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# Knowledge, risk perceptions and practices regarding rodents and their associated pathogens: environmental consultants in Chile

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## Abstract

**Background** Rodents play essential ecological roles but are also significant reservoirs of zoonotic pathogens, posing risks to humans. Individuals with frequent occupational contact with rodents face an elevated risk of exposure to rodent-borne diseases. This study examines the knowledge, risk perceptions, and practices of Chilean environmental consultants (ECs) concerning rodents and rodent-borne diseases.

**Methods** A 32-item questionnaire, which focused primarily on biologists, veterinarians, and environmental engineers, was administered. The questionnaire included closed, open-ended, and semi-open-ended questions. Data analyses, performed using R software, involved calculating frequencies and proportions for questions related to knowledge of rodents and rodent-borne diseases, rodent management and handling, biosafety procedures, and training. Additionally, generalized linear models (GLMs) were used to assess knowledge of rodent hosts and diseases, whereas correspondence analysis was used to examine associations between EC characteristics (undergraduate fields of study and years of experience) and responses regarding risk perception and the importance of zoonotic disease training.

**Results** Completed questionnaires were received from 206 ECs. Although the ECs demonstrated a strong awareness of hantavirus cardiopulmonary syndrome, identifying it as a significant rodent-borne threat, knowledge gaps were evident regarding the specific role of certain rodent reservoir species and other rodent-borne diseases in Chile. For example, leptospirosis was well recognized, particularly among veterinarians, whereas emerging zoonoses such as scrub typhus was rarely mentioned. The study also revealed the frequent use of live trapping and direct handling of rodents, resulting in injuries to 32% of the respondents. Despite the widespread use of personal protective equipment, key elements such as respiratory protection and disposable suits were underutilized, and inadequate cleaning practices for traps were reported. Nevertheless, ECs expressed a willingness to participate in zoonotic disease training, underscoring the need for further education.

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**Conclusions** This study highlights the critical need for ongoing education for ECs on rodent reservoirs, diseases, and biosafety measures to enhance their safety and reduce the risk of zoonotic infections. The findings offer valuable insights for developing strategies aimed at improving awareness and strengthening biosafety practices within this occupational group.

**Keywords** Biosafety measures, Ecological consultants, Occupational risks, Rodentia, Zoonoses risk

## Introduction

Rodents are the most diverse mammals in the world and play important ecological roles as seed dispersers, ecosystem engineers, and prey for a variety of predators [1]. They are also recognized as major reservoirs of zoonotic pathogens, with more than 85 zoonotic diseases associated with rodents [2–4]. Examples of rodent-borne diseases include viruses (e.g., Hantavirus disease, Lassa fever, and tick-borne encephalitis), bacteria (e.g., Lyme disease, plague, and leptospirosis), protozoa (e.g., toxoplasmosis, leishmaniasis, and Chagas disease), and helminths (e.g., hymenolepiasis, trichinellosis, and echinococcosis) [5]. The transmission of these diseases is influenced by the ecological dynamics of rodent populations and the environments they inhabit, which often overlap with human activities. Rodent reservoir hosts are frequently generalist species with a broad distribution [6] and can adapt to diverse environments, including rural and urban settings [7–9].

Human infections caused by rodent-borne pathogens are closely linked to socioenvironmental and behavioral factors that increase exposure to rodents, their pathogens, and vectors [10]. For example, rural dwellers, as well as agricultural and forestry workers, are at high risk of developing hemorrhagic fever with renal syndrome and Hantavirus cardiopulmonary syndrome (HCPS) [11]. Additionally, certain outdoor activities have been reported to increase the risk of Lyme borreliosis in Europe [12]. Individuals with frequent occupational contact with rodents, such as pest controllers, mammalogists, biologists, and environmental health specialists, face an elevated risk of exposure to rodent-borne diseases [13, 14]. For example, several cases of HCPS have been reported among field workers involved in rodent sampling and handling [15–17]. To mitigate the risks of zoonotic transmission during rodent handling, the appropriate use of personal protective equipment can significantly reduce transmission risk [18]. Moreover, a thorough understanding of zoonotic diseases, pathogen transmission routes, and proper rodent handling techniques can further minimize the risk of transmission [5, 18–20].

In many countries, environmental impact assessment (EIA) serves as a legal and administrative tool to manage the actual and potential environmental impacts associated with specific developments [21]. As part of EIA activities, field surveys, wildlife monitoring, and data collection are frequently conducted by professionals known as environmental consultants (ECs), also referred to as ecological or wildlife consultants. Consequently, these professionals may be exposed to zoonotic hazards (i.e., wild reservoirs and vectors) due to the nature of their fieldwork, which brings them into close proximity with wildlife. In Chile, South America, ECs working with wildlife represent a heterogeneous group, with backgrounds in various undergraduate disciplines, primarily biologists, veterinarians, environmental engineers, and forest engineers. While many Chilean ECs engage in the sampling and monitoring of small mammals as part of their activities, their knowledge and perceptions regarding rodents and rodent-borne diseases, as well as their biosafety practices when capturing and handling wild rodents, remain unassessed.

In Chile, a significant rodent-borne disease is HCPS caused by Andes virus (ANDV), which is considered the most important pathogenic hantavirus in South America [22]. Other rodent-associated pathogens found across various locations and habitats in the country include *Cryptosporidium* spp., *Giardia* spp., *Leptospira* spp., *Hymenolepis diminuta*, and *Trypanosoma cruzi*, among others [23–26]. Additionally, human cases of scrub typhus have been reported in central and southern Chile in recent years [27, 28], introducing another zoonotic disease transmitted by trombiculid mites associated with rodents [29, 30]. Notably, there is a documented case in which researchers in southern Chile acquired trombiculiasis and subsequently developed scrub typhus disease after sampling rodents and ectoparasites [31]. Finally, several wild native cricetid rodents from Chile, such as *Abrothrix olivaceus*, *A. longipilis*, *A. sarborni*, and *Oligoryzomys longicaudatus*, possess ecological and life history traits that place them among the rodent species with the greatest potential reservoir capacity for pathogens transmitted directly or environmentally worldwide [32].

Given the complex interplay between human health, wildlife, and ecosystems, a One Health approach is essential for understanding and mitigating the risks posed by rodent-borne zoonotic diseases. This framework emphasizes the need for interdisciplinary collaboration to address health challenges at the human–animal–environment interface. The objective of this study was to assess the knowledge, risk perceptions, and practices of Chilean ECs regarding rodents in the field and rodent-borne diseases. Our findings may help inform the development of strategies aimed at increasing awareness of the risks of exposure to rodent-borne diseases and improving biosafety practices when working with wild rodents.

