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RESEARCH ARTICLE

Biological invasions in brazilian environmental science courses: do we need new approaches?

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Abstract

The increasing destruction of natural environments worldwide favored more and more alien species' dispersal, distancing people from nature and consequently from native species. We investigated undergrad students' perception about alien and native Brazilian species evaluating classes of the first (freshmen) and last semesters (seniors) of four courses in environmental sciences in three institutions and assessed these students' knowledge level in different aspects related to native and alien species. The 509 interviewees were able to identify Brazilian native species better than alien species. They also produced better identifications among taxonomic groups of mammals (either alien or native), native birds, and exotic fish compared to invertebrate species. Most students did not consider themselves well informed about the topic. We found an association between the courses/semesters attended and the level of knowledge of the students. Thus, we concluded that, on the one hand, the students demon-

strated relevant knowledge about the native species but, on the other, presented deficiencies in invasive alien species' knowledge. Therefore, we suggest the revision/restructuring of how the biological invasions theme is covered in the academic curricula of undergraduate courses in the environmental area.

Keywords
Biodiversity, biological invasion, conservation, environmental education

Introduction

The increasing globalization associated with people and goods' increased flow has intensified the transport and dissemination of animal species, plants, and microorganisms throughout the planet (Pysek and Richardson 2010). Therefore, human activities brought many species around us from other regions; these species are called aliens (Richardson et al. 2000). Most of the transported exotic species cannot disperse in the new environment and, therefore, do not cause environmental impacts (Richardson et al. 2000). However, with adequate environmental conditions, such as available resources, lack of competitors, predators, or parasites, they can reproduce and expand their distribution, causing severe damage to the ecosystem and the economy of the invaded regions, being thus considered invasive species (Richardson et al. 2000; Pimentel et al. 2001, 2005; Crowl et al. 2008; Blackburn et al. 2011; Bellard et al. 2016; Doherty et al. 2016; Pyšek et al. 2020).

Invasive alien species (IAS hereafter) may cause reductions in native populations, local extinctions, regional, or even global, changes in ecological interactions, productivity modification, nutrient cycling, and habitat structure (Simberloff 2005; Pejchar and Mooney 2009; Blackburn et al. 2019). Therefore, IAS can affect the survival of native species, decreasing their species richness and abundance (Blackburn et al. 2014). These species can also harm various ecosystem services, such as the production of food, water, wood, medicinal plants, climate stability, flood control, disease spread, soil fertility, pollination, and seed dispersal (Pejchar and Mooney 2009). Therefore, the increase in biological invasions may end up homogenizing the planet's biological diversity, making terrestrial ecosystems increasingly poorer in species (McNeely et al. 2001; Hautier et al. 2018).

However, the impacts caused by IAS go beyond environmental issues, as these species also cause economic losses and may cause other problems to Humanity (e.g., health problems; Pejchar and Mooney 2009; Bellard et al. 2016). A survey conducted in the United States of America, United Kingdom, Australia, South Africa, India, and Brazil estimates that economic losses caused by invasive species related to agriculture, forestry, and other segments of the economy, exceed $ 336 billion per year (Pimentel et al. 2001, 2005). In addition to generating high costs, the control and management of alien species after the introduction is too complex (Mack et al. 2000; Pimentel et al. 2005; Bradshaw et al. 2016; Novoa et al. 2018). Therefore, prevention is one of the simplest and cheapest ways to combat IAS, and public education is an essential element in prevention programs (Wittenberg and Cock 2001). Through information, dialogue, and reflection on the problem

of biological invasions (Novoa et al. 2017; Shackleton et al. 2019), humans may mitigate the damage caused by these species, helping to prevent further invasions and control the alien species already present in the environment (Reis et al. 2013; Shackleton et al. 2019).

It is vital to intensify the accomplishment of programs and activities that awaken people's interest and appreciation for native species (Lindemann-Matthies 2005). In megadiverse countries, such as Brazil, it is essential to prioritize knowledge about native biodiversity and increase the protection and valorization of these species (Proença et al. 2014). Previous studies have indicated that, in general, there is little knowledge among the population about native biodiversity, especially when compared to knowledge about lien species (Bizerril and Andrade 1999; Lindemann-Matthies and Bose 2008; Genovart et al. 2013; Amaral et al. 2017).

Environmental education (EE from now on) is a fundamental tool to change the trend of increasing biodiversity degradation (Jacobi 2003) because it contributes to developing students' knowledge and attitudes towards biodiversity (Sousa et al. 2016; Verbrugge et al. 2021). EE in schools and universities helps prepare new generations of citizens to have more active and critical attitudes towards nature conservation and environmental problems (Reis et al. 2013). In this sense, the environmental perception survey helps clarify how people perceive and relate to the environment and their expectations and behaviors (Rebouças et al. 2015; Verbrugge et al. 2021). Subsequently, the research can contribute by proposing improvements for the construction of methodologies that stimulate people's awareness and awareness of environmental problems (Palma 2005; Novoa et al. 2018).

