

## Popular knowledge and perceptions of invasive exotic species in Acre, Brazil Conhecimento e percepção popular sobre espécies exóticas invasoras no estado do Acre, Brasil

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### ABSTRACT

Invasive exotic species (IES) have the potential to promote biological invasions (BI), impacting environmental, economic, and social dimensions, and have increased in the last centuries, due to human activities. In order to efficiently prevent and manage IES, the participation of society in the formulation of public policies is pivotal. However, the popular perception of these subjects (IES and BI) is not commonly integrated into public policies. In this study, we investigated the popular perception and knowledge of IES, BI, their impacts, and awareness of public policies involving IES of residents of the state of Acre, in the Southwestern Brazilian Amazon. We used a questionnaire form distributed online to the 22 municipalities of the state. We obtained a sample of 302 responded questionnaires. Objective responses were analyzed by comparison of frequencies, and open-ended responses were submitted to a textual analysis by hierarchization and similarity. Higher education levels amongst respondents were positively related to the level of understanding on the topic. Most respondents reported possessing knowledge on issues involving IES and BI and about both negative and positive impacts caused by IES. More than 70% of respondents reported a lack of awareness of public policies to prevent or eradicate IES. Our pioneering study presents evidence that the popular perception of IES and BI is complex. It provides relevant material showing the importance of understanding popular perception and assimilating this perception into the development of effective strategies to prevent IES in the future.

**Keywords:** biological invasions; non-native species; civil society; environmental policies; Southwestern Brazilian Amazon.

### RESUMO

Espécies exóticas invasoras (EEI) possuem potencial para promover invasões biológicas (IB), impactando dimensões ambientais, econômicas e sociais, e têm aumentado nos últimos séculos, por conta das atividades humanas. Para prevenir e gerir eficazmente as EEI, a participação da sociedade na formulação de políticas públicas é fundamental. No entanto, a percepção popular acerca desse tema (EEI e IB) não é comumente integrada nas políticas públicas. Neste estudo nós investigamos a percepção e o conhecimento popular sobre EEI, IB, seus impactos e conhecimentos sobre políticas públicas envolvendo EEI, de residentes do estado do Acre, no sudoeste da Amazônia brasileira. Usamos questionários distribuídos on-line para os 22 municípios do estado. Obtivemos uma amostra de 302 questionários respondidos. Respostas objetivas foram analisadas por comparação de frequências, e respostas abertas foram submetidas a uma análise textual por hierarquização e similaridade. O nível superior de escolaridade apresentou relação positiva com o nível de compreensão sobre o tema. A maioria dos entrevistados relatou possuir conhecimento sobre questões envolvendo EEI e IB e relatou possuir conhecimento sobre os impactos negativos e positivos causados por EEI. Mais de 70% dos entrevistados relataram falta de conhecimento sobre políticas públicas para prevenir ou erradicar as EEI. Nosso estudo pioneiro apresenta evidências de que a percepção popular das EEI e IB é complexa e fornece material relevante que mostra a importância de compreender a percepção popular e de assimilar essa percepção no desenvolvimento de estratégias eficazes para prevenir EEI no futuro.

**Palavras-chave:** invasões biológicas; espécies exóticas; sociedade civil; políticas ambientais; Amazônia Sul Ocidental Brasileira.

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## Introduction

In general, a species is defined as native (endemic or indigenous) to a certain area, region, or ecosystem when its occurrence in such a locality is a result of natural processes. On the other hand, an exotic (introduced, non-native, non-indigenous, or alien) species is an organism that evolved somewhere apart from a certain region (Lowry et al., 2013; Simberloff, 2015; Daly et al., 2023). In turn, biological invasions (BI) are a phenomenon that results when species colonize new geographic areas, that are originally isolated from their natural occurrence (Simberloff, 2015). Thus, BI arises when an invasive exotic species (IES) (an expression we adopted in this study due to its popularity in the scientific field) invades a new area where it does not occur naturally. It is important to notice that not all exotic species (ES) are necessarily invasive (e.g., crops, some ornamental plants, and certain domesticated animals). However, when an IES successfully establishes in a new environment and BI occurs, it may cause ecological imbalance across different levels and geographic scales, negatively affecting human health, plant, and animal interrelationships, alterations in climatic and ecosystem processes, overexploitation of resources, pollution, and extinction of local native species (Simberloff et al., 2013; Mollot et al., 2017; Adelino et al., 2021).

Humans have transformed invasion dynamics with the increase of global trade in the last centuries, especially between century XVI and the last XIX and XX centuries, when records of BI have increased (Ricciardi, 2007; Seebens et al., 2017, 2021). However, despite the awareness of the impacts on public health, the environment, and economy caused by BI, popular and decision-makers' knowledge remain rudimentary, which results in inefficient action to avoid the impacts of BI (Rufino et al., 2019). Even though BI are predominantly associated with human activities, social concepts related to the occurrence of BI are still insufficiently discussed (Nuñez and Pauchard, 2010).

IES can result in either a positive or negative impact or both. IES usually cause considerable negative ecological and economic impacts (Moro et al., 2012; Vimercati et al., 2020). In general, the negative ecological impacts of IES are promulgated, which demonstrates the need for an inclusive transdisciplinary approach between environment and society to grow this debate (Shrestha et al., 2019). Although negative economic impacts caused by IES are still emerging in Brazil, costs incurred by such organisms are estimated to exceed 100 billion dollars in a few decades (Adelino et al., 2021). If we include human behavioral factors that cannot rationally be excluded from the equation, such as empathy or biased actions that favor a given ES, the whole picture of the issue becomes even more complex.

