Ecología Austral 36:047-058 Abril 2026
Asociación Argentina de Ecología
https://doi.org/10.25260/EA.26.36.1.0.2629

Study on community knowledge and awareness of invasive species

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Abstract

1. In a globalized world, invasive species (IS) have significant ecological and socio-economic impacts, underscoring the need for public awareness and effective management. Their continued expansion increases pressure on key sectors such as agriculture, forestry, and public health. Understanding public perception of IS is therefore essential for improving prevention and control strategies.

2. This study analyzes the perception and knowledge of IS among teaching and non-teaching staff in Argentina, and, within the teaching community, compares the responses of natural sciences teachers with those of teachers from other disciplines. Data were collected via a semi-structured online questionnaire, capturing demographic profiles, perceptions of environmental impact, and knowledge of biological invasions.

3. Results revealed that teachers perceived greater environmental and invasion-related impacts than non-teachers. While most respondents acknowledged the high impact of IS, teachers exhibited higher levels of awareness and concern.

4. Unintentional human-mediated transport was identified as the primary threat and concerns for human health were the main reason cited for species removal.

5. This study highlights the importance of strengthening environmental education in both formal and informal settings to address IS impacts.

6. Implications. A multidisciplinary approach is recommended to raise public awareness and promote the sustainable management of invasive species across all sectors of society.

[Keywords: biodiversity, biological invasion, environmental education, environmental impact, perception]

Resumen. Estudio sobre el conocimiento y la concienciación comunitaria de especies invasoras

1. En un mundo globalizado, las especies invasoras (EI) tienen importantes repercusiones ecológicas y socioeconómicas, lo que resalta la necesidad de sensibilizar a la población y de aplicar una gestión eficaz. Su expansión continua intensifica las presiones en sectores clave como la agricultura, la silvicultura y la salud. Por lo tanto, comprender la percepción pública de las EI es esencial para mejorar las estrategias de prevención y gestión.

2. El objetivo de este estudio es analizar la percepción y el conocimiento de las EI entre las comunidades docentes y no docentes, y, dentro de la comunidad docente, entre los profesores de ciencias naturales y los profesores de otras materias en la Argentina, mediante un cuestionario en línea semiestructurado. Se obtuvieron datos sobre perfiles demográficos, percepciones del impacto ambiental y conocimiento de las invasiones biológicas.

3. Los resultados mostraron que los profesores percibían un mayor impacto ambiental y de invasión biológica que los no profesores. Si bien la mayoría de los encuestados reconoció el alto impacto de las EI, los profesores mostraron mayores niveles de concienciación y preocupación.

4. La mayoría de los encuestados consideró que el transporte involuntario de EI era la principal amenaza, y las preocupaciones por la salud humana fueron la razón principal para la eliminación de especies.

5. Este estudio destaca la importancia de mejorar la educación ambiental tanto en entornos formales como no formales para abordar los impactos de las EI.

6. Implicancias. Se recomienda un enfoque multidisciplinario para sensibilizar al público y garantizar una gestión sostenible de las especies invasoras en diversos sectores de la comunidad.

[Palabras clave: biodiversidad, invasión biológica, educación ambiental, impacto ambiental, percepción]

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Recibido: 23 de Septiembre de 2025
Aceptado: 5 de Enero de 2026

Introduction

In this world of constant change and largely connected by globalization, the invasive species (IS) represent one of the main threats to ecosystems and biodiversity (Pysek et al. 2020). The movement of species into non-native regions causes profound ecological changes, leading to biotic homogenization across regions (Capinha et al. 2015). When the species are moved far from their native ranges into new regions, they can overcome different biogeographical barriers, resulting in escalating ecological, economic and social impacts (Remmele and Lindemann-Matthies 2020; de Melo et al. 2021). Over the past 50 years, the transport of IS to non-native regions has intensified and is now recognized as one of the five main drivers of profound global environmental change (IPBES 2023). The arrivals of non-native species have significant ecological and socio-economic consequences, particularly affecting agriculture, forestry and health sectors and generate control and eradication costs that impact national economies (Bacher et al. 2018; Latombe et al. 2023; Hulme et al. 2024).

Considering IS as a serious and growing problem, it is a priority to develop strategies to reduce their impacts and prevent new biological invasions. Public awareness and education play a central role in this context, as public opinion can influence both the introduction and management of IS. Therefore, it is imperative to understand the public's level of knowledge and attitudes toward these species (Kapitza et al. 2019). Previous research has highlighted the importance of social perception in IS management, with most studies focusing on the public (Sosa et al. 2021; Haley et al. 2023; Lipták et al. 2024). However, social perception and attitudes toward IS control are often controversial and can generate conflicts, particularly in relation to biosecurity measures implemented in vulnerable ecosystems (Shine and Doody 2011; Dunn et al. 2018; Sutcliffe 2018). These social conflicts appear to be linked to the low public knowledge regarding appropriate management actions and the potential ecological and health impacts that IS may cause (Hulbert et al. 2023; Lipták et al. 2024). For that reason, public engagement and awareness should be considered essential components of IS management.