## Materials and methods

### Study area

Chile, located in South America, spans a diverse range of climates and ecosystems due to its extensive longitudinal configuration, stretching over 4,300 km from north to south. These geographical characteristics create distinct climatic zones, from arid deserts in the north to cold temperate forests and rainy Patagonian regions in the far south. Chile is divided into macrozones (Fig. 1), each of which is defined by unique geographical and climatic features.

### Study design

A cross-sectional, questionnaire-based study was conducted among ECs working across Chile. The total number of Chilean ECs is unknown, and there is no information on the number of ECs performing specific tasks related to small mammals. Therefore, we did not calculate the sample size in advance. The survey was conducted between August 11 and October 12, 2021, with a total of 206 participants completing it.

The survey was distributed online through various strategies: (1) it was sent to several environmental consulting companies for distribution to their employees; (2) it was posted in a private Facebook group for ECs in Chile; and (3) it was shared on LinkedIn with individuals whose profiles indicated that they work as ECs in Chile. A brief description of the survey objectives was included in the invitation. Users who clicked on the invitation were provided with full study information, an opportunity to give informed consent, and a link to the survey (Google Forms; Google LLC; Menlo Park, California, USA). The survey was administered in Spanish. To be included in the sample, participants had to live and work as ECs in Chile and have worked with rodents in the last five years. If a participant did not meet the inclusion criteria, the survey was terminated.

The questionnaire was drafted by four researchers (AVR, EV, DAP, and DM-A) in consultation with individuals involved in environmental consulting, public health, and eco-epidemiology of rodent-borne diseases. A 32-item questionnaire was developed, which included closed, open, or semi-open questions. Likert scales were used for several questions to assess frequency or perception. The questions addressed (1) the respondents' sociodemographic, educational, and work-related information; (2) knowledge of rodent hosts and rodent-borne diseases; (3) perceptions of health risks; (4) information on the management and handling of rodents during sampling; (5) biosafety procedures during fieldwork; and (6) courses or training related to zoonotic diseases. The detailed questionnaire is available in Additional file 1.

### Data analysis

First, the data, including age, sex, undergraduate fields of study, and years of experience, were exported to

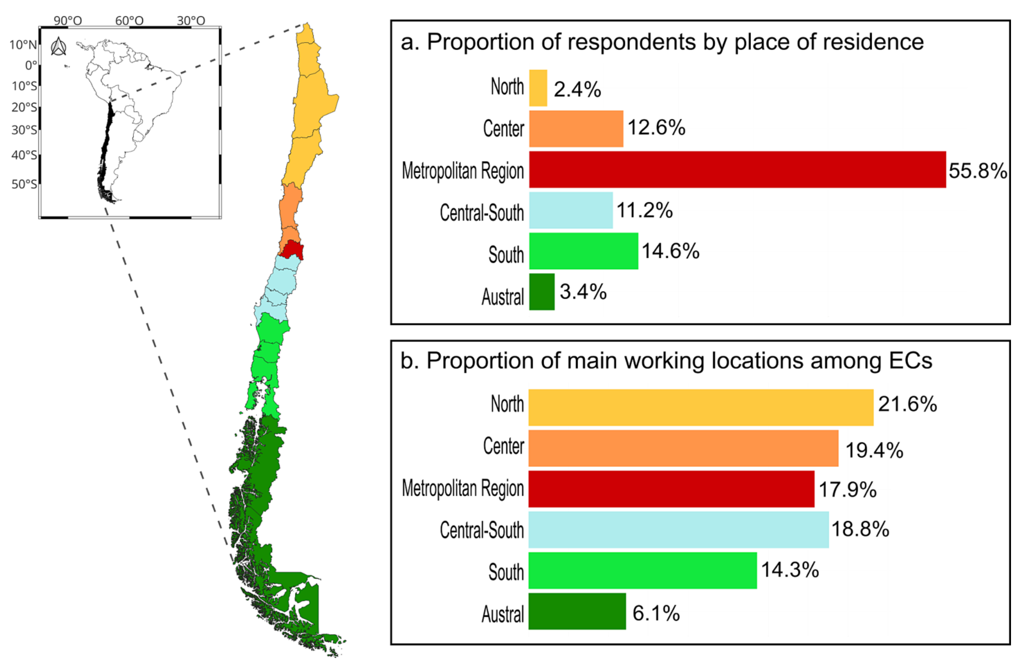


**Fig. 1** Map of Chile, South America. Different colors within the country represent the macrozones (North, Central, Central-South, and Austral), as well as the Metropolitan Region, where the capital city, Santiago, is located. The bar graphs display information on the respondents' places of residence and the locations where environmental consultants (ECs) conduct fieldwork, categorized by macrozones

Microsoft Excel for cleaning and analysis of the descriptive information of the respondents. Several questions related to knowledge of rodents and rodent-borne diseases, rodent management and handling, biosafety procedures, and training were analyzed descriptively by calculating relative frequencies and response frequencies. Some questions related to knowledge of rodent host species and rodent-borne diseases were analyzed using generalized linear models (GLMs) with a binomial distribution and logit link function. The dichotomous response variables for each model were whether a specific rodent species, disease, or pathogen was mentioned. The explanatory variables analyzed were EC characteristics (undergraduate fields of study and years of experience as an EC). Model selection for all GLMs was based on the corrected Akaike Information Criterion (AICc) [33]. To validate the selected models, goodness of fit was assessed through deviance analyses. The models were compared to null models, and those with statistical significance ($P<0.05$) were considered well-fitted.

**Table 1** Sociodemographic, educational, and work-related characteristics of respondents ($n=206$)

| Attribute | Response | Proportion of respondents (%) |
|---|---|---|
| Sex | Female | 49.8 |
| | Male | 57.3 |
| | Did not answer | 2.9 |
| Age (years) | 24–29 | 15.5 |
| | 30–39 | 49.5 |
| | 40–49 | 24.8 |
| | 50–59 | 6.8 |
| | 60–69 | 3.4 |
| Residence (Macro-zones) | North | 2.4 |
| | Center | 12.6 |
| | Metropolitan Region | 55.8 |
| | Central-South | 11.2 |
| | South | 14.6 |
| | Austral | 3.4 |
| Undergraduate fields of study | Biologist | 33.5 |
| | Veterinarian | 33.5 |
| | Environmental engineer | 25.2 |
| | Others | 7.8 |
| Educational levels | Graduate | 56.3 |
| | Master | 35.0 |
| | Doctorate | 7.3 |
| | Other | 1.4 |
| Work experience as EC (Years) | ≤ 2 | 19.0 |
| | 3–5 | 21.8 |
| | 6 – 10 | 35.9 |
| | > 10 | 23.3 |
| Periodicity in fieldwork (Times a year) | < 5 | 53.4 |
| | > 5 | 46.6 |
| Employment status as EC** | Employed | 43.7 |
| | Self-employed | 53.9 |
| | Did not answer | 2.4 |
| Time devoted as EC | Full-time | 49.0 |
| | Part-time | 51.0 |
| Main working locations as EC* (Macro-zones) | North | 22.0 |
| | Center | 19.7 |
| | Metropolitan Region | 18.2 |
| | Central-South | 19.2 |
| | South | 14.6 |
| | Austral | 6.3 |