Investigations aiming to comprehend people's perception of the environment and its components may serve as a useful tool to close the gap between modern humanity and the natural environment. Within this context, it is of interest to science to understand how people perceive biodiversity and its modifications. The natural mi-

gration of species to different regions is an important phenomenon that promotes changes in biodiversity, unlike species movement beyond their natural distribution by human hands. Thus, civil society must assume a leading role in the environmental management of IES, also because humans are the agents of species introduction, establishment, and dissemination of IES worldwide. In general, civil society is excluded from environmental management and public policies, which makes the mitigation or resolution of problems caused by IES more difficult. Therefore, it is pivotal to consider social components in the processes involving BI to improve policies of IES management (Dechoum et al., 2019; Shrestha et al., 2019; Crête et al., 2020).

Thus, in order to understand the real impacts caused by IES and BI, we must consider multiple factors such as ecology, socio-economics, and people's perception of IES. To describe the popular understanding of impacts caused by IES and BI, people's perception of the topic needs to be investigated — environmental education actions, popularization campaigns, popular participation in environmental management, and mitigation of the impacts caused by IES may provide a broader and more effective basis for understanding (Essl et al., 2020). It is valuable to comprehend the potential risks of IES because it may allow society to understand the magnitude of the issues and may encourage society to cooperate to prevent novel introductions and manage the negative impacts caused by IES (Simberloff et al., 2013; Pyšek et al., 2020).

Herein, we investigated the popular knowledge of IES in Acre, a state located in the Southwestern Brazilian Amazon. Our aim was to understand the capacity to recognize IES by the civil society, their perception of the impacts caused by IES and BI, and their level of awareness on public environmental policies. We specifically addressed the following questions: a. how much is known about IES and BI by civil society?; b. how broad is the people's knowledge on the impacts caused by IES and BI?; and c) what is the people's recognition of environmental policies to promote or manage IES in the state?

## Methodology

### Study area

A survey of people's perception of IES and BI was made in Acre (Figure 1), a Brazilian state located in the Southwestern Amazon which is bordered by Amazonas and Rondônia (also states within the Brazilian Amazon), and the countries of Peru and Bolivia. Acre is mostly covered by the pristine Amazonian Forest (Veríssimo et al., 2002; Medeiros et al., 2014) and currently harbors more than 830 thousand citizens distributed in 22 municipalities (IBGE, 2022). In general, the municipalities of Acre are large and isolated, and fluvial transportation is essential since road infrastructure and airplane networks are poor.