Furthermore, education on IS is particularly relevant during the early educational stages —primary and secondary school— because children and adolescents often have limited direct contact with nature (Chawla 1999; Wells and Lekies 2006). Consequently, their perceptions of natural environments are largely shaped by online content that emphasizes a small number of iconic and charismatic species (Genovart et al. 2013; Courchamp et al. 2018). This may distort their understanding of IS and the risks associated with their establishment (Ballouard 2011; Díez et al. 2018).

Although biological invasions have recently gained importance, the topic remains relatively new within environmental education (Waliczek et al. 2017). Therefore, both knowledge and teaching practices in this field are still developing, making teachers' scientific literacy on IS a key factor (Verbrugge et al. 2021). Teachers act as mediators between scientists and students, yet teaching biodiversity conservation issues —such as IS, which encompass ecological, economic and social dimensions— pose significant challenges (Borg et al. 2012). Moreover, teachers' personal and professional perceptions of the environment and IS influence how they assume their role as mediators of student learning. The controversial nature of environmental issues, together with the inherently complex and abstract concept of biodiversity, may further hinder effective teaching (Büssing et al. 2018).

In order to address the specific challenges related to community perceptions of IS, it is essential to assess the knowledge and attitudes of both teaching and non-teaching communities toward biological invasions and to identify the concepts that should be introduced or reinforced mainly in educational programs. Therefore, the general objective of this study is to analyze the perception and knowledge of IS among teaching and non-teaching communities in Argentina. The specific objectives are: 1) to explore whether there are differences in environmental perceptions, biotic components and global and local threats between teaching and non-teaching communities, as well as within the teaching community between natural science teachers (NsT) and teachers of other subjects (non-NsT), and 2) to evaluate whether there are differences in awareness of biological invasions between teaching and non-teaching communities and within the teaching community (between NsT and non-NsT).

Materials and Methods

Data collection

A survey was designed to query a sample of individuals from teaching and non-teaching communities regarding their perception of the environment and their understanding of biological invasions. It consisted of an online semi-structured questionnaire of 14 sequenced questions using Google Forms with an introductory paragraph indicating the purpose of the study. The questionnaire covered three main areas: 1) characterization of the respondents; 2) perception of the environment (biotic components and environmental threats), and 3) awareness of biological invasions (Supplementary Material-Table S1).

A snowball sampling approach was used through emails and social media platforms (i.e., X, Facebook and Instagram). The survey was initially distributed randomly by contacting teacher-training institutes across the country, aiming to minimize biases in respondent profiles and to ensure broad regional and educational-level coverage. Responses were recorded over a period of 124 days (between June 3 and October 4, 2024). The questionnaire was anonymous in terms of personal information from the participants.

The methods were carried out in accordance with the regulations of the Ethics Committee of the Faculty of Exact and Natural Sciences of the University of Buenos Aires. Formal written consent was not required, in accordance with institutional guidelines for anonymous surveys.

Characterization of the respondents

To characterize the socio-demographic profile, respondents were asked to provide their place of residence, age, highest education level obtained, and whether they are related to teachers or not. If they were teachers, they were asked level and subject (Supplementary Material-Table S1).

Perception of the environment

In this section, respondents were asked to rate from 1 to 3 (1: low impact; 2: medium impact; 3: high impact) the impact of seven threats (i.e., flooding, climate change, biological invasion, pollution, natural habitat degradation, expansion of agriculture and overexploitation of natural resources) have on the environment at global and local scale (Q7 and Q8) (Supplementary Material-Table S1).

The threats were analyzed with Generalized Linear Model (GLM) analysis using lme4 package in R 4.5.0 (R Core Team 2022). GLM were performed considering: 1) the scale —local and global— as factor; 2) teaching relationship (teacher or non-teacher) as factor for each scale (local and global) separately, and 3) teaching subjects as factor where two groups were established, one with all teachers teaching natural sciences —NsT— and the other with teachers teaching other subjects —non-NsT—, for each scale (local and global) separately.

Awareness of biological invasions

Perception of biological invasions was addressed in six total questions. Respondents were asked whether they were familiar with the issue of biological invasions and if they were aware that biological invasions are taking place in their place (Q9 and Q10). Respondents were also asked about their consideration of IS as a serious problem (Q11 and Q12), what would be the main method of entry (Q13) and in which case they consider that IS should be eliminated (Q14) (Supplementary Material-Table S1). To analyze whether there were differences between the different groups of respondents, for each of the 6 questions separately, the frequency of answers was analyzed and compared using the chi-square (X^2) test, both between teachers vs. non-teachers, as well as between NsT vs. non-NsT.