*Respondents could choose more than one macro-zone of the country

** Employed: individuals who work for an employer under a contract or formal agreement; Self-employed: individuals who provide services independently

Correspondence analyses (CA) were conducted to explore the associations between EC characteristics (undergraduate fields of study and years of experience) and Likert scale responses related to the perceived risk of infection from rodent-borne diseases and the perceived relevance of zoonotic disease training. For the undergraduate field of study, we did not include the "other" group because of the small sample size. For the years of experience category, we separated respondents into two groups: "less experience" (less than one year to five years) and "more experience" (more than six years). We decided on this separation and no more groups to avoid having a very low number of responses for each group.

All analyses and graphs were performed using R software (R Core Team 2024), including the R packages 'MuMIn', 'factoextra', 'FactoMineR', 'ggplot2', and 'treemapify'.

The survey was approved by the Research Ethics Committee of the Faculty of Social Sciences, University of Chile (No. 16–21/2021). All participants were informed about the purpose of the questionnaire and had the option to decline participation or withdraw at any stage of the process. The responses were analyzed anonymously.

## Results

### Survey participation and respondent characteristics

The questionnaires were collected from 206 ECs, and their sociodemographic, educational, and work-related characteristics were analyzed. Specifically, these characteristics included sex, age, and residence (sociodemographic); undergraduate fields of study, and educational level (educational); as well as work experience, frequency of fieldwork, employment status, time dedicated to EC work, and main working locations (work-related). The detailed characteristics of the respondents are shown in Table 1. Regarding the residence of respondents, most ECs live in the Metropolitan Region of Chile (Santiago city), although their field activities as ECs are conducted across all macrozones of the country, with a lower frequency in the extreme southern zone (Austral Zone)

(Table 1; Fig. 1). The respondents' ages ranged from 24 to 69 years (median = 37 years), and the majority were male (57.3%). Most respondents (67%) held undergraduate degrees in biology or veterinary medicine, while a significant proportion (25.2%) had backgrounds in environmental engineering and related fields (e.g., environmental engineers, forestry engineers, agronomists, natural resources engineers), which were categorized under "environmental engineers". A smaller group (7.8%) held degrees that were not closely related to wildlife or environmental issues, including designers, biochemists, mechanical engineers, and civil engineers.

### Knowledge of respondents regarding rodent hosts and rodent-borne diseases

Most respondents (94.6%) mentioned the common or scientific name of at least one rodent species they considered relevant to the transmission of zoonoses (Table A.1), whereas 5.8% indicated that all rodent species present in Chile were relevant. Only two respondents indicated that no rodent species were relevant for zoonotic transmission, and one did not answer this question.

The most frequently mentioned rodent species was long-tailed colilargo (*O. longicaudatus*) (89.3%), the main reservoir of ANDV. Other rodent species mentioned less frequently by the ECs included invasive rats (*Rattus* spp.; 45%), house mice (*Mus musculus*; 22.8%), olive mice (*Abrothrix olivacea*; 19%), and shaggy mice (*A. longipilis*; 12%) (Table A.1). When the frequency of these species was analyzed using binomial GLMs, the best model for *O. longicaudatus* showed that ECs tended to mention this rodent species less frequently as their experience increased (Table 2). Although the p value was significant ($p = 0.004$), the standardized regression coefficient was low (β = -0.09). For *M. musculus*, *A. olivacea*, *and A. longipilis*, the binomial GLMs considering undergraduate fields of study and years of experience were not significant (Table 2). In the case of *Rattus* sp., the best models did not show a good fit ($\chi2 = 5.76$, df = 3, $P = 0.12$), indicating that the model did not adequately capture the underlying patterns or structure of the binary response variable. The best model for *Rattus* spp. indicated that veterinarians mentioned *Rattus* spp. significantly more often than environmental engineers did, while no significant differences were found among other professional groups (biologists and others) (Table 2).

Regarding knowledge of rodent-borne diseases, 29 diseases or pathogens were mentioned, with the most common being hantavirus (98%), leptospirosis (44.6%), salmonellosis (18.4%), and rabies (16.9%) (Fig. 2). While several of these diseases have been reported in Chilean rodents, 11 of the diseases or pathogens mentioned have not been documented in Chile or associated with rodents, based on the reviewed literature (Fig. 2). When the frequency of responses for the most common diseases was analyzed using binomial GLMs, veterinarians were significantly more likely to mention leptospirosis compared to all other undergraduate fields of study

**Table 2** Results of the best GLMs for response frequencies of known reservoir rodent species in Chile. Models were built for the fifth more mentioned rodents. Binomial (analyses of deviance) use goodness of fit against null models ($P < 0.05$ is interpreted as fit). When the null model is a better fit, then it replaces the other models. *P values < 0.05. The question was: which pathogens or zoonotic diseases transmitted by rodents in Chile do you know of?

| | β | ±SE | Z | *P* value | OR | CI low (2.5%) | CI high (97.5% |
|---|---|---|---|---|---|---|---|
| 1. *O. longicaudatus* (binomial GLM: $\chi2 = 8.13$, df = 1, $P = 0.004$) | | | | | | | |
| Intercept | 2.97 | 0.40 | 7.34 | < 0.001* | | | |
| Experience (years) | -0.09 | 0.03 | -2.91 | 0.004* | 0.91 | 0.86 | 0.97 |
| 2. *Rattus* sp. (binomial GLM: $\chi2 = 5.76$, df = 3, $P = 0.12$)[a] | | | | | | | |
| Intercept | 0.26 | 0.24 | 1.08 | 0.28 | - | - | - |
| Environmental engineer | -0.81 | 0.38 | -2.16 | 0.031* | 0.44 | 0.21 | 0.93 |
| Biologist | -0.64 | 0.35 | -1.87 | 0.062 | - | - | - |
| Others | -0.51 | 0.56 | -0.92 | 0.36 | - | - | - |
| 3. *Mus musculus* (binomial GLM: null model) | | | | | | | |
| Intercept | -1.22 | 0.17 | -7.34 | < 0.001* | | | |
| 4. *Abrothrix olivacea* (binomial GLM: null model) | | | | | | | |
| Intercept | -1.39 | 0.17 | -8.00 | < 0.001* | | | |
| 5. *Abrothrix longipilis* (binomial GLM: null model) | | | | | | | |
| Intercept | -1.98 | 0.21 | -9.28 | < 0.001* | | | |