Thus, this work aims to evaluate undergraduate students' perceptions of native and invasive exotic fauna in the country in courses related to environmental sciences from three higher education institutions in Goiás, Brazil. Specifically, we seek to answer the following questions: 1) Are alien species more recognized than native Brazilian species? 2) Do students know how to differentiate the place of origin of the species? 3) Do students learn more about mammals and exotic fauna than other taxonomic groups and native fauna? 4) Is there a difference in students' knowledge among those studying Biological Sciences, Ecology, Veterinary Medicine, and Agronomy courses? 5) Do senior students have a greater understanding of alien and native species' fauna than first-semester freshmen students? 6) Do students learn more about the subject in college than in high school? 7) Is there an association between the courses/semesters and the knowledge level of the students?

Materials and methods

Data collection

We gathered data at three different higher education institutions, Federal University of Goiás – *Campus* Goiânia (UFG from now on), Federal Institute Goiano – *Campus* Urutaí (IFGO from now on), and the State University of Goiás – *Campus* Anápolis (UEG from now on). From those institutions, we selected four undergraduate

courses related to Environmental Sciences from those three different institutions. We selected the Agronomy, Biological Sciences, Ecology, and Veterinary Medicine courses in UFG. From IFGO, we evaluated the Agronomy, Biological Sciences, and Veterinary Medicine courses. In UEG, we assessed the Biological Sciences course. The whole sample universe consisted of 16 course-classes; half consisted of first-semester freshmen students, while the other half consisted of last-semester senior students from each different institution (Table 1). We applied questionnaires to assess the students' environmental perception and know their opinions and understandings about Brazil's alien and native species.

There was considerable student participation, with an average of 31 participating students per class. We invited all students, either older or minor, to present in the classroom to participate in the research. Specifically for minor students, only those who had the authorization of their parents and/or guardians with a signed Informed Consent Form (ICF) participated in the research.

The students answered the questionnaires without any previous intervention. The researcher's definitions and concepts about a Brazilian alien and/or native species were not clarified since this test's objective was to evaluate students' previous knowledge. We submitted the project to the UEG ethics committee, linked to the Ministry of Health, which approved the applied procedures (the process in CAAE: 77679717.2.0000.8113).

For data collection, we developed two questionnaires. The first questionnaire was descriptive and included 12 questions, which involved: 1) definition of alien species; 2) examples of alien species; 3) its benefits and losses; 4) definition of native species; 5) examples of native species; 6) invasive species taught in classes in high school and higher education; 7) invasive species taught on college courses; and 8) five questions for the student to evaluate their knowledge about different aspects of the theme (invasive species, environmental impacts, control techniques, and Cerrado.

We classified and evaluated the descriptive questions in this questionnaire into five categories: Great: complete answer with a clear and precise concept; Good: much of the answer corresponding to what we previously expected; answer with a satisfactory concept; Regular: an incomplete answer showing, at least, some level of knowledge on the asked topic; Bad: completely incorrect answer; and Blank: the answer was not answered. The second questionnaire consisted of a cardboard game containing photos of different animal species. For this cardboard game, we chose 40 animal species from five zoological groups: mammals, fish, birds, amphibians/reptiles, and invertebrates. For the choice of species, we requested the collaboration of specialists from each zoological group we considered. The specialists helped us select the most likely species recognized by students as native or invasive exotic. We identified as alien species those that were not original in any of the Brazilian biomes. We consider native species that were originally from the Brazilian territory (Colautti and MacIsaac 2004). The photos of native species in our cardboard game were specifically of species present in the Cerrado biome to effectively verify the students' recognition of the species commonly found in the surveyed cities' local fauna. In total, we produced four different cardboard games to evaluate the students'

Table 1. The number of students surveyed at the three higher education institutions from March to April 2018.

Class	Institution	Course Semester	Course	Number of participants
1	IFGO	Freshmen	Agronomy	36 students
2	IFGO	Seniors	Agronomy	25 students
3	IFGO	Freshmen	Biological Sciences	37 students
4	IFGO	Seniors	Biological Sciences	25 students
5	IFGO	Freshmen	Vet. Medicine	31 students
6	IFGO	Seniors	Vet. Medicine	28 students
7	UFG	Freshmen	Ecology	34 students
8	UFG	Seniors	Ecology	23 students
9	UFG	Freshmen	Agronomy	35 students
10	UFG	Seniors	Agronomy	46 students
11	UFG	Freshmen	Biological Sciences	41 students
12	UFG	Seniors	Biological Sciences	32 students
13	UFG	Freshmen	Vet. Medicine	45 students
14	UFG	Seniors	Vet. Medicine	27 students
15	UEG	Freshmen	Biological Sciences	23 students
16	UEG	Seniors	Biological Sciences	21 students
			Total	509 students

knowledge more broadly, considering a more significant number of species. Each card had 11 photos of animal species. Five of them were of exotic fauna species, and five were of Brazilian native animal species. Each zoological group explained above had two representatives in each cardboard: one was a Brazilian native species, and the other was an exotic animal). Finally, each cardboard also had a domestic animal photo, such as a cat or dog.