In addition, to analyze possible correlations between Q9, Q10 and Q11, the questions were ranked from 1 to 5, from 'definitely no'=1 to 'definitely yes'=5. Pearson correlation analyses were carried out between Q9, Q10 and Q11 for different participant groups separately: all respondents, teachers, non-teachers, NsT, non-NsT. All analyses were performed with R 4.5.0 (R Core Team 2022).

Results

A total of 604 responses were obtained from across the country, covering 22 of the 23 provinces of Argentina (Figure 1). Participants ranged from 19 to 73 years old (mean=39.5 years). Regarding educational attainment, 4% of respondents reported incomplete secondary school, 28% completed secondary school, 22% completed tertiary studies, 22%

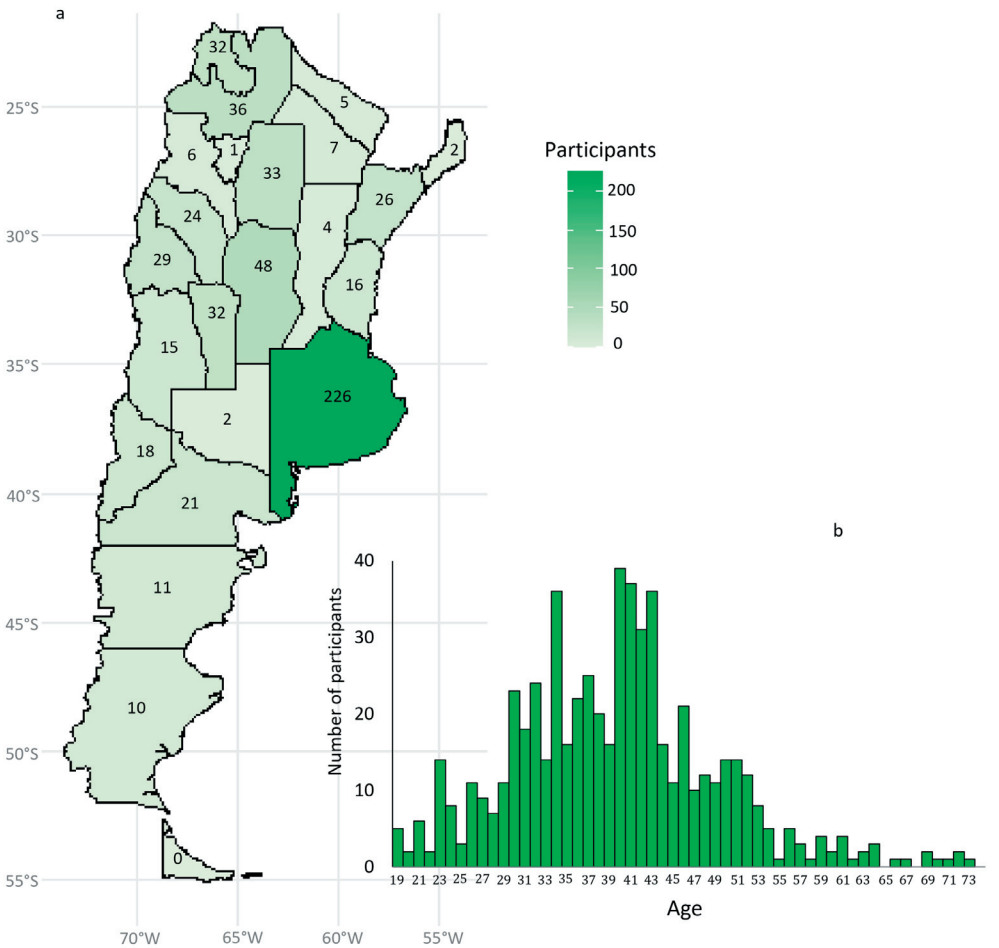

Figure 1. Survey sample characteristics. a) Number of respondents in each Argentine province. b) Histogram of respondents' ages.

Figura 1. Características de la muestra obtenida mediante la encuesta. a) Número de encuestados en cada provincia argentina. b) Histograma de las edades de los encuestados.

held a university degree, 16% were currently undertaking a university degree, 5% held a postgraduate degree and 3% were currently undertaking postgraduate studies. Of the 604 respondents, 312 were teachers and 292 were non-teachers. Among teachers, 27 worked at kindergarten level, 71 at primary level, 171 at secondary level, 1 at the tertiary level and 41 at the university level. Based on specialization, 165 teachers were classified as NsT and 147 as non-NsT.