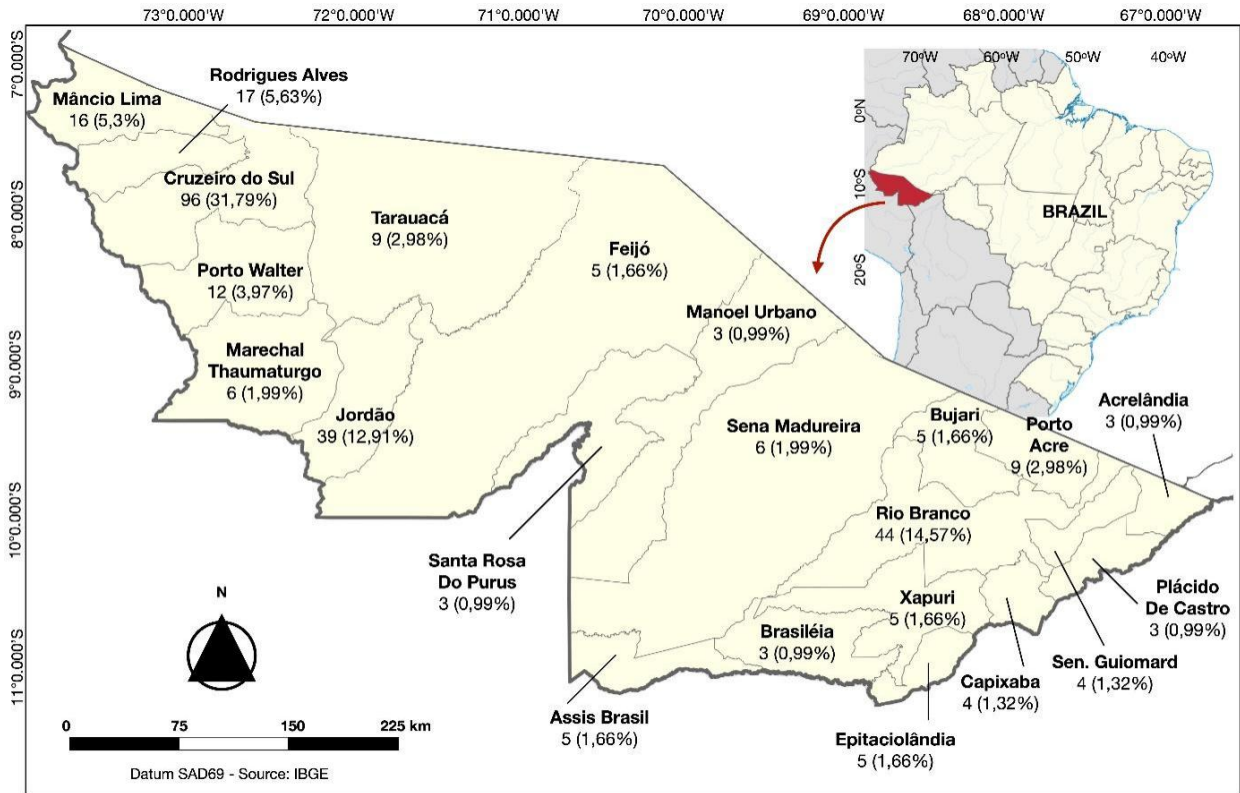


Figure 1 – Location of the state of Acre in Brazil, and the distribution of frequencies of responses per municipality in absolute numbers and percentage (%) (n=302).

**Data collection**

Data were collected by the application of an online form (implemented in the Google Forms platform), which was available for completion from July 6 to August 6, 2022. To encourage participation in the research, the questionnaire was announced actively on social media (Facebook, WhatsApp, Instagram), and e-mail. Data were collected with the permission of the Research Ethics Committee of the Federal University of Acre (CAAE 52696721.1.0000.5010, permission 5.396.519). To be part of the sample, each participant was invited to freely sign an Informed Consent Form. Forms completed by people who lived outside Acre were discarded.

The questionnaire presented 11 questions organized in four sections, designed to capture sociodemographic information, people’s perception and knowledge of IES, BI and their impacts, and awareness of public policies to prevent such impacts (Table 1). A list of 20 IES (Table 2) was elaborated based on exhaustive lists obtained from the results of the First Symposium of Invasive Exotic Species in Acre, a meeting of experts and the general public that occurred in 2019, and from the Hórus Institute (<https://bd.institutohorus.org.br/especies>) compilations. The selection of species considered a limit of 20 IES to avoid overloading respondents throughout the form.

**Data analyzes**

Data collected were downloaded, stored, and then organized into worksheets for later scrutiny. In the next step, the sociodemographic profile of participants was submitted to exploratory statistics and  $\chi^2$  analysis to detect differences in the frequencies of responses and the perceptions of the respondents through sociodemographic categories. We applied the Likert scale analysis, which is commonly used in social research questionnaires and consists of a unidimensional scale that permits the measurement of replies in a range of ordered values (Joshi et al., 2015). We used the packages likert (Bryer, 2016) and ggplot2 (Wickham, 2016), implemented in the software R, version 3.6.3 (R Core Team, 2022), to perform this analysis.

Open-ended responses were analyzed in the software Iramuteq, version 0.7 alpha 2 (e.g. Souza et al., 2018; Sousa et al., 2020; Sousa, 2021), which uses an algorithm of descending hierarchical classification of words to perform qualitative analysis. Each set of responses was organized in a textual corpus that was segmented and submitted to a lemmatization process, which produces a contingency table with segments of the corpus. Then, the segments of text were grouped by hierarchy and class of similarity by the metric of the  $\chi^2$  test. The outputs are diagrams of similarity based on the Simpson score and the optimal community grouping method. These procedures allow the analysis of relevance by frequency and connection among the most frequent terms and words related to a given issue under investigation (Sousa et al., 2020; Sousa, 2021).

**Table 1 – Structure of the questionnaire form to survey the popular perception of IES in the state of Acre.**

Sections	Response options
Section I: Sociodemographic evaluation	Age group, gender, education, profession/occupation, municipality of residence
Section II: Popular perception of IES in Acre	
Question 1: Have you ever heard of invasive exotic animal and plant species?	No, yes, possibly
Question 2: How do you classify your understanding on the topic?	Very unsatisfied, unsatisfied, indifferent, satisfied, very satisfied
Question 3: Have you ever heard of initiatives to prevent IES?	No, yes, possibly
Question 4: Do you consider your knowledge on the topic sufficient?	Very unsatisfied, unsatisfied, indifferent, satisfied, very satisfied
Question 5: Do you consider the coverage by the media, government, schools, and NGOs (Non-Governmental Organizations) to the subject sufficient?	No, yes, possibly
Section III: Knowledge on IES	
Question 6: What are an exotic species?	Respond freely
Question 7: Which species do you recognize as IES?	Mark any picture freely in the list*
Question 8: Which IES did you already encounter personally?	
Section IV: People's perception on the impacts caused by IES	
Question 9: Which impacts do you think IES can cause?	Respond freely
Question 10: Which IES do you think can cause positive impacts?	Mark any picture freely in the list*
Question 11: Which IES do you think can cause negative impacts?	

\*A list with 20 invasive exotic species (Table 2) was presented to respondents. IES: invasive exotic species.