[a]Veterinarian group is used as the reference category

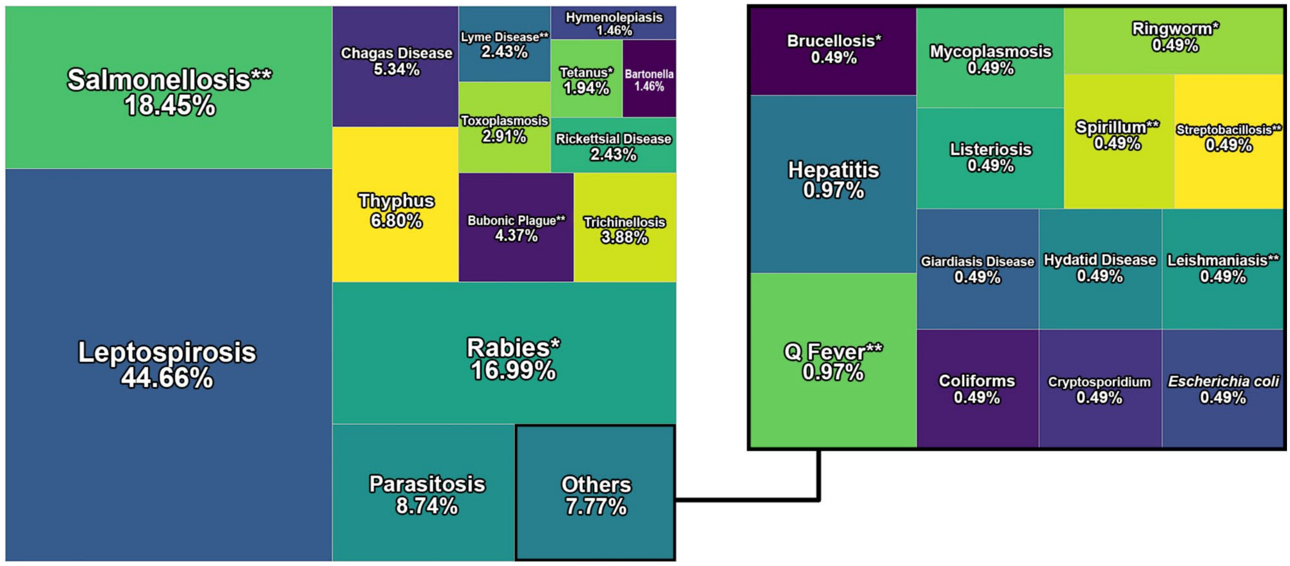


**Fig. 2** Percentage of responses to known rodent-borne pathogens or diseases in Chile (excluding hantavirus). The question was: *Which pathogens or zoonotic diseases transmitted by rodents in Chile do you know of?* One asterisk denotes diseases or pathogens not associated with rodents. Two asterisks denote diseases or pathogens associated with rodents but not yet reported in Chile

**Table 3** Results of the best GLMs for response frequencies of known rodent-borne diseases in Chile. Models were built for the fourth more mentioned diseases. Binomial (analyses of deviance) use goodness of fit against null models ($P<0.05$ is interpreted as fit). When the null model is a better fit, then it replaces the other models. *P values < 0.05. The question was: what rodent species of zoonotic importance do you know of in Chile?

| | β | ±SE | Z | *P* value | OR | CI low (2.5%) | CI high (97.5% |
|---|---|---|---|---|---|---|---|
| 1. Hanta<br>(binomial GLM: null model) | | | | | | | |
| Intercept | 3.92 | 0.50 | 7.77 | < 0.001* | | | |
| 2. Leptospirosis<br>(binomial GLM: $\chi 2=82.8$, df = 3, $P=0.000$)[a] | | | | | | | |
| Intercept | 1.90 | 0.36 | 5.31 | < 0.001* | | | |
| Environmental engineer | -3.10 | 0.49 | -6.39 | < 0.001* | 0.05 | 0.02 | 0.17 |
| Biologist | -3.27 | 0.47 | -7.00 | < 0.001* | 0.04 | 0.02 | 0.10 |
| Others | -2.41 | 0.63 | -3.83 | < 0.001* | 0.09 | 0.03 | 0.31 |
| 3. Salmonelosis<br>(binomial GLM: $\chi 2=11.06$, df = 3, $P=0.011$)[b] | | | | | | | |
| Intercept | -2.80 | 0.60 | -4.70 | < 0.001* | | | |
| Veterinarian | 1.83 | 0.65 | 2.80 | 0.005* | 6.21 | 1.73 | 22.32 |
| Biologist | 1.24 | 0.67 | 1.83 | 0.070* | - | - | - |
| Others | 1.69 | 0.83 | 2.04 | 0.041* | 5.44 | 1.07 | 27.64 |
| 4. Rabia<br>(binomial GLM: $\chi 2=9.26$, df = 4, $P=0.054$)[b] | | | | | | | |
| Intercept | -1.22 | 0.37 | -3.29 | 0.001* | | | |
| Veterinarian | -1.16 | 0.49 | -2.37 | 0.018* | 0.31 | 0.12 | 0.82 |
| Biologist | -1.15 | 0.49 | -2.36 | 0.018* | 0.32 | 0.12 | 0.82 |
| Others | -0.82 | 0.74 | -1.10 | 0.270 | | | |
| Experience (years) | 0.05 | 0.03 | 1.57 | 0.117 | | | |

a: Veterinarian group is used as the reference category

b: Environmental engineer group is used as the reference category

groups (Table 3). For salmonellosis, environmental engineers were six times less likely to mention this disease than veterinarians (odds ratio = 6.2) and five times less likely than those in the "other professions" group (odds ratio = 5.4). Conversely, environmental engineers were significantly more likely to mention rabies, three times more often than veterinarians and biologists (odds ratio = 0.31 for both comparisons) (Table 3). The GLM results for hantavirus, however, were not significant for either the undergraduate fields of study or years of experience (Table 3).