Perception of the environment

The results showed that most respondents (78.02%) perceived environmental threats as having medium to high impacts on the environment. At the global scale, all threats —except flooding— were considered to have significantly higher impacts than at the local scale (Figure 2a).

When groups were analyzed separately, teachers consistently considered all environmental threats as having higher impacts than non-teachers, both globally and locally (Figure 2b and 2c). A similar pattern emerged when comparing NsT and non-NsT: in both scales, NsT considered all environmental threats to have significantly greater impacts than non-NsT (Figure 2d,e).

Awareness of biological invasions

Knowledge about biological invasions (Q9). Overall, 43% of respondents reported knowing almost nothing about biological invasions and 33% reported an intermediate knowledge level. Knowledge differed significantly between teachers and non-teachers ($\chi^2_{df=4}$=94.5, P<0.001): 51% of teachers reported intermediate knowledge, while 66% of non-teachers reported knowing almost

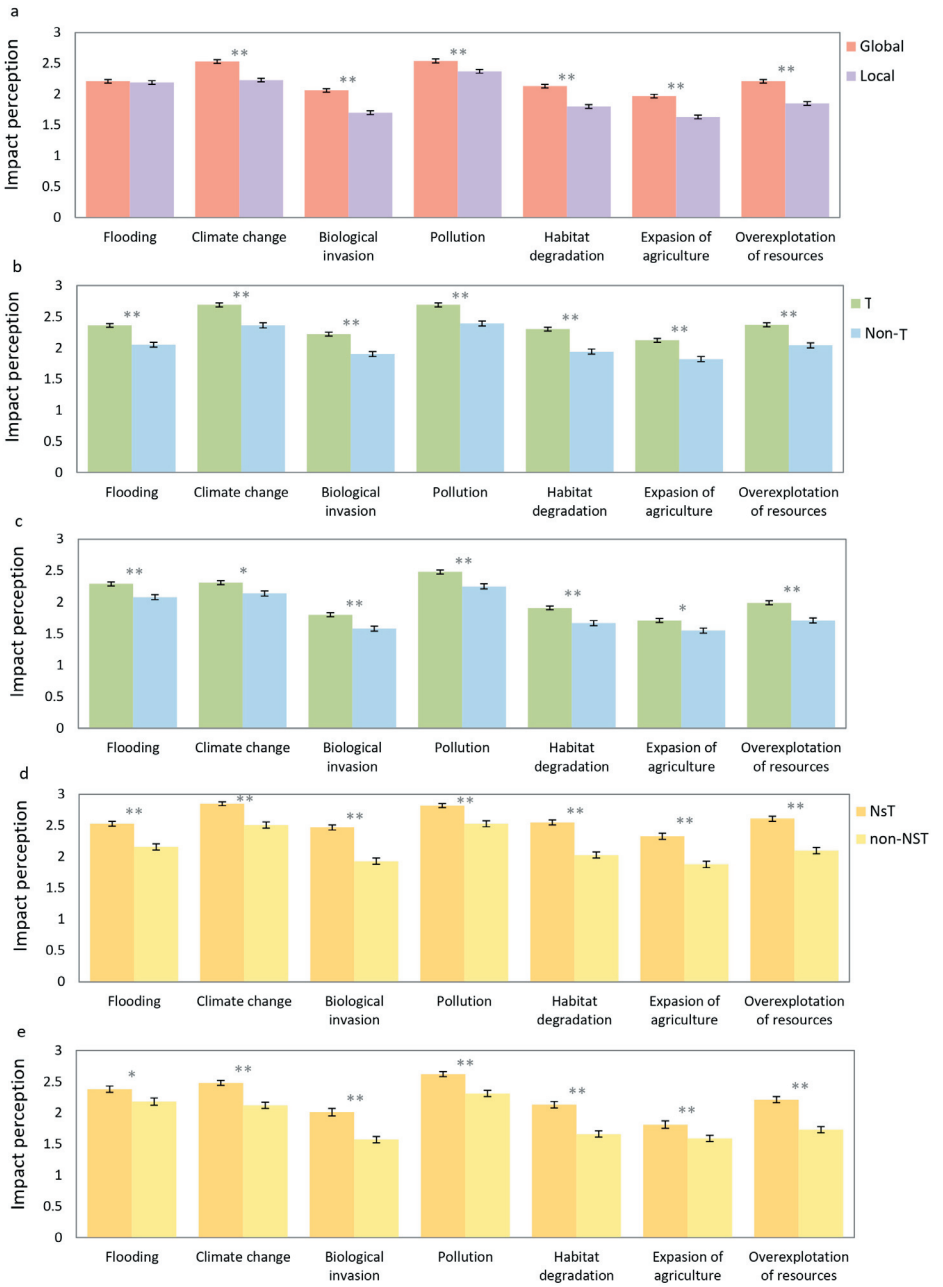

Figure 2. Impact perception of different threats to the environment. a) At global and local scale. b) For teachers (T) and non-teachers (non-T) at global and c) local scale. d) For NsT and non-NsT at global and e) local scale. Asterisks indicate significant differences (*P<0.01; **P<0.001).