**Table 2 – Invasive exotic species listed for the state of Acre. Species marked with an asterisk (\*) were included in the present study on the popular perception of invasive exotic species in the state of Acre.**

Biological Form	Common Name	Common name (Portuguese)	Species Name
Shrubs	Silk Cotton Tree	Algodão-de-seda	<i>Calotropis procera</i> (Aiton) Aiton fil.
	Indian Hemp	Cânhamo-da-índia	<i>Crotalaria juncea</i> L.
	Rattlebox*	Chocalho-de-cascavel*	<i>Crotalaria spectabilis</i> Roth
Trees	Neem*	Margosa*	<i>Azadirachta indica</i> A.Juss.
	Guava*	Goiabeira*	<i>Psidium guajava</i> L.
Herbaceous Plants	Kudzu*	Puerária*	<i>Neustanthus phaseoloides</i> Benth.
	Wandering Jew*	Lambari-roxo*	<i>Tradescantia zebrina</i> Bosse
	Mexican Sunflower*	Margaridão*	<i>Tithonia diversifolia</i> (Hemsl.) A.Gray
	Brazilian Signal Grass*	Capim-braquiara*	<i>Urochloa decumbens</i> (Stapf) R.D.Webster
	Humidicola Grass	Braquiariinha	<i>Urochloa humidicola</i> (Rendle) Morrone & Zuloaga
Palms	African Oil Palm*	Dendê*	<i>Elaeis guineensis</i> Jacq.
Birds	Rock Pigeon*	Pombo-doméstico*	<i>Columba livia</i> J.F.Gmelin, 1789
	House Sparrow*	Pardal*	<i>Passer domesticus</i> (Linnaeus, 1758)
Insects	Africanized Bee*	Abelha-africana*	<i>Apis mellifera</i> Linnaeus, 1758
	African Dung Beetle*	Besouro-africano*	<i>Digitonthophagus gazella</i> (Fabricius, 1787)
	Argentine Ant*	Formiga-cabeçuda-urbana*	<i>Pheidole megacephala</i> (Fabricius, 1793)
	Dengue Mosquito*	Mosquito-da-dengue*	<i>Aedes aegypti</i> (Linnaeus, 1762)
Mammals	Dog*	Cachorro*	<i>Canis familiaris</i> Linnaeus, 1758
	Wild Boar*	Javali*	<i>Sus scrofa</i> Linnaeus, 1758
Fish	Tilapia*	Tilápia*	<i>Oreochromis</i> sp. Günther, 1889
Reptiles	Common House Gecko*	Lagartixa*	<i>Hemidactylus mabouia</i> (Moreau De Jonnés, 1818)
Mollusks	African Giant Snail*	Caramujo-africano*	<i>Lissachatina fulica</i> (Bowdich, 1822)
Fungi	Cacao Moniliasis*	Monilíase-do-cacau*	<i>Moniliophthora roreri</i> (Cif.) H.C.Evans, Stalpers, Samson & Benny

## Results

### Sociodemographic profile

The questionnaire was completed by 302 people living in Acre with three municipalities being the most represented: Cruzeiro do Sul (31.79%), Rio Branco (17.57%), and Jordão (12.91%) (Figure 1). Sociodemographic groups with the highest frequency of responses were women (54.65%), between the ages of 26 and 35 (32.45%) years, with complete graduation (27.15%), and who worked as public agents (42.72%). On the other hand, groups with fewer representatives were composed of men (45.36%), older than 60 years (1.66%), with complete elementary school (1.99%), and retired (2.32%) (Table 3).

### Popular perception of invasive exotic species

In general, most of the respondents indicated that they possessed previous knowledge of IES (65.89%), especially those with complete higher education, and post-graduation (Table 4). On the other hand, people with incomplete elementary school education were the group who demonstrated the least familiarity with IES (2.01%). More public agents were represented in the group that possessed previous knowledge of IES (48.74%), than other occupation groups, while retired citizens were the least well represented (2.01%).

When questioned about their comprehension of the topic, most respondents reported limited understanding (50.66%), while 7.62% indicated complete unfamiliarity. The first group was composed mostly of people with postgraduate education (44.00%), while the latter, was formed by people with incomplete elementary education (26.09%). Yet, rural workers were the group that exhibited the highest frequency of complete unfamiliarity with the topic (30.43%), whereas public agents that declared sufficient knowledge on the topic constituted 56.35% of the sample.

When asked about their awareness of public policies or government initiatives to prevent or eradicate IES, most respondents (54.3%) declared complete unawareness, while 28.15% declared the opposite. More specifically, the groups of people with complete higher and post-graduate education, both corresponding to 35.29% each, were the most well represented in the group that answered positively to this query. The initiatives and/or policies presented to participants and the proportion of responses were as follows: dengue mosquito control (55%, n=48), cacao moniliasis control (17%, n=15), wild boar control (19%, n=17), golden mussel control, plant eradication, policies for tilapia farming, policies for beekeeping, African snail control, and sanitary inspections (1%, n=1 each).

In an attempt to comprehend people's perception of the sufficiency of their own knowledge and clarity regarding IES, the following questions were addressed: a. Do you consider your knowledge on the topic sufficient?; and b. Do you consider the coverage of the subject by the media, government, schools, and NGOs (Non-Governmental Organizations) sufficient? According to the replies obtained, most respondents (77%) declared the coverage of IES by the media, government,

schools, and NGOs insufficient, and 38% of the participants declared sufficiency of knowledge (Figure 2).

### Recognition of exotic species and invasive exotic species

When questioned about the definition of ES, the textual analysis based on the similarity of the open-ended responses revealed several groups organized according to different understandings and perceptions (Figure 3A). The term "exotic species" was central to the largest group, which was linked to terms, such as "uncommon", "other\_habitat", "other\_environment", "other\_place", "other\_places", and "introduced", among others. The second largest group, connected to the first by the term "harmful", had "not" as the central expression, being linked to "occurrence", "belonged", "naturally", "fauna", and "flora". Associated with this group, the expressions "introduce", "organism", "area", and "distribution" were related, as well as the association of "accidental", "intentionally", "live", and "exotic". Peripheral groups represented the terms used by respondents who declared unfamiliarity with IES.