We consider this last domestic animal's presence in our questionnaires merely to detect potentially careless responses and, on purpose, erroneous ones. Thus, when the student did not respond correctly about the domestic animal, we eliminated her/his sample universe responses. There were four alternative answers for each photo of a fauna species concerning its name: a correct one and three incorrect ones. Besides the species' names, there was also a question of whether the species represented in that photo was native from Brazil, with 'yes or no' alternatives. In each course-class, we applied the descriptive questionnaire to students and then applied the second questionnaire. We applied the questionnaires in this manner to avoid interference of the second questionnaire upon the responses of the first questionnaire. A more detailed explanation of our methods may be found in Melo et al. (2021). We made available the entire database, questionnaires, templates, charts, and statistical analysis to allow this study's reproducibility and the results' improvement and quality through the following link https://github.com/hersonpc/mestrado-exoticas-nativas.

Data treatment and analysis

We classified the students' answers in our questionnaire's descriptive questions as we previously indicated (e.g., Great, Good, Regular, Bad, Blank). We quantified the students' responses and assigned numerical values to their answers in cardboard game

analyses. Thus, we defined three types of rates, in which we calculated: A) the average proportion of correct species identification; B) the correct average proportion of each species' origin identification (alien or native); and C) the average recognition rate – the association between the identification proportion of the species' name and the origin, a rate calculated only when the correct answers occurred in the two previous questions (name and origin). We calculated the recognition rate to verify students' correctness between the two previous identification ratios. In this way, we compared each interviewee's responses about the correctness between alien and native species.

To perform the association tests on the classification of the students' knowledge levels related to questions 8 to 12 (descriptive questionnaire), we grouped the five knowledge classification options ("great", "good", "regular", "bad" and "very bad") in three groups: a) Good Knowledge (gathers the knowledge levels classified as "excellent" and "good"); b) Regular knowledge; c) Bad Knowledge (gathers the knowledge levels classified as "bad" and "very bad").

We performed the analyses in the statistical software R, version 3.4.3 (R Core Team 2018), and the packages: dplyr, stringr, reshape2, ggplot2, grid, gridExtra, knitr, kableExtra, mvar, nortest, and stats. Initially, we performed a dependent t-test to answer the following hypotheses: 1) Students achieved a higher score for alien species than for native Brazilian species; 2) Students achieved a higher score on the origin of IAS than for native species; 3) Students have a higher score on recognizing alien species than native species. We used ANOVA to test the hypotheses: 4) Students have a higher proportion of correct answers about groups of mammals than about other groups; 5) There is a difference between the correctness scores for alien and native species among the four surveyed courses; 6) Students from the last semesters have a higher proportion of correct answers about alien and native species than students from the first semesters. We used the Chi-square test to test the hypotheses: 7) Students learn more about invasive alien species in higher education than in high school; and 8) There is an association between the attended course/semester and the students' knowledge level. Finally, we used correspondence analysis to examine association relationships among variables and to plot perception maps.

Results

Descriptive data of the sample universe

Among the students surveyed, 59% (n = 300) were female. The average age of the students was 21 years old, ranging from 16 to 52 years old. Regarding the proportion of students among the four courses, 35% (n = 179) were studying Biological Sciences, 28% (n = 142) were Agronomy students, 26% (n = 131) were in Veterinary and 11% (n = 57) were studying Ecology. Approximately 55% (n = 282) of the students were freshmen attending the first semester, and 45% (n = 227) were seniors attending the last semester of their courses. Regarding the researched institutions, 55.6% (n = 283) of the students studied at UFG, 35.8% (n = 182) at IFGO, and 8.6% (n = 44) at UEG.

Results of the application of the subjective questionnaire

More than 40% of the students had a misconception and/or incomplete (Regular or Bad) knowledge about the concept of alien species, and many described the alien species as follows: "*it is a difficult to find species*", "*rare/different*", " *little known/found*", "*wild*" and "*adapted*". However, for the concepts of native species, most students (n = 426; 82.8%) presented a concept classified as "*Good*" or "*Great*" [Good = 73.3% (n = 377) and Great = 9.5% (n = 49)] (Table 2).

When asked about the benefits or losses that the alien species bring to the environment, we classified 41.6% of the students' concepts as "*Bad*" or "*Regular*", as they presented misconceptions and/or incomplete answers, such as: "*do not bring harm*", "*bring benefits because they are part of the ecosystem/food chain*", "*all bring benefits*", "*all species are important*", "*keep the biome in balance*", "*no species brings harm to the environment*" or just "*yes/no*" (Table 2).