Figura 2. Percepción del impacto de diferentes amenazas sobre el medio ambiente. a) A escala global y local. b) Para docentes (T) y no docentes (non-T) a escala global y c) local. d) Para NsT y non-NsT a escala global y e) local. Los asteriscos indican diferencias significativas (*P<0.01; **P<0.001).

nothing. Within the teacher group, NsT showed higher knowledge levels than non-NsT ($\chi^2_{df=4}$=92.6, P<0.001) (Figure 3a).

Knowledge about current invasions (Q10). Most respondents reported low knowledge of current biological invasions. Significant differences emerged between teachers and non-teachers ($\chi^2_{df=4}$=90.02, P<0.001), with teachers reporting higher knowledge. NsT also showed higher knowledge compared to non-NsT ($\chi^2_{df=4}$=94.3, P<0.001): 50% of NsT declared intermediate knowledge, whereas 52% of non-NsT reported knowing almost nothing (Figure 3b).

Perceived risk posed by invasions (Q11). The most frequent response was “sometimes

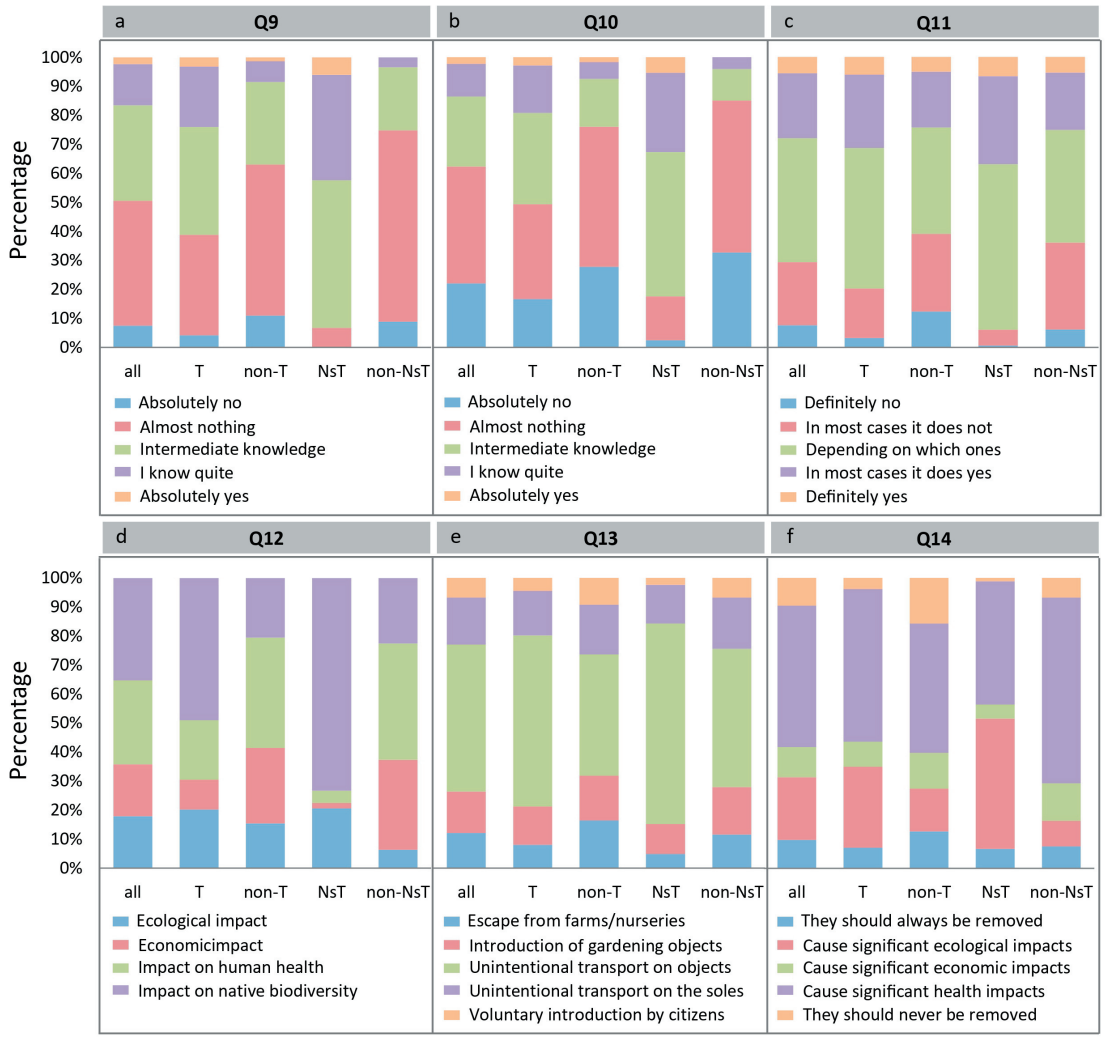

Figure 3. Percentage of responses about biological invasions awareness questions. a) Knowledge of biological invasions (Q9). b) Awareness of biological invasions (Q10). c) Perception of the level of impact (Q11). d) Perception of type of impact of biological invasions (Q12). e) Perception of the main pathways of entry of IS (Q13). f) Responses about when IS should be removed (Q14). Responses are shown for all respondents and also partitioned between teachers (T) and non-teachers (non-T), and NsT and non-NsT.

Figura 3. Porcentaje de respuestas sobre preguntas relacionadas con la concienciación sobre las invasiones biológicas. a) Conocimiento sobre las invasiones biológicas (Q9). b) Concienciación sobre las invasiones biológicas (Q10). c) Percepción del nivel de impacto (Q11). d) Percepción del tipo de impacto de las invasiones biológicas (Q12). e) Percepción de las principales vías de entrada de las IS (Q13). f) Respuestas sobre cuándo deben eliminarse las IS (Q14). Las respuestas se muestran para todos los encuestados y también se dividen entre profesores (T) y no profesores (non-T), y NsT y non-NsT.

yes/sometimes no" (42%). Perceptions differed significantly between teachers and non-teachers ($\chi^2_{df=4}$=93.4, P<0.001) and between NsT and non-NsT ($\chi^2_{df=4}$=57.5, P<0.001) (Figure 3c).

Perceived impacts of invasions (Q12). Respondents most frequently selected impacts on native biodiversity (35%) and human health (29%). Teachers selected biodiversity impacts more often (49%), whereas non-teachers emphasized human health (38%), resulting in significant group differences ($\chi^2_{df=4}$=66.7, P<0.001). Differences between NsT and non-NsT were also significant ($\chi^2_{df=4}$=72.4, P<0.001), with NsT mainly selecting biodiversity impacts (73%) and non-NsT selecting human health (39%) (Figure 3d).