**Table 3 – Distribution of frequencies of responses per category of sociodemographic variable in the state of Acre (n=302).**

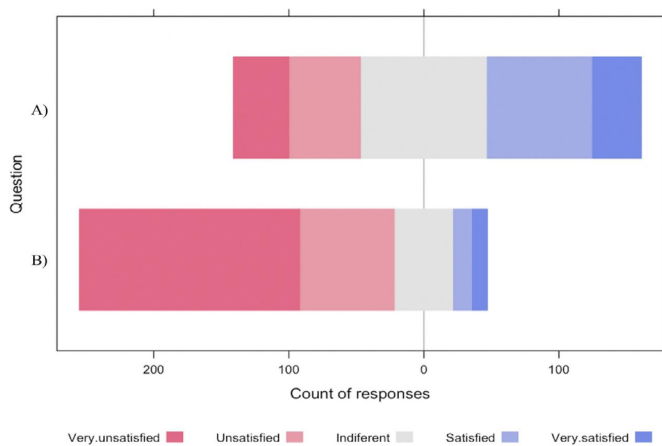
	n (%)
<b>Gender</b>	
Female	165 (54.64)
Male	137 (45.36)
<b>Age group (years old)</b>	
14 to 25	75 (24.83)
26 to 35	98 (32.45)
36 to 45	90 (29.80)
46 to 59	34 (11.26)
>60	5 (1.66)
<b>Education</b>	
Incomplete elementary school	13 (4.30)
Complete elementary school	6 (1.99)
Incomplete high school	22 (7.28)
Complete high school	53 (17.55)
Incomplete high education	45 (14.90)
Complete high education	82 (27.15)
Post-graduation	81 (26.82)
<b>Occupation</b>	
Retired	7 (2.32)
Freelancer	35 (11.59)
Student	55 (18.21)
Public agent	129 (42.72)
Others	27 (8.94)
Private sector	26 (8.61)
Rural worker	23 (7.62)



**Table 4 – Frequency of responses (%) for questions Q1, Q2, and Q3 of the questionnaire by categories (Gender, Age Group, Education, and Occupation). Q1: Have you ever heard of invasive exotic plants and animals?; Q2: How do you classify your understanding on the topic?; Q3: Have you ever heard of initiatives to prevent invasive exotic species?**

Categories		Questions and frequency of responses (%)								
		Q1			Q2			Q3		
		N	Y	PSB	S	PS	I	N	Y	PSB
Gender	Female	56	57.29	43.40	53.97	58.17	34.78	53.66	58.82	50.94
	Male	44	42.71	56.60	46.72	41.83	65.22	46.34	41.18	49.06
p-value		0.191			0.107			0.619		
Age Group (years)	14 to 25	28	23.10	28.30	23.02	26.80	21.74	26.22	22.35	24.53
	26 to 35	28	33.60	32.08	28.57	35.98	30.43	32.32	24.71	45.28
	36 to 45	32	29.60	28.30	36.51	23.53	34.78	28.05	38.82	20.75
	46 to 59	12	11.51	9.43	10.32	12.42	8.7	11.59	11.76	9.43
	>60	0	2.01	1.89	1.59	1.31	4.35	1.83	2.35	0
p-value		0.965			0.500			0.272		
Education	Incomplete Elementary School	10	2.01	7.55	0.79	3.92	26.09	4.88	2.35	5.66
	Complete Elementary School	2	0.50	7.55	0	3.27	4.35	3.66	0	0
	Incomplete High School	8	4.52	16.98	3.97	8.5	17.39	10.98	0	7.55
	Complete High School	12	14.07	35.85	7.14	26.8	13.04	14.46	14.12	26.42
	Incomplete Higher Education	20	14.57	11.32	17.46	13.73	8.70	12.80	16.47	18.87
	Complete Higher Education	22	32.16	13.21	26.19	29.41	17.39	25.61	35.29	16.98
	Post-graduation	26	32.16	7.55	44.44	14.38	13.04	25.61	35.29	16.98
p-value		<0.001**			<0.001**			0.015*		
Occupation	Retired	0	3.02	1.89	3.17	1.96	0	1.83	4.71	0
	Self-Employed	14	10.55	13.21	5.56	16.34	13.04	12.80	7.06	15.09
	Student	20	16.58	22.64	19.05	18.3	13.04	18.90	20.00	13.21
	Public Agent	44	48.74	18.87	56.35	36.64	21.74	40.85	50.59	35.85
	Others	6	8.04	15.09	6.35	10.46	13.04	7.32	9.41	13.21
	Private Sector	8	8.54	9.43	7.14	9.80	8.70	7.93	4.71	16.98
	Rural Worker	8	4.52	18.87	2.38	8.50	30.43	10.37	3.53	5.66
p-value		0.010*			<0.001**			0.069		
Total (n=302)		16.56	17.55	65.89	41.72	50.66	7.62	54.30	28.15	17.55

N: No; Y: Yes; PSB: Possibly; S: Sufficient; PS: Partially Sufficient; I: Insufficient; P: Pearson's  $\chi^2$  test, \*\* $\alpha=0.001$ , \* $\alpha=0.05$ . Responses to Q2 presented in this table were adapted from the original questionnaire.



