specify what diseases pets can transmit to other animals and humans? (d) Could you specify what diseases pets can transmit to other animals and humans? (e) What actions do you think are the most suitable for reducing FRDAs effects? (f) What actions do you think are the most suitable for reducing FRDAs effects? DK=Doesn't know, Ra=Rabie, P=Parasite, R=Ringworm, RO=Responsible ownership, EWA=Encompassing the wetland area, E=Education, FRDAs=Free-roaming domestic animals.

$p = 0.76$). Perceptions about ecological and health risks were positively and significantly correlated with each other ($r = 0.54$; $p = 3.57 \times 10^{-31}$). Likewise, both variables were positively and significantly correlated with the number of proposed actions (ecological risks: $r = 0.88$; $p = 2.22 \times 10^{-20}$; health risks: $r = 0.85$; $p = 2.48 \times 10^{-22}$).

Discussion

Results indicate that the perception of FRDAs differs significantly between residents and tourists,

with residents showing a higher perception of the presence of these species than tourists. This finding aligns with previous studies suggesting that people living in the area are more attuned to the environment and have a better understanding of local wildlife dynamics than tourists. This emphasizes the influence of familiarity and local experiences on individual perceptions of the local environment [56]. The prevalence analysis of FRDAs identified dogs, cows, horses, and cats as the most common FRDAs

Table-1: Percentage of respondents' opinions on mitigating the negative effects of free-roaming domestic animals in the Batuco wetland.

Actions	Very much in agreement (%)	Agree (%)	Neutral (%)	Disagreement (%)	Very much in disagreement (%)	NA (%)
Inspection of muleteers, livestock, and poultry owners	64.16	18.55	7.77	0.75	1.75	7.02
Inspection of loose dog and cat owners	71.43	14.79	5.01	0.75	0.75	7.27
Education for responsible pet ownership	80.70	7.77	3.26	0.25	0.75	7.27
Education for responsible livestock and poultry ownership	78.45	9.02	3.76	0.50	1.00	7.27
Assistance with fence construction	61.90	14.54	8.52	2.76	4.76	7.52
Fencing off the lagoon area	52.88	12.53	12.53	5.26	7.77	9.02
Prohibition of pets entering wetland areas	57.14	8.52	11.78	6.02	9.27	7.27
Prohibition of livestock from entering wetland areas	67.67	10.03	8.27	3.01	4.01	7.02
Assistance with livestock and poultry feeding (forage and water)	42.36	20.55	16.04	5.26	7.52	8.27
Assistance with dog and cat feeding	28.32	18.05	18.80	10.03	16.29	8.52
Education on the risks associated with free roaming of domestic animals	76.44	9.27	4.26	0.25	2.01	7.77
Adoption campaigns for ownerless domestic animals	69.67	12.28	6.27	0.75	3.01	8.02
Veterinary support (sterilization, vaccines, medical check-ups, others)	78.95	8.27	3.51	0.50	1.25	7.52

Table-2: Linear models showing the relationship between perception and knowledge about the risks of FRDAs according to the status (resident/tourist) and gender (female/male) of the respondents (n=399).

Effect of FRDA perception	Estimate	SE	p-value
Intercept	1.49	0.04	<2e-16***
Status ^a	-0.73	0.05	<2e-16***
Gender ^a	-0.00	0.05	0.966
Effects on the perception of health risks	Estimate	SE	p-value
Intercept	1.77	0.04	<2e-16***
Status ^a	0.00	0.04	0.92
Gender ^a	-0.18	0.04	3.08e-05***
Effect of perception of ecological risks	Estimate	SE	p-value
Intercept	1.54	0.03	<2e-16***
Status ^a	0.24	0.04	5.74e-08***
Gender ^a	-0.09	0.04	0.02*
Knowledge about actions to reduce the effects of FRDAs	Estimate	SE	p-value
Intercept	3.79	0.01	<2e-16***
Status ^a	0.13	0.01	<2e-16***
Gender ^a	-0.09	0.01	1.45e-09***

FRDA=Free-roaming domestic animals. ^aParameter estimates and se were estimated relative to "tourist" level in the variable Status and "male" level in the gender variable. Significant codes: 0***; 0.001**; 0.01*; 0.05, SE=Standard error

in the Batuco wetland. This finding aligns with global trends, in which dogs are known to be among the most common types of FRDAs worldwide [57, 58]. In addition, the presence of free-roaming domestic cats, influenced by increased human density in peri-urban

areas such as Batuco, is recognized as a longstanding international conservation issue, highlighting the complex dynamics between FRDAs and human settlements [59, 60]. In line with this, most respondents recognized that FRDA causes damage to the ecosystem. Tourists highlight the negative effects on wildlife, while residents are more concerned about fecal contamination and dog attacks on people and other animals. These contrasting views of tourists are often influenced by their distinct roles, experiences, and priorities within a community or ecosystem [56]. Tourism often brings individuals closer to natural habitats and wildlife, fostering heightened awareness of the adverse impacts of anthropogenic factors. Tourists may emphasize these effects due to their immersive but temporary experience in the environment, which includes wildlife encounters and direct observation of ecosystems [61, 62]. In contrast, residents' attitudes toward wildlife and their use can influence their perceptions of the impacts of FRDAs. Concerns about contamination by feces and attacks by dogs may stem from the immediate and tangible experience of these issues in the community [63].