When we asked them about examples of IAS, the students listed 269 species; among the ten most-cited alien species, at least three were native to Brazil (the Hyacinth macaw, the Maned wolf, and the Golden lion tamarin). There were also plant species cited as alien ones (e.g., Eucalyptus, soybean). The ten species most cited as alien were the African snail, followed by the Wild boar, the Hyacinth macaw, the Eucalyptus, the Maned wolf, soybean, the Golden lion tamarin, giraffe, lion, and pigeon. However, many students (39.3%) did not mention any correct examples of alien species (Fig. 1A).

On the other hand, when we asked students to cite examples of native species, only 15.4% of them (n = 79) cited incorrect examples. Still, the students also cited some plant species (e.g., the Pequi, the Ipê, the Baru, the Mangaba, and the Brazilwood, all native plants from the Brazilian cerrado). The students cited a total of 208 species as native, and the ten most-cited species were: the Maned wolf, the Pequi, the Giant anteater, the Jaguar, the Macaw, the Ipê, the Baru, the Mangaba, the Golden lion tamarin, and the Brazilwood (Figure 1B). We asked early first-semester freshmen students if they had learned about EIS during high school, and the majority of students, 67% (n = 189), answered "No". Most senior students, 74% (n = 168), when asked if they had learned about EIS in higher education, answered "Yes". We asked students to rate their knowledge level on five aspects related to the topic (native species of the Cerrado, information on invasive species, environmental impacts,

Table 2. Classification of students' responses concerning the concepts described in questions 1, 3, and 4 of the descriptive questionnaire.

Answers	Question 1	Question 3	Question 4
	Alien species	Benefit/losses	Native species
Excellent	7%	5.6%	9.5%
Good	46.9%	41.6%	73.3%
Average	7.4%	13.4%	11.7%
Bad	35.4%	29.6%	2.5%
Blank	3.3%	9.7%	2.9%

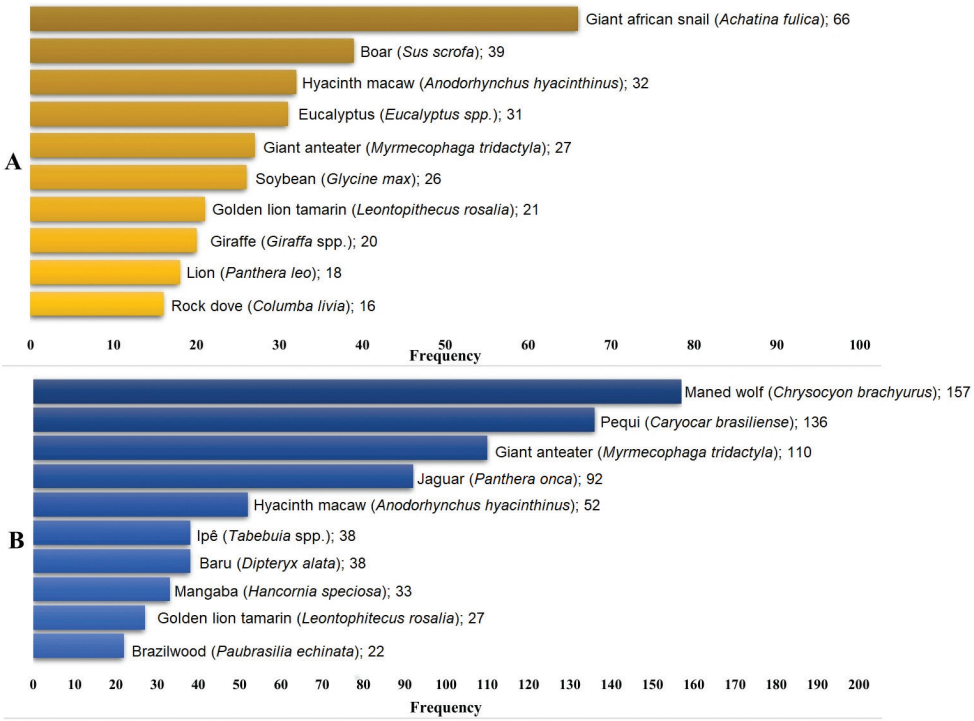

Figure 1. Ranking with the species most cited by students as examples of alien species (**A**) and native species (**B**).

prevention and control techniques, invasive species in the Cerrado), and we asked them to classify it in one of the following categories: "Great", "Good", "Regular", "Bad" and "Terrible". We observed the students expressively classified their knowledge in all five aspects related to the theme as "Regular or "Bad" (Fig. 2).