**Figure 2 – Distribution of responses on the Likert scale. (A) Replies to the questions: “How do you classify your understanding on the topic?”; and (B) “Do you consider your knowledge on the topic sufficient?”.**

To the question that investigated the recognition of IES by respondents, several species were identified as previously known (Figure 3B): giant African snail, wild boar, cacao moniliasis, tilapia, Brazilian signal grass, Africanized bee, and dengue mosquito. Conversely, respondents exhibited less familiarity with the following IES: common gecko lizard, neem tree, domestic dog, guava tree, and rattlebox. The respondents most frequently indicated previous personal observations of the domestic dog, guava tree, and dengue mosquito. On the other hand, neem tree, wandering jew (*Tradescantia zebrina*), and rattlebox were the less frequently observed IES. Lastly, participants (n=60) mentioned additional species that they consider as IES, but that were absent from the list we presented: domestic cat, golden mussel, wattle, African catfish, water buffalo, weeping fig, bamboo, lionfish, coronavirus, and gum trees (*Eucalyptus* spp.).

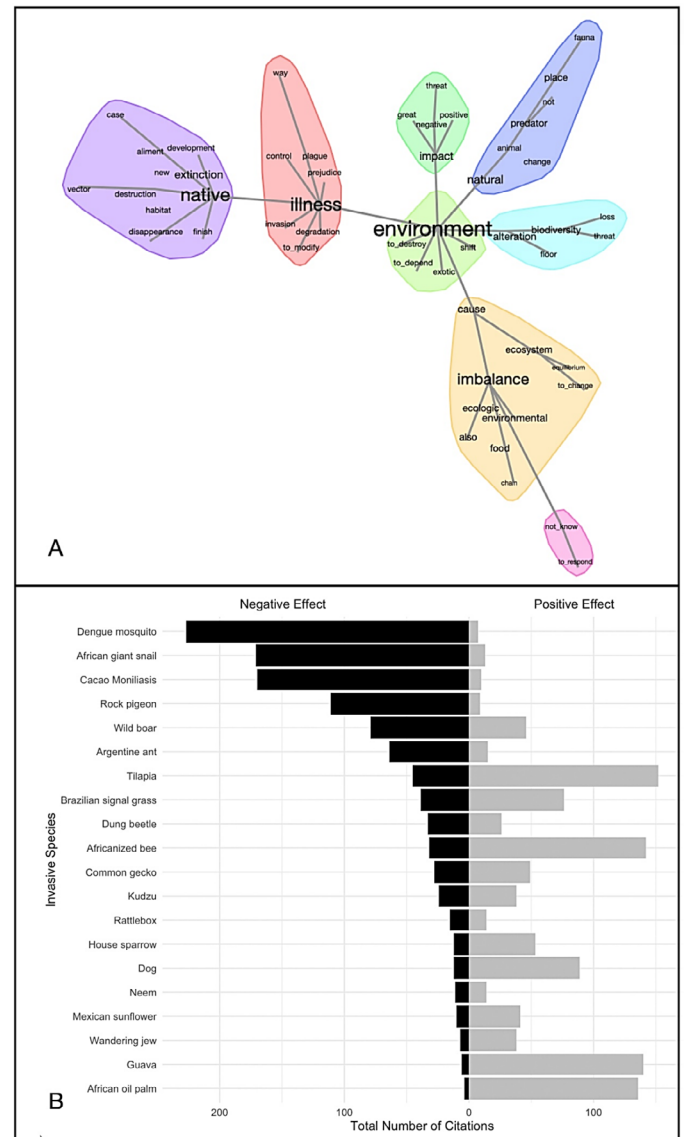
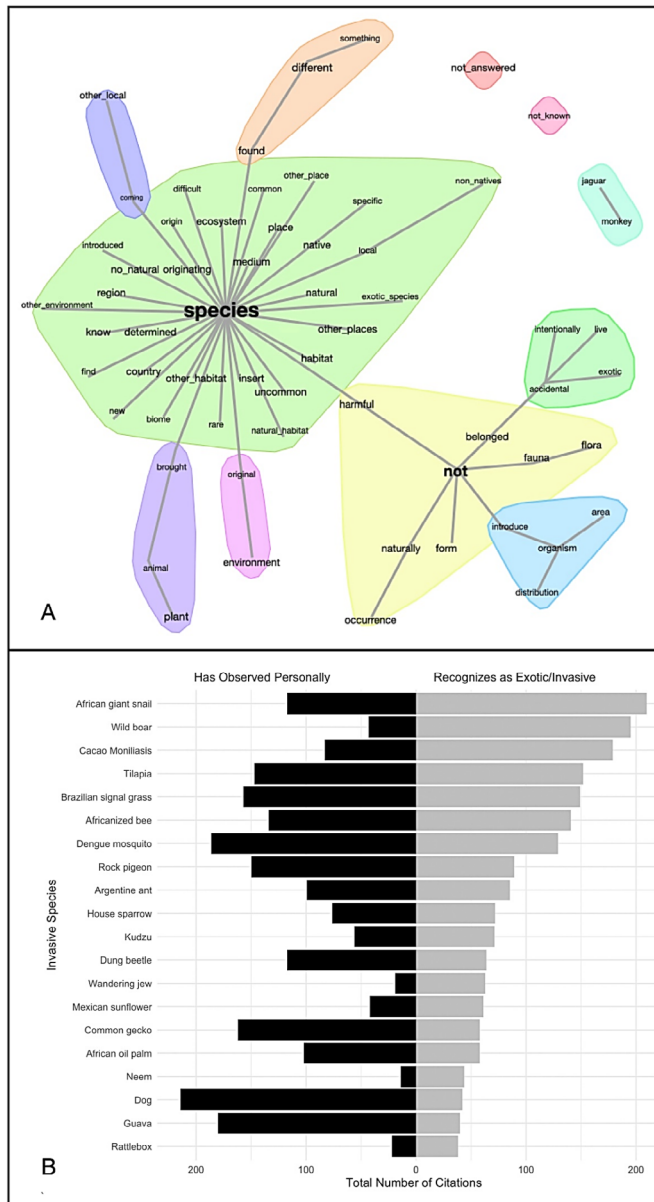