Entry pathways (Q13). Across all respondents, the most frequently perceived pathway was unintentional transport on imported objects (51%). Although significant differences existed between teachers and non-teachers ($\chi^2_{df=4}$=53.4,

P<0.001) and between NsT and non-NsT ($\chi^2_{df=4}$=48.5, P<0.001), response patterns were broadly similar across groups, with the same dominant pathway (Figure 3e).

Conditions for IS removal (Q14). The most frequent answer was removal when human health is affected (48.7%). Differences between teachers and non-teachers were significant ($\chi^2_{df=4}$=79.3, P<0.001); both groups prioritized human health impacts. Significant differences also emerged between NsT and non-NsT ($\chi^2_{df=4}$=89.4, P<0.001): NsT prioritized ecological impacts (45%), while non-NsT prioritized human health (64%) (Figure 3f).

Correlations. Pearson correlations between Q9 and Q10 were significant across all groups, whereas the correlations between Q9 and Q11 and between Q10 and Q11 were significant for all groups except non-teachers (Table 1).

Discussion

With the increasing degradation of ecosystems, more sustainable environmental behavior and management is necessary for the preservation of the environment (Olsen et al. 2020). To this end, it is important to ensure that the community —mainly through education— is provided with adequate knowledge to enable the acquisition of optimal skills and attitudes (Parra et al. 2020). This includes not only greater knowledge of ecological concepts and processes but also understanding of human impacts on ecosystem functioning and services, including those resulting from IS, which constitute one of the main threats to biodiversity (Gallardo et al. 2019).

According to the data, the study shows that the community generally perceives environmental threats as more severe at the global level than at the local level, for most factors included in the survey. These factors were also considered the most damaging in other studies related to the educational environment (Vilches et al. 2015; Sosa et al. 2021), alluding responsibility to demographic growth of the human population. The results also indicate that the teaching community exhibits a higher level of perception and concern for environmental drivers than the non-teaching community. Although biological invasions are among the main drivers of biodiversity loss, this work found that both teaching and non- teaching communities considered them less important compared to other drivers. Similar results have been reported in previous studies (Vilches et al. 2015; Bermudez et al. 2020; Sosa et al. 2021), suggesting that biological invasions may be underrepresented in educational curricula and thus fail to reflect the threat that IS pose to ecosystems and biodiversity (Waliczek et al. 2017; Remmele and Lindemann-Matthies 2020).