When asked which rodent-associated disease they considered the most serious, some respondents mentioned more than one disease (11.2%). Hantavirus was identified by 91.3% of the respondents, followed by rabies (9.1%), leptospirosis (3.8%), scrub typhus and Chagas disease (1.4% each), and *Salmonella* and plague (0.5% each). Regarding the routes of pathogen transmission from rodents to humans, the most frequently mentioned routes were airborne transmission (57.2%), feces (52.9%), urine (53.4%), direct transmission (40.7%), secretions (20.8%), vectors (15.5%), and fomites (12.6%).

### Perceptions of health risks related to rodents and their pathogens

Two questions were analyzed using CA. For the first Likert scale question, *How much of a risk do rodents pose to human health?*, no significant relationship between variables was found (EC groups and response; $\chi^2=20.01$, $p=0.46$). However, the cumulative variance percentage of the first two CA dimensions was high (96.9%), prompting further exploration through a contribution biplot [34]. Veterinarians with less experience are associated with "low risk" responses, with a slight influence from "medium risk" responses, whereas veterinarians with more experience are slightly associated with "low risk" responses (Fig. 3a). For biologists, "no risk" and "medium risk" responses are minimally associated with both experience levels (Fig. 3a). Environmental engineers with high experience are moderately associated with "high risk" responses and slightly associated with "very high risk", whereas those with low experience are slightly related to the "low risk" response (Fig. 3a).

For the second Likert scale question, *How likely are you to contract a zoonotic disease while working with rodents?*, no significant relationship between variables was found (EC groups and response; $\chi^2=23.99$, $p=0.24$). However, the cumulative variance percentage of the first two CA dimensions was high (84.6%). Veterinarians of both experience levels are positioned near the "neutral" and "very likely" responses, with more experienced veterinarians leaning toward "very likely" and the less experienced veterinarians leaning toward "neutral" (Fig. 3b). More experienced biologists are strongly associated with the "very unlikely" response, whereas less experienced biologists are weakly associated with the "likely" response (Fig. 3b). Less experienced environmental engineers are strongly linked to the "likely" response, whereas their more experienced counterparts are influenced by both "very unlikely" and "likely" responses.

### Training related to zoonoses and health risks

A total of 24.7% of respondents reported having attended a course, workshop, or seminar on zoonoses. Of these, 62.7% were veterinarians, 19.6% were biologists, 15.6% were environmental engineers, and 2% belonged to other professions. Regarding the venue of the course, 88% took place at universities, 4% at the Chilean Institute of Public Health (ISP), and 2% at environmental consulting companies and other public health agencies in Chile. When asked if they would be willing to take a course on zoonotic diseases, 73.8% of the respondents answered "yes", 21.8% answered "maybe", and 4.4% answered "no".

To assess the importance of zoonotic disease courses for professional activities, CA was conducted using the same characteristics as in the previous section (i.e., health risk perceptions). A chi-square test of independence revealed a significant relationship between undergraduate fields of study and responses ($\chi^2=34.19$, $p=0.02$), with the cumulative variance percentage of the first two CA dimensions being high (90.6%). Veterinarians (regardless of experience) are closely associated with "very important" responses (Fig. 3c). High-experience biologists are moderately associated with "very important", whereas low-experience biologists are more strongly associated with "moderately important" (Fig. 3c). Environmental engineers with high experience are linked to "important" and "moderately important" responses, whereas those with low experience are less associated with "important" (Fig. 3c). No group was close to the "not important" response.

### Work with rodents, exposures, and injuries

With respect to the methods used to study and monitor rodents, the survey results indicated that live trapping was the most commonly employed technique (91.7%). Other indirect techniques included camera trapping (61%), scat identification (54%), identification of biological remains (e.g., hair, bones) (51.4%), burrow identification (45%), and tracking of rodent footprints (37%). Overall, 73% of the respondents reported directly handling rodents. The most common activities are performed for the identification of rodent species, including photography and morphometric measurements, whereas the least common activities involved biological or ectoparasite sampling (e.g., collection of fleas, blood, and scat) (Fig. 4).

When asked if they had been injured while handling rodents, 32% of the respondents reported injuries. Specifically, 20% had been bitten, 3% had suffered scratches, and 9% had suffered both bites and scratches. None of the respondents reported being diagnosed with an illness related to rodent handling. Additionally, 52% considered handling specimens to be the most hazardous part of their work as an EC when dealing with rodents, 37%