Figure 4 – (A) Similarity diagram of terms indicated in the answers to the question “What impacts can IES cause to the environment?”; (B) distribution of the impacts caused by invasive exotic species indicated by the respondents.

Popular perception of the impacts caused by invasive exotic species

The similarity of terms presented in the responses to the impacts caused by IES revealed a central group with the word “environment” as a knot that connects to the other groups (Figure 4A). Within the central group, the expressions “to\_destroy”, “to\_depend”, and “shift” were connected. Other prominent groups and their central words were: “imbalance” (connected to “ecological” and “environmental”), “illness” (linked to “invasion”, “degradation”, “prejudice”, “plague”, and “control”), and “native” (associated with “extinction”, “destruction”, “disappearance”, “finish”, and “development”). Smaller groups were connected by the terms: “alteration”, “natural”, and “impact”.

In answer to the question about the perception of the type of impacts caused by IES (Figure 4A), respondents identified the following IES with negative impacts (more than positive): dengue mosquito, giant African snail, cacao moniliasis, rock pigeon, wild boar, Argentine ant, dung beetle, and rattlebox. Additionally, negative impacts such as diseases, extinction of species, and economic loss were mentioned by respondents in association with these IES. On the other hand, IES reported as having more positive than negative impacts were Nile tilapia, Brazilian signal grass, Africanized bee, common gecko, kudzu, house sparrow, domestic dog, Mexican sunflower, wandering jew, guava tree, and African oil palm. These species were considered valuable for economic, social, and environmental goods by respondents.

## Discussion

The state of Acre is isolated and movement within it is limited. As such, it is functionally a type of “final frontier” for the arrival and establishment of IES, with few registered events of BI (e.g., early cases of dengue caused by *Aedes aegypti* were recorded around 30 years after first outbreak in southern Brazil). Nevertheless, although most participants indicated previous knowledge of IES, a great proportion of our sample admitted insufficient understanding of the subject under investigation. This result aligns with that of Japelj et al. (2019), which assessed public preferences for IES management, with 76% of the respondents claiming to know the definition of IES. The dissemination of information about IES and discussion within society have increased in recent years to the point that it is less usual to find individuals who are completely unaware of the impacts and hazards caused by IES. In contrast, if at first individuals did not associate the impacts of a particular species with its invasive potential, our results consistently indicated that a significant proportion of the participants reported awareness of the impacts IES can cause in different areas. Yet, these groups of respondents exhibited the ability to associate IES with specific positive and negative impacts. Overall, the level of knowledge about the topic we investigated was strongly associated with the education level of the respondents (Shackleton and Shackleton, 2016).

It is important to emphasize that the tools we used to distribute and apply the questionnaire probably created a bias, and influenced, especially, the social demographic of respondents that had access to the questionnaire for research. People from urban areas with access to the internet may have had less difficulty accessing and answering to the questionnaire. This is consistent with the greater proportion of people with complete higher education in the sample. Nevertheless, the sample was composed of a broad and relevant group of people from diverse professional occupations, and the public agents demonstrated a consistently good understanding of the subject. Our results are consistent with the study conducted by Pires (2021), who evaluated that career public agents had a better perception of environmental issues than outsourced service providers.

The impact of IES in the Legal Amazon is poorly known and considerably little information is disseminated to the public domain (Dechoum et al., 2021). Consequently, people questioned about their knowledge on the issues involving IES and BI and how they consider their own understanding of what IES are, tend to have a range of responses. In general, our results evidenced that several respondents exhibited a consistent comprehension that IES are from “other” ecosystems, places, or habitats, and have the potential to produce negative or positive impacts. Answers that confused IES with rare, unusual, or exotic (in the sense of being different) organisms were present in our results, which was expected (García-Llorente et al., 2008). Five main factors usually influenced popular perception of IES: 1. the individual (how each person visualizes an invasive species); 2. the species itself (whether there is information about it); 3. the effect (of the species on

the individual); 4. the landscape (rural or urban); and 5. the cultural context (the local society an individual lives in) (Shackleton et al., 2019). Perception is unique to each person, and individuals perceive, react, and respond differently to distinct situations. Therefore, when species like the domesticated dog, oil palm, or Nile tilapia are considered positive, it is likely that this response reflects the factors mentioned above. Indeed, collectively, it is reasonable to assume that these factors play an important role in shaping popular opinion. For this group, what matters is the perspective of the species itself, partly due to its charisma (Steele and Pienaar, 2021), partly due to its appearance as a “beautiful” or a “hideous” species (Shackleton et al., 2019), or due to its utility (Santafe-Troncoso and Loring, 2020).