Regarding the health impacts of FRDAs, most respondents believed that livestock (including poultry) and pets can transmit diseases to other animals and humans. However, many respondents were uncertain about the specific types of diseases transmitted by livestock and poultry. In the case of pets, only rabies and parasites were commonly mentioned. This finding highlights a knowledge gap regarding zoonotic diseases in the study population. Historically, there has been a disconnect between the human, veterinary, and environmental health sectors, which has contributed to challenges in effectively communicating information

about zoonotic diseases to the public [64–66]. Evidence indicates that the lack of integration between humans, veterinary and environmental health sectors has hindered the understanding and management of zoonotic diseases. This issue is particularly acute in developing countries, where the burden of zoonotic diseases is high but is often underestimated due to a lack of diagnosis and underreporting [66]. The emergence of zoonotic diseases is closely linked to agricultural intensification, environmental changes, and human activities that facilitate interactions among wildlife, domestic animals, and humans [67, 68]. Our findings underscore the critical need for enhanced communication and education within communities to understand these interactions and the risks they pose, which is essential for preventing disease spillover and mitigating public health threats [67]. The One Health approach, which emphasizes the interconnectedness of human, animal, and environmental health, is pivotal in addressing these challenges [46].

Moreover, the results indicate that women exhibit a heightened awareness of the health and environmental risks associated with FRDAs. Research suggests that women are generally more concerned about ecological and health risks than men [69]. Several factors may contribute to this difference in perception. For instance, women traditionally shoulder a significant portion of caregiving responsibilities within families and communities, which often makes them more attuned to health risks that could affect their children, elderly family members, and other dependents. Their daily activities frequently involve managing household health and hygiene, thereby increasing their awareness of potential health threats and the importance of maintaining a healthy environment [70]. In addition, studies have shown that women are more likely to seek health information and engage in preventive health behaviors [71]. Women also tend to exhibit higher levels of empathy and a greater propensity for nurturing behaviors [72], which may translate into a broader concern for community health and environmental well-being.

Similarly, knowledge about actions to mitigate the effects of FRDAs in the Batuco wetland is influenced by the perspectives of residents, tourists, and gender. Residents who face daily challenges and potential risks associated with interactions among humans, domestic animals, and wildlife, often emphasize responsible ownership practices to address these issues. Conversely, tourists who may have a more temporary experience in the area are more likely to suggest physical measures such as enclosing the wetland and educational initiatives to tackle the challenges posed by FRDAs. Higher levels of empathy and nurturing behaviors among women [72] may also explain why women tend to be more knowledgeable about actions to mitigate the effects of FRDAs in the Batuco wetland. As expected, there is a direct correlation between perceptions of health risks and ecosystems caused by FRDAs and knowledge of mitigation actions. This

correlation suggests that people who are more aware of risks also have a better understanding of actions to mitigate those risks, underscoring the importance of disseminating knowledge about the risks associated with FRDAs to encourage protective actions for both the environment and public health.

Conclusion

Our findings underscore the importance of developing targeted educational initiatives to address the impacts of FRDAs on health and the ecosystem by focusing on residents and tourists. For instance, implementing community engagement programs using a One Health approach can help promote responsible pet ownership and emphasize the crucial role of pet ownership in biodiversity protection and disease prevention. In addition, providing educational materials about the dual impact of FRDAs on human health and the ecosystem in strategic locations can help raise awareness among tourists. Moreover, there is a need to develop targeted educational programs based on the One Health approach to improve knowledge and awareness of zoonotic diseases. These programs should involve health professionals, veterinarians, and ecologists to provide a holistic understanding of disease transmission. Promoting the participation of men and women in these programs is key to reducing gender gaps in ecological and health risk awareness associated with FRDAs. These programs should align with integrated management plans involving local authorities, veterinary services, and environmental agencies to control FRDAs through sterilization programs, vaccination campaigns, and stricter regulations on animal ownership.

Finally, sample size, geography, and the lack of longitudinal data limitations could affect the study's representativeness. Thus, future efforts that allow the study to expand to other regions and ecosystems will help determine whether the findings and proposed interventions are applicable in different contexts to the effective management of FRDAs and their impacts on health and ecosystems.

Data Availability

Supplementary data, including questionnaires, can be available from the corresponding author upon request.

Authors' Contributions

YP: Conceptualization, project administration, formal analysis, and writing of the original draft. CS and TP: Survey administration and data collection. YP, FDP, MF, IB, and RJ: Survey transcription and database creation. IB, FDP, MF, CS, TP, and RJ: Methodology and manuscript review. All authors have read, reviewed, and approved the final manuscript.

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Competing Interests

The authors declare that they have no competing interests.

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