Results of the application of the subjective questionnaire

Based on the data obtained through the image game applied to higher education classes, we found that the students correctly matched the names of alien and native species ($t = 2{,}026$; d.f. = 15; $p = 0.060$; Fig. 3). On the other hand, students were able to better identify the origin of native species (A) than the origin of alien species IAS (B) ($t = -9{,}767$; d.f. = 15; $p < 0.05$; A = 0.75, B = 0.62; Fig. 3). Finally, considering the species recognition rate, we also observed that students were able to better identify native species (A) than IAS (B) ($t = -2{,}713$; d.f. = 15; $p < 0.05$; A = 0.57; B=0.53; Fig. 3).

When we analyzed the students' knowledge concerning the different zoological groups sampled, we found that the students were better able to identify the taxonomic groups of native birds, mammals (alien and native), and alien fish ($F = 39{,}647$; d.f. = 4; $p < 0.050$). The lowest proportion of correct answers was related to invertebrate taxa (alien and native), native fish, and alien reptiles/amphibians (Figure 4).

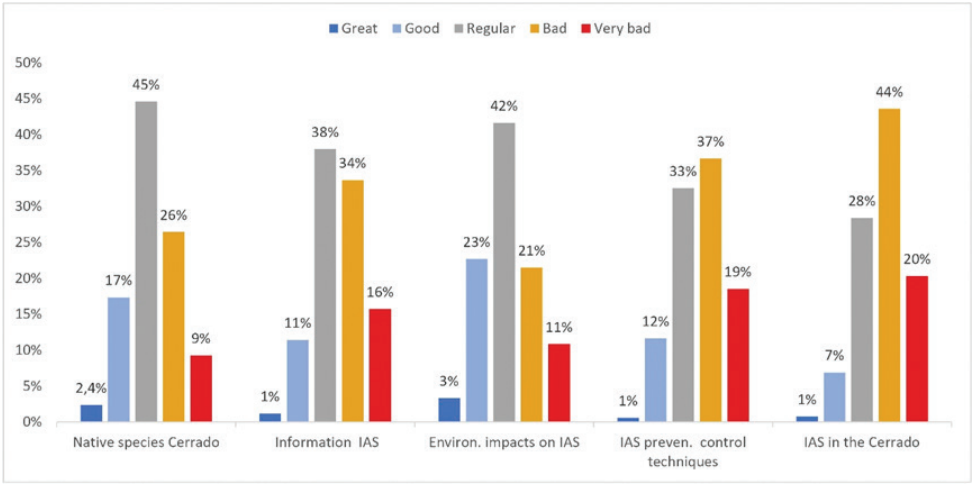

Figure 2. Classification of students' knowledge level on five aspects of the theme: native species of the Cerrado, information on invasive alien species, environmental impacts on invasive alien species, techniques for the prevention and control of invasive alien species and invasive alien species in the Cerrado – for questions 8 to 12 of the descriptive questionnaire, the bars correspond to the 95% confidence intervals.

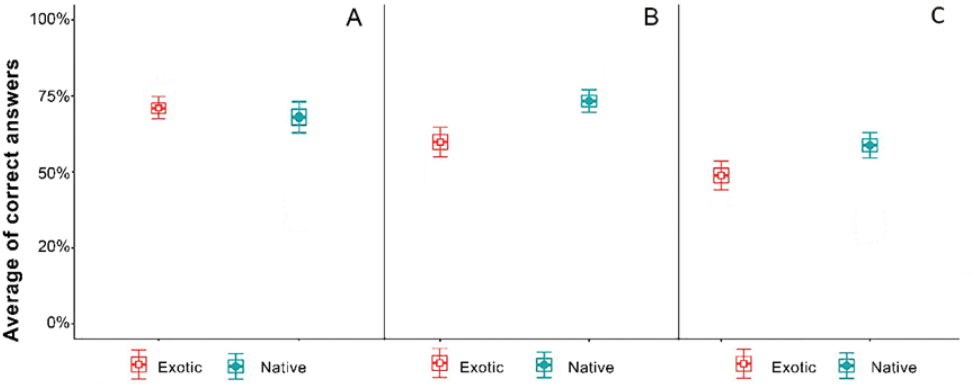

Figure 3. Average percentage of recognition levels **A**) proportion of species identification **B**) proportion of identification of the origin and **C**) recognition rate. The central point corresponds to the averages, the boxes correspond to the standard error, and the bars correspond to the 95% confidence intervals.

We observed a difference between the correctness of identification between alien and native animals in birds, fish, and reptiles. However, the correctness of identification between alien and native groups of mammals and invertebrates was similar.