Our results evidenced that respondents are familiar with IES when their common names are well-known. This was more frequent, particularly, for some plants such as the “Mexican sunflower” and the “kudzu.” The latter became common in urban areas and has multiple common names, depending on the locality (Liesefeld et al., 2022). However, people from urbanized areas are often unaware of its original use and do not associate it as an IES. This common situation illustrates the lack of knowledge about IES, which may lead people to tolerate invasions by simply lacking knowledge. In these cases, managers may face difficulties gathering support from people to manage or eradicate IES (Kalnicky et al., 2014).

The individual perspective on the effects caused by IES can be evaluated based on the relationship between environmental impacts and the choice of whether the species causes a negative or positive impact. The three most cited negative impacts by respondents were extinction of species, diseases, and environmental degradation. Species that cause direct impacts on human health and agricultural losses were strongly identified as species with negative impacts, which are directly related to the effects experienced by respondents during recent public health crises or agricultural losses (e.g., COVID-19 pandemics, cupuassu moniliasis outbreak). Meanwhile, the economic potential of some IES may be central to its evaluation as positive (Cordeiro et al., 2020; Steele and Pienaar, 2021; Kourantidou et al., 2022). Nonetheless, ambivalent views (simultaneous perception of positive and negative impacts) and misconceptions about species can prevent the formulation of effective public policies (van Eeden et al., 2020). Since humans are the primary disseminators of IES, if they do not perceive the impacts that these species can cause, people may not feel motivated to support the implementation of control, management, and eradication measures for IES (Bertolino et al., 2021).

It was noteworthy that respondents from urbanized areas recognized the dengue mosquito as an IES because it is a common species and highly impactful in such areas. In parallel, for rural workers, the brachiaria grass was recognized as an IES as well. These results emphasized how perceptions are distributed across multiple social and cultural structures, and the understanding of stakeholders is influenced by the context of the landscape they live in, which may



determine their engagement in initiatives to manage IES (Carter et al., 2021). Thus, the motivation, expectation, and experience of the stakeholders must be considered in the development of public policies involving IES, as popular participation is critical for the success of such policies (Shrestha et al., 2019). Therefore, strengthening the dialogue between civil society and policy makers, with science providing relevant technical background on the IES issue, is paramount (Li et al., 2021; Mason et al., 2022).

The dissemination of information about IES by the media, schools, government agencies, and NGOs through awareness campaigns was considered important by respondents. Such information channels need to be monitored to guarantee the proper accuracy and veracity of information transmitted and avoid the spread of false, incomplete, or negative content, and denialism (Ricciardi and Ryan, 2018). Our results indicate that respondents considered the coverage of IES by the media, government, schools, and NGOs insufficient. Although some initiatives to control IES were mentioned by respondents, a significant proportion of the sample reported they had no awareness of any initiative. Across Brazil, guidance and effective IES management policies are still largely inadequate, and this is no different in the state of Acre. Such a deficiency has the potential to lead to economic, social, and environmental losses caused by IES (Zenni et al., 2016; Adelino et al., 2021).

As the spread of IES is closely related to human activities, conflicts of perceptions among conservationists, the general population, and other sectors of society that shape the development of public policies and actions involving IES, are frequent (Van Eeden et al., 2020). Therefore, understanding the difficulties of each sector of society to truly comprehend the risks and impacts of IES by analyzing their discourses, perceptions, and practices may be an important step for the effectiveness of IES management actions (Cottet et al., 2015). The pursuit of efficient multidimensional planning, involving individuals, institutions, and government, requires a shift of paradigms within social, economic, and ecological contexts, as well as in discourses and proposed outcomes. Shifting these paradigms may help to address complex issues

like IES by connecting the understanding of such phenomena, aiming at successful negotiations between specific cultural and economic interests and IES management (Kull et al., 2018).

## Conclusion

Our investigation of popular knowledge about IES and BI in the state of Acre revealed interesting patterns. Considering the profile of the participants, our results evidenced a strong correlation between the level of education a person has and the amount of information on the topic they hold. Several respondents demonstrated awareness of the IES, including the correct identification of some well-known exotic species. Yet, most people report an association of IES with negative impacts, especially on human health, economic loss, and on the environment, and that perception is linked to information provided by traditional media. Regarding the knowledge of initiatives to prevent or eradicate IES by the government, few respondents indicated awareness of such efforts, citing a few well-known popular programs, such as the dengue campaign.

Most participants who exhibited significant knowledge of the IES and BI were young, graduate/postgraduate women who worked as public agents. Although the profile of the respondents was not intentional, it is important to highlight that it is an evident bias and a similar study with an audience from different social groups may reveal different patterns and should be fostered to elicit greater understanding of a complex narrative. Nevertheless, our study is a pioneer in the state and our data provide evidence that the issues of IES and BI are not sufficiently known by people in general.

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## Authors' contributions

AMORIM, M.D.B.O.: data curation, formal analysis, investigation, methodology, resources, software, writing – original draft. OLIVEIRA, I: conceptualization, methodology, software, validation, writing – review & editing. LIESENFELD, M.V.A.: conceptualization, formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, writing – original draft, writing – review & editing.

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