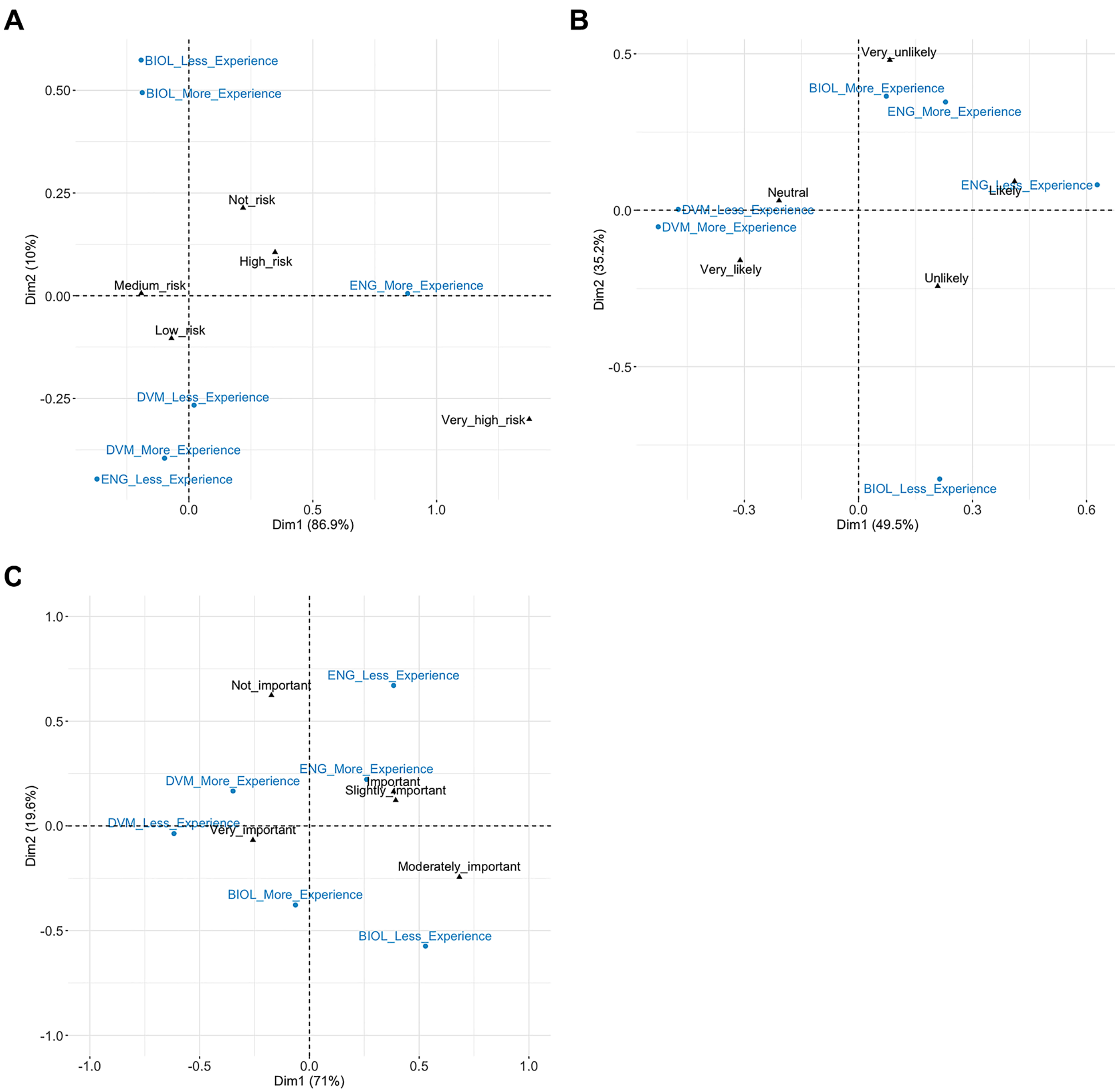


**Fig. 3** Correspondence analysis (CA) biplots. The light blue dots represent Likert scale variables, and the black triangles represent occupations grouped by experience. BIOL = biologist, DVM = veterinarian, ENG = environmental engineer. (**a**) Question: How much risk do rodents pose to human health? The first two dimensions (Dim1 and Dim2) explain 97% of the variance. (**b**) Question: How likely is it that you will contract a rodent-borne zoonotic disease in the course of your work? The first two dimensions (Dim1 and Dim2) explain 84.6% of the variance. (**c**) Question: How important do you consider a course on zoonotic diseases for your job? The first two dimensions (Dim1 and Dim2) explain 90.6% of the variance

identified handling traps to be the riskiest task, and 15% cited environmental factors, such as working in shaded areas, near streams, or in poorly ventilated locations, as the greatest risk.

## Protective measures

A total of 92% of the respondents reported disinfecting equipment used in the field, such as traps, clamps, and bags. Among them, 47% cleaned traps "after every rodent capture", 38% cleaned them "before or at the end of the trapping period" and 6% cleaned traps "only after some trapping periods". The most commonly used disinfectant was 70% bleach. Further details can be found in Figure A.1.

The use of personal protective equipment (PPE) during rodent sampling was reported by the majority of respondents (98%). However, there was a high variability in the type and frequency of PPE use. For example, while glove

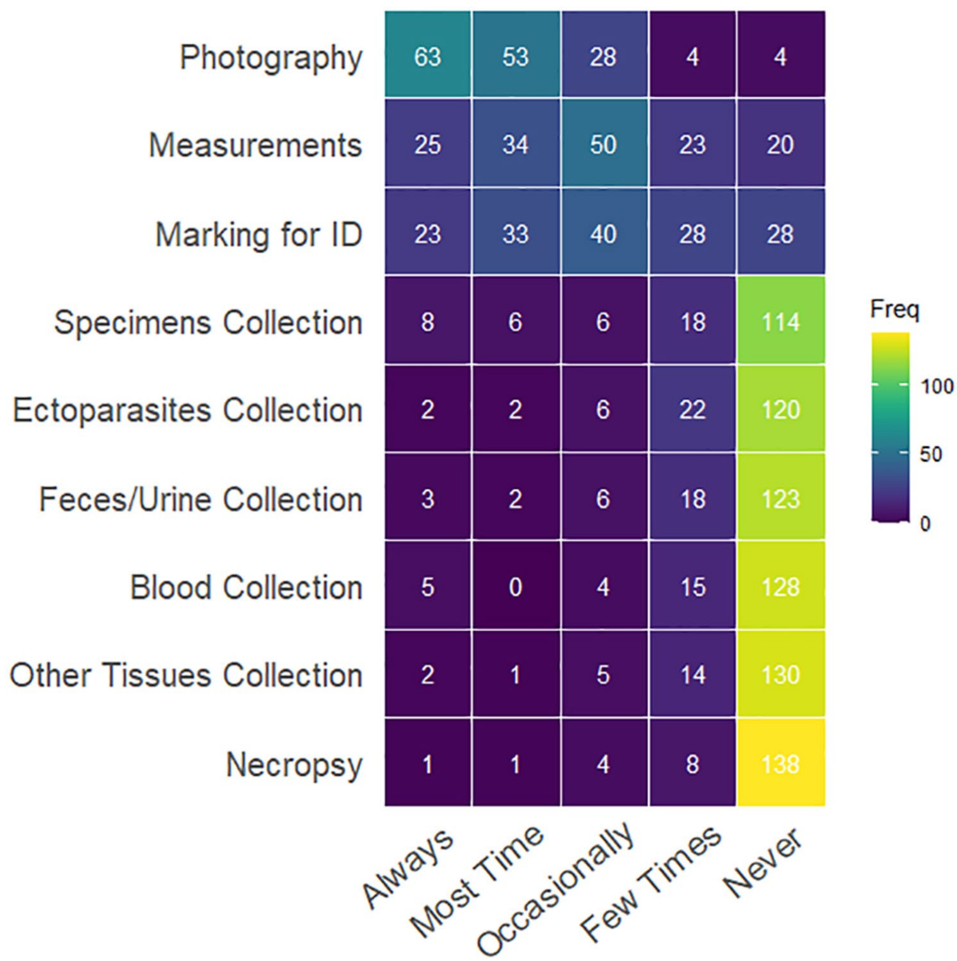


**Fig. 4** Frequency of response to the question: *Please indicate what type of activities you do with rodents*. The activity options are listed within the figure

use was common, appropriate clothing, such as disposable or reusable suits, was less frequently used, and some ECs reported never using masks (Fig. 5).

Regarding the provision of PPE, biosafety protocols, and usage instructions by employers (or by respondents themselves if self-employed), 93% of respondents indicated that PPE was provided by their employers. Additionally, 55% of the respondents reported receiving biosafety protocols from their employer, and 57% stated that they were given instructions on how to use the PPE.