Students' knowledge of alien and native species was similar among higher education courses ($F = 2.1837$; d.f. = 3; $p = 0.089$) and between the beginning and the end of the course ($F = 0.1195$; d.f. = 1; $p = 0.72$). There was an association between learning about EIS and the students' education level ($\chi^2 = 83.1$; d.f. = 1; $p < 0.001$), that is, there was a higher proportion of students who did not learn about

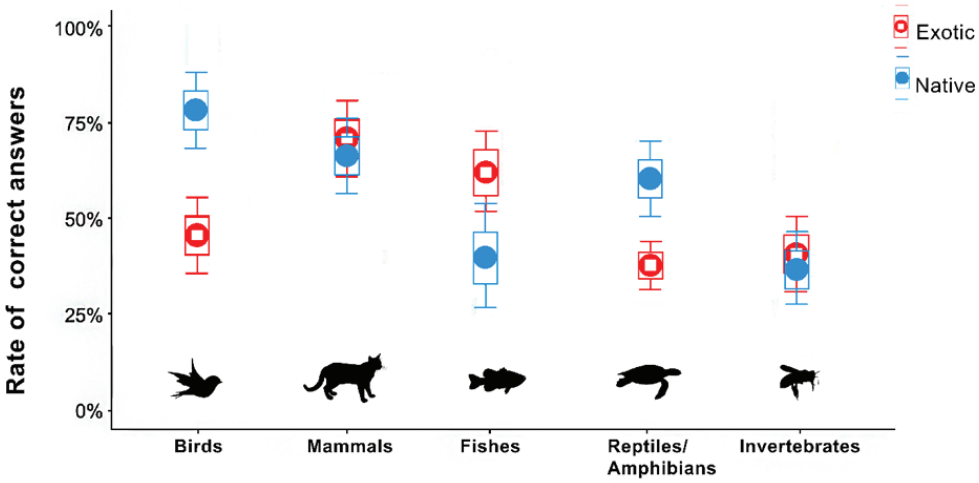

Figure 4. Average rate of correct student identification responses between alien and native animal species in different taxonomic groups. The central point corresponds to the averages, the boxes correspond to the standard error, and the bars correspond to 95% confidence intervals.

EIS in high school (67%), while there was a higher proportion among students who learned about EIS in higher education (74%).

We found an association between the courses/semesters attended and the level of knowledge on the five aspects of the theme (native species of the Cerrado, information on IAS, environmental impacts, prevention and control techniques, and invasive species the Cerrado). We observed a strong association between classes and students' knowledge ($\chi^2 = 54.069$; d.f. = 14; $p < 0.001$). We illustrated the data on a perception map; the first coordinate explains 90.08%, and the second coordinate explains 9.92% of the total data variance (Fig. 5A). We observed that the "Bad" knowledge group was related to the first-semester freshmen groups in the four courses (Agro1, Bio1, Eco1, and Vet1). The "Regular" knowledge grouping was related to the classes of the last semesters of Veterinary (Vet2). The "Good" knowledge grouping was related to course-classes from senior students of Agronomy, Biology, and Ecology (Agro2, Bio2, and Eco2) (Fig. 5A).

We observed an association between the classes and the students' knowledge ($\chi^2 = 43{,}105$; d.f. = 14; $p < 0.001$). We illustrated the data on a perception map; the first coordinate explains 74.37%, and the second coordinate explains 25.63% of the total data variance (Figure 5B). We observed that "Bad" knowledge group was associated with the freshmen students of the Veterinary, Agronomy, and Ecology courses and the senior students of Veterinary (Agro1, Eco1, Vet1, and Vet2). The "Regular" group was related to the senior students from Ecology course-classes and the freshmen and senior students of Biology (Eco2, Bio1, and Bio2). The group of "Good" knowledge levels was only related to the course-classes of senior students of Agronomy (Agro2) (Fig. 5B).