When investigating knowledge of biological invasions and their impacts on native biodiversity, the results showed that teachers were more aware of biological invasions —especially, NsT— than non-teachers. In addition, a positive correlation was observed between the level of knowledge about IS and their perceived impact on native biodiversity in all groups of teachers, whereas no such correlation was found in the non-teaching community. Considering that biological invasions are expected to increase in the coming decades, with significant biodiversity, ecological and socio-economic impact, urgent management policies are required (Busso et al. 2013; Seebens et al. 2021). Therefore, the effective reception and acceptance of IS management —with the participation of all citizens— may be related to the community's environmental knowledge (Waliczek et al. 2017; Ekanayake et al. 2020).

Findings of this study are reinforced and contextualized by the complementary study of Sosa et al. (2021), which also investigated

Table 1. Pearson correlation coefficients between Q9, Q10 and Q11, for all respondents together, as well as for the groups of teachers, non-teachers, NsT and non-NsT, separately. Asterisks indicate statistically significant correlations (**P<0.01; ***P<0.001).

Tabla 1. Coeficientes de correlación de Pearson entre Q9, Q10 y Q11, para el conjunto de todos los encuestados, como también para los grupos de profesores, no profesores, NsT y non-NsT, por separado. Los asteriscos indican correlaciones estadísticamente significativas (**P<0.01; ***P<0.001).

Variables		Participant groups				
V1	V2	All	Teachers	Non-teachers	NsT	non-NsT
Q9	Q10	0.77***	0.83***	0.67***	0.28***	0.56***
Q9	Q11	0.28***	0.42***	0.08	0.22**	0.43***
Q10	Q11	0.26***	0.40***	0.06	0.26***	0.35***

the knowledge and perceptions of native and IS specifically within the Argentine teaching community. However, this study complements the approach by adopting a broader social perspective, incorporating both teaching and non-teaching communities. Aligning with these results, Sosa et al. (2021) found that natural science teachers demonstrated significantly greater recognition of native species and awareness of biological invasions compared to teachers of other subjects. Furthermore, both studies converge in revealing limited understanding of invasion pathways and the specific impacts of IS, highlighting that this knowledge gap extends beyond teachers and emphasizes the need to enhance both formal and informal environmental education. While Sosa et al. (2021) provides crucial insights into species identification skills within an educational context, this study delves deeper into the perception of global versus local impacts and attitudes towards IS management across the community. Collectively, these parallel findings from two Argentine studies emphasize the critical role of multifaceted educational strategies that address both the ecological knowledge and the social dimensions of biological invasions.

Results revealed differences in baseline knowledge of biological invasions among teaching and non-teaching communities. This evidence shows that environmental education is a powerful tool to mobilize social change and support for IS management (Expósito López 2023). International experiences show that integrating invasion biology into school curricula and teacher-training programs can effectively improve awareness and pro-environmental engagement. For example, the Maui Invasive Species Committee in Hawaii provides dedicated teacher workshops based on their Hôike o Haleakalâ curriculum, combining classroom resources with field activities for K-12 educators; the Invasive Species Council of British Columbia offers its Invasive-Wise Education program aligned with provincial curricula; and the U.S. Department of Agriculture has developed the Hungry Pests Invade Middle School curriculum to introduce invasion biology to grades 6-8. Additionally, education interventions have been shown to improve perceptions and pro-conservation behaviors in broader communities (de los Santos et al. 2022). Therefore, to build robust public support for evidence-based IS management, it is essential both to invest in structured environmental education in schools and to design outreach campaigns tailored to non-teachers (Gayford 2000; Verbrugge et al. 2021).

Regarding the question about the most significant impacts caused by IS, differences were found between the groups, where NsT identified the native biodiversity impact as the most important problem, whereas non-teachers and non-NsT considered human health impacts to be the greatest concern. These differences suggest that perception and awareness of environmental effects depend on the community's environmental and ecological knowledge (Kapitza et al. 2019). This pattern is consistent with previous studies showing that people with higher ecological literacy tend to prioritize biodiversity-related impacts, whereas the general public tends to perceive IS primarily as direct risks to humans, such as allergies, zoonotic diseases, or crop contamination (Young and Larson 2011; Shackleton et al. 2019). However, both native biodiversity and human health impacts highlighted over other options, pointing to the socio-ecological problem of IS (Kannan et al. 2014; Kelsch et al. 2020). Indeed, the multidimensional nature of IS impacts has been repeatedly documented, with marked consequences that link ecological disruption with economic losses and public health concerns (Simberloff et al. 2013; Diagne et al. 2021).