## Discussion

This study offers valuable insights into the characteristics, knowledge, health risk perceptions, and practices of Chilean ECs concerning rodents and rodent-borne diseases. ECs working with rodents are diverse in terms of their undergraduate fields of study, years of experience, and time spent as ECs, among others. This heterogeneous group conducts fieldwork across various regions of Chile, potentially exposing them to a range of rodent species and their associated pathogens and vectors. The results, although local, highlight the need to assess how wildlife practices are conducted by ECs and companies globally.

### High awareness of hantavirus but discrepancies in the recognition of other pathogens and rodent reservoirs

Chilean ECs are highly aware of *O. longicaudatus*, the main reservoir of ANDV, and that HCPS is a significant rodent-borne disease in the country. ANDV is found in Chile and Argentina, is one of the most important zoonotic hantaviruses in the Americas [22], and is among the most lethal zoonoses in Chile, with a fatality rate approaching 35% [35]. Notably, ANDV is the only hantavirus known to be transmitted between humans through close contact [36]. For years, the Chilean Ministry of Health has conducted extensive campaigns to prevent hantavirus infections, which likely explains why ANDV and *O. longicaudatus* were the most frequently mentioned pathogen and rodent species, respectively, in this survey. However, despite this awareness, our results show that *O. longicaudatus* was mentioned less frequently as a pathogen reservoir among respondents with more years of experience working with rodents. Although this

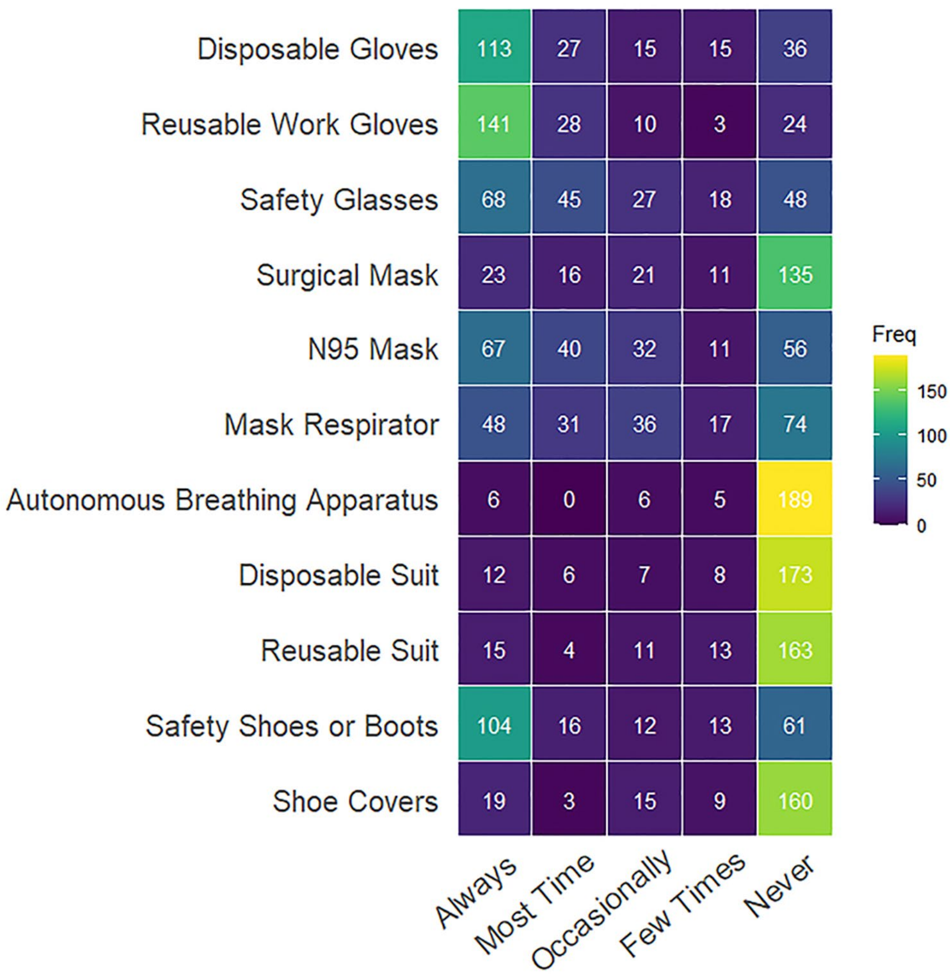


**Fig. 5** Frequency of response to the question: *Various items of personal protective equipment are presented; please check how often you use them*. The available options are shown in the figure

finding seems counterintuitive, it should be interpreted cautiously, as the model yielded a low regression coefficient. Nonetheless, these results underscore the need for continued training on the risks of rodent-borne zoonoses and their reservoirs for ECs.

After *O. longicaudatus*, the invasive rat *Rattus* spp. and the mouse *Mus musculus* were the most frequently mentioned by ECs. These rodents are well-known reservoirs of various pathogens globally [37, 38], including *Leptospira* spp., *Bartonella* spp., and *Hymenolepis diminuta* in Chile [23, 24, 39]. In particular, the black rat (*Rattus rattus*) is widespread across diverse habitats and ecosystems in the country [40, 41]. Among native rodents, *Abrothrix longipilis* and *A. olivaceus* were frequently cited. These widespread species in Chile are known hosts of *Leptospira* spp., *Bartonella* spp., and *Trypanosoma cruzi*, among others [42–45]. Less frequently mentioned species include Darwin's leaf-eared mouse (*Phyllotis darwini)* and the degu (*Octodon degus*), both of which are linked to zoonoses [46, 47]. Given that key zoonotic reservoirs, aside from *O. longicaudatus*, were mentioned by fewer than 22% of the respondents, further training of ECs on rodent reservoir species is essential.

With respect to knowledge of rodent-borne diseases, leptospirosis was the second most frequently mentioned disease after HCPS. Pathogenic *Leptospira* spp. are common zoonotic bacteria associated with rodents and have been found in various rodent species in Chile [48]. Veterinarians were the group most familiar with this disease, likely because of their undergraduate training in infectious and zoonotic diseases and their greater participation in zoonosis-related courses. Salmonellosis was the third most mentioned disease. *Salmonella* is a prevalent foodborne pathogen and public health concern globally [49], with rodents acting as long-term reservoirs [5, 50]. However, no studies on *Salmonella* in Chilean rodents exist [51], suggesting that EC knowledge may be derived from general zoonosis courses, particularly for veterinarians. Rabies (family Rhabdoviridae, genus Lyssavirus) was the fourth most mentioned disease, despite rodents not being significant reservoirs for the virus [52]. In Chile, bats are the primary reservoirs of rabies [53], and there are no records of rabies in Chilean rodents. Environmental engineers mentioned rabies more frequently than veterinarians and biologists, likely due to their limited exposure to zoonotic disease training.