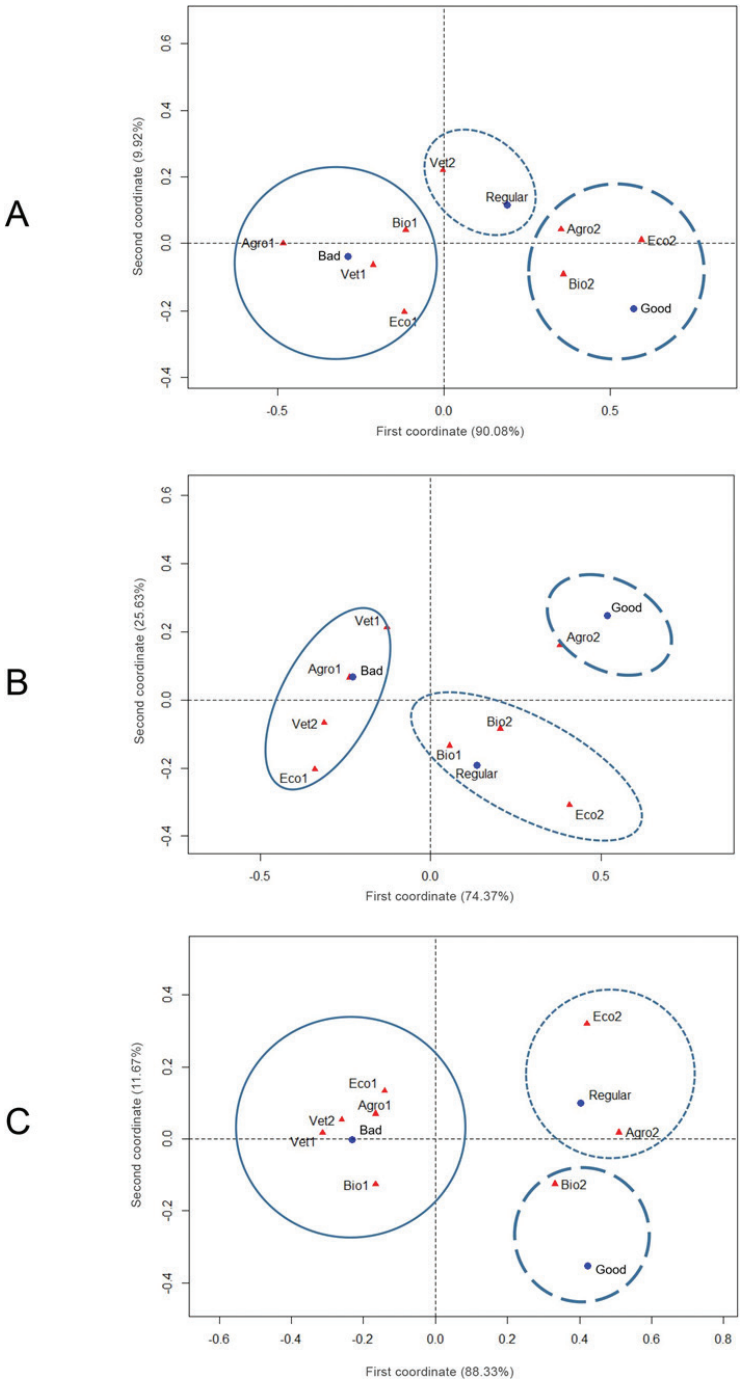

Figure 5. Knowledge perception map between different classes concerning different aspects of the theme. **A**) General information on invasive alien species **B**) Techniques for the prevention and control of invasive species, and **C**) Invasive species in the Cerrado. The circles highlighted in the graph are only intended to assist interpretation by highlighting the most homogeneous categories.

We observed an association between classes and students' knowledge about invasive alien species in the Cerrado ($\chi^2 = 53.867$; d.f. = 14; $p < 0.001$). We observed that the first coordinate explains 88.33% through the perception map, and the second coordinate explains 11.67% of the total data variance (Fig. 5C). We observed that the "Bad" knowledge group was related to the freshmen students of the four courses and the classes of the last semesters in Veterinary (Agro1, Bio1, Eco1, Vet1, and Vet2). The "Regular" knowledge group was related to course-classes of senior students of Agronomy and Ecology (Agro2 and Eco2). The "Good" knowledge group was only associated with classes from the last semesters of Biology (Bio2) (Fig. 5C).

Discussion

University students performed better when identifying, conceptualizing, and exemplifying native Brazilian species compared to IAS. We found that the best identified taxonomic groups were native birds, mammals (alien and native), and alien fish, while the least identified were the native fish, alien reptiles/amphibians, and invertebrates (alien and native). The students' performance was similar among the different higher education courses and comparing the freshmen and the senior students of each course. Most students stated that they did not learn about IAS in high school but higher education. However, academics do not consider themselves well informed on the topic, as they classified their knowledge on various aspects as fair or poor. We found an association between the courses/semesters and the classification of the students' level of expertise in different aspects related to IAS and native species. Most classes performed well on some aspects of the theme. However, the freshmen students of all courses we evaluated and the Veterinary Medicine course's senior students did not stand out positively in any aspect.

Students' good performance about native species shows that the research's target audience has adequate knowledge about Brazilian native species. Therefore, we observed a coherent result since it is expected that academic students in the environmental area will have the ability and competence to identify native species. The ability to recognize native species demonstrates the approach and involvement of students with the environment and the appreciation of local biodiversity and that the content related to native biodiversity is probably being addressed effectively by the researched institutions. This result is positive, as it expands the knowledge about the local environment and improves interactions between people and the environment, so knowing biodiversity is the first step in developing its preservation (Dal-Farra et al. 2011).

However, the students did not present similar results concerning alien species, although it is relevant that university students in the environmental area have a broad understanding of these species and the environmental, economic, and social impacts. These future professionals must identify, mitigate, and solve biological invasions problems (Smith et al. 2011; Oxley et al. 2016). The inability to identify and differentiate between alien, non-invasive, and native species can hinder the success of IAS prevention and control techniques (Somaweera et al. 2010).