On the other hand, respondents have widely recognized the 'unintentional imported objects' as the main pathway to the IS. However, they had difficulties recognizing different IS pathways to entry, especially secondary dispersal pathways such as transport on footwear, clothing and personal items, or accidental escape from farms. Similar patterns of limited public knowledge about secondary dispersal pathways have been reported in Europe and North America, where visitors often underestimate their own capacity to transport seeds, fungal spores or small invertebrates attached to clothing, footwear or equipment (Pickering and Mount 2010; Anderson et al. 2014). This lack of awareness indicates that respondents are not aware of their own role as potential vectors of IS. This is particularly relevant in protected areas or national parks where visitors can act as vectors for the transport of propagules, especially when hygiene protocols are not implemented or understood (Ford-Thompson et al. 2015). For instance, seed attachment on shoes and clothes has been documented in protected mountain areas, where trails act as

conduits for non-native species (Liedtke et al. 2020). In Australia's Kosciuszko National Park, park managers have highlighted the need for boot-cleaning stations, because backcountry huts and hiking infrastructure are associated with non-native species introductions (Gill et al. 2020). More generally, human-mediated dispersal over long distances via footwear has been quantified: seeds can remain attached to shoes for several kilometers (Wichmann et al. 2009), and many weed or non-native species' seeds accumulate on visitors' clothes and shoes (Pickering and Mount 2010). Additionally, research shows that propagules from non-native species hitchhike on clothing, underscoring the role of recreational visitors in invasive spread (Anderson et al. 2015; Valkó et al. 2020).

These results, together with previous evidence, highlight the importance of appropriate education —both formal and informal— on IS (Ladrera et al. 2020; Remmele and Lindemann-Matthies 2020). Educational interventions focused on invasion biology have been shown to improve risk perception, increase willingness to follow biosecurity measures and strengthen public support for management actions (Novoa et al. 2017; Jubase et al. 2021). This education should lead teaching and non-teaching communities to understand IS potential threat to biodiversity and the negative impact on the appropriate functioning of the whole socio-ecological system, including economic and human health threats. In line with global assessments such as IPBES (2023), improving public understanding of IS is considered essential for building social acceptance of management strategies and ensuring effective long-term prevention and control.

Most respondents considered that IS should be removed, especially when they cause human health problems. In the case of NsT, secondly, they considered the need to remove IS when they cause ecological impacts. But in all cases, a very small proportion of respondents pointed to the need to always remove IS from invaded territories. These results show that the respondents are not aware that all IS, by definition, cause impacts of a different nature and their elimination imply benefits of different types. Therefore, the results highlight the need for the broader community to understand the rationale behind specific IS management strategies. Ladrera et al. (2020) showed that the perception of IS as potential threats depends on the species, as humans tend to empathize more with species similar to themselves, primarily mammals, which receive greater care and conservation efforts. In contrast, there is greater social rejection of other types of organisms, mainly invertebrates, which may lead to stronger support for the removal or sacrifice of invasive taxa of this type (Leandro and Jay-Robert 2019). The social acceptance of certain IS control measures has been extensively studied, and several studies have pointed to the importance of robust knowledge about biological invasions and environmental issues in promoting positive attitudes toward their management (Green et al. 2016; Waliczek et al. 2017). In this regard, increased training in the area both through formal and non-formal education, such as outreach and awareness-raising activities, could lead to greater knowledge and a better understanding of the problem. Likewise, it can translate into more positive attitudes toward IS management.

It is urgent to enhance the community's background knowledge on this subject. To achieve this, the present study suggests that the knowledge about IS and their potential threats should be focused on educational actors —both teachers and students— as well as citizens outside formal education. Within formal education, curricula at all levels should be promptly updated to incorporate a cross-curricular approach across subjects (Ladrera et al. 2020). Simultaneously, within the context of non-formal education, outreach activities in strategic establishments such as museums, nature parks, ecological reserves, gardens and eco-parks could serve as fundamental tools to increase and disseminate environmental knowledge and awareness among the general community (Reed et al. 2010). On the other hand, knowledge about IS needs to be addressed through a multidisciplinary approach and in diverse ways, as environmental problems are interconnected with multiple social issues, including health, ecology, economy, cultural heritage and religion (Estévez et al. 2015).

Finally, it is important to acknowledge the limitations of this study. The sample may not fully represent all demographic groups, as some provinces had a small number of participants, and survey-based measures may be subject to biases in the information provided. Therefore, future studies should expand the sampling and assess the effectiveness of educational interventions in changing perceptions and behaviors.

In conclusion, addressing global environmental challenges —including biodiversity loss, climate change and the accelerating spread of invasive species— requires strengthening public awareness of human roles as potential vectors, as well as the benefits of effective management. Achieving this goal demands inclusive participation across society, through coordinated efforts among policymakers, scientists, educators, students and the broader community.

Acknowledgements. The author would like to thank all the teachers and non-teachers who accepted the collaboration and completed the form. The author also thanks the editor and the reviewers for their help to improve this article.

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