Scrub typhus was mentioned by only six respondents, whereas seven others referred to "typhoid fever," creating ambiguity about the intended disease. Scrub typhus, caused by *Orientia* spp. and transmitted by rodent-associated trombiculid mites, is prevalent in the Asia–Pacific region [54] but has recently been reported in southern Chile [55]. Studies in Chile have detected *Orientia* spp. in trombiculid mites parasitizing various rodent species [29, 30], with some researchers becoming infected after working with rodents and collecting ectoparasites [31].

### Varied perceptions of zoonotic risk and training importance shaped by experience and professional backgrounds

Analysis of Likert scale questions on the perceived risk of rodents to human health and the likelihood of acquiring zoonotic diseases revealed no significant relationships between these variables among different groups of ECs. This suggests that perceptions of risk may be influenced by factors not captured in the analysis. Understanding these additional factors is essential for effective risk communication and intervention strategies. Some trends have emerged, such as veterinarians with different levels of experience displaying nuanced risk perceptions. Less experienced veterinarians perceived lower risk, whereas more experienced ones showed weaker associations. This suggests that experience alone may not determine risk perception. In contrast, biologists, regardless of their experience, exhibited distinct patterns. For example, highly experienced biologists often perceive the risk of zoonotic transmission as "very unlikely," possibly because of their long-term work with rodents without contracting a disease.

While more than 70% of ECs expressed a willingness to take a course on zoonoses, perceptions of its importance varied by professional group. A significant relationship was found between undergraduate fields of study and the perceived value of such a course, highlighting the influence of educational background. Veterinarians consistently rated zoonotic disease courses as very important, likely because of their focus on animal health and awareness of human−animal disease interactions. Conversely, biologists showed variation based on experience: more experienced biologists rated the course as highly important, whereas less experienced biologists rated it as moderately important. This may reflect differences in exposure to zoonotic topics (e.g., mandatory courses) during training or practice. Similarly, environmental engineers, especially those with more experience, viewed the course as important or somewhat important, whereas less experienced engineers showed weaker associations. Importantly, no group tended toward the "not important" response, underscoring the broad recognition of the value of zoonotic disease education across disciplines.

### Injuries and underutilization of PPE reveal gaps in biosafety protocols for rodent handling among environmental consultants

Our survey revealed that most ECs working with rodents engage in live trapping and direct contact, primarily for species identification and measurements rather than biological sampling. Notably, 32% reported rodent-inflicted injuries. While no illnesses were reported, best practices for rodent handling need reinforcement. Many consulting companies fail to provide biosafety protocols or proper PPE instructions, and certain protective equipment, such as respiratory protection and disposable suits, are underused. This is critical, as respiratory protection is essential for preventing hantavirus transmission [18, 20], and appropriate clothing, such as disposable suits, is crucial to avoid exposure to ectoparasites (e.g., fleas, mites, ticks). In Chile, rodent ectoparasites transmit *Rickettsia* spp., *Bartonella* spp., and *T. cruzi* [30, 56–58], highlighting the need for full-body coverage to minimize vector-borne disease risks.

A key issue is the low frequency of cleaning traps after rodents are caught, which increases the risk of pathogen transmission through urine, feces, and aerosols [59]. While more than 50% of ECs are aware that rodent-borne diseases can be transmitted via these routes, this knowledge does not always lead to protective measures being consistently implemented. In contrast, ECs consistently report high use of disposable and work gloves, indicating that hand protection is a common priority.

The use of PPE is essential not only for protecting humans when handling animals but also for preventing potential pathogen transmission from humans to wildlife. Although this aspect of human-to-animal transmission was not analyzed in this study, growing concern about reverse zoonosis has emerged since the SARS-CoV-2 pandemic [60]. Consequently, this dimension should also be considered, particularly as ECs frequently handle wild animals and, in many cases, exhibit a low usage of certain PPEs.

### Limitations of the study

Although this is the first study addressing the management of rodents by ECs in Chile, we acknowledge some limitations stemming from the study design. The first limitation is the lack of precise data on the total population of professionals working with this group of animals, which hindered the calculation of a representative sample. As a result, the generalizability of the findings may be restricted. Future studies should prioritize obtaining a more representative sample and a clearer estimate of the total EC population in the country. Additionally, the primary use of online distribution through environmental consulting companies and social media platforms introduces the potential for participation bias, as more active consultants in these networks may be overrepresented. This could lead to a less comprehensive reflection of the full diversity of consultants involved in rodent-related fieldwork.

## Conclusions

This study highlights the pressing need for interdisciplinary collaboration to enhance education and training on zoonotic diseases for ECs who work with rodents, along with the development and enforcement of comprehensive biosafety protocols. The findings underscore the importance of integrating ECs into the broader One Health framework to ensure effective management of their occupational risks, ultimately contributing to the prevention and control of rodent-borne zoonoses.

While most research on knowledge and practices related to wildlife and zoonotic risks has focused on researchers, national park personnel, or high-risk local communities [10, 61–66], ECs remain an underexplored group despite their significant exposure to wildlife and potentially to zoonotic pathogens. Although this study focuses on Chilean consultants, the issue is likely relevant to similar professionals globally, underscoring the need for continued investigation within the One Health paradigm.

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42522-024-00123-7.

Supplementary Material 1: Additional file 1. Questionnaire submitted through Google Forms.

Supplementary Material 2: Table A.1. Rodent species and genera mentioned by the respondents.

Supplementary Material 3: Figure A.1. Frequency of response to the question: what products do you disinfect the elements used for trapping, and how often do you disinfect them? The options are listed in the same figure.

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**Author contributions**
Conceptualization (EV, DP, DM-A, AVR), formal analysis (EV, RS, HM, AVR), original drafting (EV, AVR), review and editing (EV, RS, HM, DP, DM-A, AVR).

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**Data availability**
The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

## Declarations

**Ethics approval and consent to participate**
The survey was approved by the Research Ethics Committee of the Faculty of Social Sciences, University of Chile (No. 16–21/2021). All participants were informed of the purpose of the questionnaire and were free not to participate or to withdraw at any stage of the process. Responses were analyzed anonymously. A brief description of the survey objectives was included in the survey invitation. Users who clicked on the invitation text received full study information, an opportunity to provide informed consent, and a web link to the survey.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare that they have no competing interests.

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