The low perception of students concerning invasive species can be explained by the syndrome of base change, in which the absence of information or experiences about the previous conditions of the environment leads the current population to accept the present situation as being "normal" or "natural" (Pauly 2004; Miller 2005; Soga and Gaston 2017). In this way, due to the short-term view on biodiversity, new generations do not perceive biological invasions and the progressive disappearance of species (Clavero 2014). This phenomenon is recognized as one of the main obstacles to addressing numerous current environmental problems (Soga and Gaston 2017). In this sense, universities face the challenge of developing up-to-date training with society's growing problems and training professionals prepared to deal with such problems (Bilert et al. 2014).

We found that university students massively stated that they had not learned about IAS during high school, as already noted by Melo et al. (2021) for high school students, thus reinforcing the existence of deficiencies in developing the theme at this stage of teaching. These results are similar to what was found by Oxley et al. (2016), whose work shows that respondents who attended only high school had less knowledge about invasive species than respondents with higher education. In this way, we realized that IAS's information should be formally inserted in both primary and secundary educations, mainly through environmental education programs and projects, to stimulate the students' environmental responsibility (Azevedo-Santos et al. 2015). Therefore, we perceive the need for greater emphasis when addressing the topic of biological invasion so that it is not worked only as a topic within the Biology content. The biological invasion must be handled as a theme to be worked on in a transversal way in high school, exploring all the theme's complexity and scope. For instance, both high-school teachers and university professors should take more time to actively introduce such topics to the students in classes and lectures. Specific disciplines for undergraduate students should be taught in their institutions, elucidating to them what are invasive exotic species and how they may be controlled/managed. Also, technical visitation and/or lectures from experts involved with the control of invasive species would be of great importance so that the students would learn from the practice itself, with professionals involved with this kind of research. Finally, it is also important that books and teaching materials address biological invasions at different education levels, with contextualized, continuous, and in-depth development (Azevedo-Santos et al. 2015).

The IAS instruction appears to be more effective in higher education than in high school since most students claimed to have learned about invasive species during undergraduate courses. Thus, we found that higher education can positively influence academics' knowledge and attitudes concerning IAS (Waliczek et al. 2018). Although university students have more access to learning about the topic, this knowledge seems insufficient since most students do not consider themselves well informed about the subject, indicating shortcomings and flaws in the students' knowledge about IAS. Knowledge deficiency related to IAS was also observed by Smith et al. (2011), using a review of the curricula of several undergraduate and graduate courses in Canadian universities.

The use of alternative techniques and methodologies, such as lectures, practical classes, and case studies, can effectively improve teaching and learning and, consequently, reverse these deficiencies. Fox and Loope (2007) and Waliczek et al. (2018) investigated the use of simple pedagogical techniques and methodologies, such as case studies, and found a significant increase in knowledge about invasive species, mainly by contextualizing the theme with the students' daily lives. In this way, developing well-planned curricular activities and targeting specific audiences allow better education results on IAS (Vanderhoeven et al. 2011). Therefore, teaching and learning must go beyond traditional disciplinary education, so knowledge on invasive species needs to be treated in a multiple and contextualized way since environmental problems involve and relate to numerous aspects of society (Smith et al. 2011).

Each surveyed course stood out concerning the following aspects of knowledge about IAS: senior students of Biological Sciences assessed their knowledge as best in general aspects about IAS and the IAS in the Cerrado. The senior Ecology evaluated their knowledge as better regarding the general aspects of IAS. The senior students of Agronomy considered their knowledge better regarding the techniques on prevention and control of IAS. Senior students of Veterinary Medicine did not rate their knowledge positively in any aspects related to IAS. In this way, we noticed gaps in the interviewees' knowledge concerning IAS's several aspects in all the surveyed courses, especially in the Veterinary Medicine course. Therefore, we understand that it is necessary to rethink how biological invasion has been addressed in the curricula, including specific disciplines and research programs related to biological invasions in academic curricula, mainly in courses related to the environmental sciences (Azevedo-Santos et al. 2015). Besides, it is crucial to develop interdisciplinary programs that powerfully address IAS issues (Smith et al. 2011; Hautier et al. 2018). Therefore, it is essential to apply more environmental and scientific education programs to raise awareness and public interest about the importance of native biodiversity and environmental problems (Lindemann-Matthies and Bose 2008; Novoa et al. 2018).

Conclusion

Our study's results show that the knowledge of undergraduate students in interviewees about invasive alien species is low. Therefore, it is a consequence of the lack of information about alien species. We observed deficiencies in the development of the theme, which suggests to us that there is a severe need to review how the theme of biological invasions has been inserted and worked into the academic curricula of courses related to the environmental area. We also suggest using new teaching strategies so teachers and professors teach the invasion ecology topic better and students can learn more about IAS. By doing this, the target audiences will act directly in the prevention and control of biological invasions and, consequently, minimize the impacts caused to biodiversity, health, and economy caused by invasive species.

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