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Ecotourism, Sensory Trails and Social Inclusion: university extension experiences in protected natural areas in the state of Rio de Janeiro –

Ecoturismo, Senderos Sensoriales e Inclusión Social: experiencias de extensión universitaria en áreas naturales protegidas del estado de Río de Janeiro – Brasil

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Abstract: Human activities have transformed landscapes, eliminating native vegetation and altering ecosystems, affecting the environmental stability and functions of natural areas. Tourism, especially ecotourism, guided by conservationist and pedagogical principles, can enhance natural and cultural assets without depleting them. This study analyzes two University Extension Projects of the UERJ Department of Tourism in parks in Rio de Janeiro and São Paulo: (1) Partiu Trilha UERJ – DTUR, focused on democratizing ecotourism; and (2) Senderos y Rutas Sensoriales, oriented towards environmental perception, non-formal education, and the inclusion of people with disabilities. Using action research methodology, bibliographic reviews, observations, questionnaires, and reports were applied. Between 2016 and 2024, Partiu Trilha carried out 55 activities in eight parks with 986 participants, and Sensory Trails implemented 56 activities in 11 parks with 947 participants. Both projects promoted environmental education, inclusion, conservation, and accessible experiences, contributing to SDGs 3, 4, 10, 15, and 16.

Keywords: natural protected areas; ecotourism; environmental education; nature-society relationship; sensory trails

Resumen: Las actividades humanas han transformado paisajes, eliminando vegetación nativa y alterando ecosistemas, lo que afecta la estabilidad ambiental y las funciones de las áreas naturales. El turismo, especialmente el ecoturismo, guiado por principios conservacionistas y pedagógicos, puede valorizar activos naturales y culturales sin agotarlos. Este estudio analiza dos Proyectos de Extensión Universitaria del Departamento de Turismo de la UERJ en parques de Río de Janeiro y São Paulo: (1) Partiu Trilha UERJ – DTUR, enfocado en democratizar el ecoturismo; y (2) Senderos y Rutas Sensoriales, orientado a la percepción ambiental, la educación no formal y la inclusión de personas con discapacidad. Con metodología de investigación-acción, se aplicaron revisión bibliográfica, observaciones, cuestionarios e informes. Entre 2016 y 2024, Partiu Trilha realizó 55 actividades en ocho parques con 986 participantes, y Sensory Trails ejecutó 56 actividades en 11 parques con 947 personas. Ambos proyectos promovieron educación ambiental, inclusión, conservación y experiencias accesibles, contribuyendo a los ODS 3, 4, 10, 15 y 16.

Palabras clave: áreas naturales protegidas; ecoturismo; educación ambiental; relación naturaleza-sociedad; senderos sensoriales

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1. Introduction

In the historical process of land use and occupation, human activity has frequently led to the removal of original vegetative cover, converting ecosystems into anthropic landscapes and causing adverse consequences for environmental stability (Pereira, 2012). These transformations are not limited to the material production of goods, but also reconfigure symbolic, recreational, and economic functions of natural spaces. In this regard, natural areas have come to be recognized and utilized as resources for commercial and leisure activities (Pepper, 2006), among them, tourism. When guided by conservationist and pedagogical principles, tourism (especially ecotourism) can render natural and cultural assets attractive without necessarily leading to their systematic depletion, provided visitation practices are properly planned and managed (De Andrade, 2004).

Given the worsening of environmental degradation at various spatial scales, it is urgent to develop actions and projects that bring society and nature into closer, more harmonious, and sustainable relations, fostering a perception that recognizes human beings as integral parts of natural systems (Pereira & Ghisoni, 2017). It is within this horizon that the two University Extension Projects analyzed in this work are situated, both developed by the Department of Tourism of the State University of Rio de Janeiro (UERJ), with activities carried out in Natural Parks within the states of Rio de Janeiro and São Paulo: 1) Partiu Trilha UERJ – DTUR: Ecotourism and the Nature–Society Relationship, whose focus was on the democratization of ecotourism; and 2) Sensory Trails and Routes as Instruments of Environmental Perception and Education in the State of Rio de Janeiro, aimed at the development of sensory trails and routes for educational purposes, playful and non-formal environmental perception, and inclusion of people with disabilities (highlighting work with individuals with Down Syndrome). The body of the article also discusses how these initiatives interface with the Sustainable Development Goals (Agenda 2030) (United Nations, 2015), the limitations imposed by the COVID-19 pandemic, and the future challenges for the execution and expansion of the initiatives.

The central objectives of this work are therefore: (a) to present the methodologies adopted in the two extension projects; (b) to systematize and discuss the main results and indicators obtained; and (c) to reflect on the contributions of these practices to environmental education, inclusive tourism, and biodiversity conservation. To accomplish these objectives, the article is structured as follows: 1) introduction and presentation of objectives; 2) literature review (society–nature relationship; protected natural areas; public use, ecotourism and sensory trails; inclusive tourism); 3) methodology; 4) results, with case study descriptions; and 5) final considerations.

1.1. Literature Review

Understanding the nature–society relationship requires recognizing the plurality of viewpoints and the varied perceptions that different social groups, cultures, and individuals hold regarding natural environments. These differences influence the configuration of landscapes and associated social dynamics, making landscapes dynamic processes emerging from the interaction of multiple social actors whose actions impact the structure and functioning of ecosystems (Pereira, 2012). At the same time, the long history of anthropic transformation of landscapes demonstrates that there is a need for practices that reconcile biodiversity maintenance with fulfilling social needs through sustainable use of natural environments (Pereira & Ghisoni, 2017).

One institutional response to the environmental crisis has been the establishment of protected natural are (Cecconello, 2009). In Brazil, the normative framework of the National System of Conservation Units (SNUC), Federal Law No. 9,985/2000, instituted Conservation Units (UCs) (the terminology used for protected natural areas in Brazil), divided into major categories such as sustainable use UCs and integral protection UCs, respectively influenced by conservationist and preservationist perspectives (Brasil, 2000, Art. 7°). SNUC also mandates that, in certain categories of UCs (such as the "Natural Park" category), educational, recreational, and environmental interpretation activities shall be promoted, especially through visitation and

public use (Brasil, 2000, Art. 3º). Under these conditions, tourism, in the forms of ecotourism, adventure tourism, or contemplation tourism, when properly conducted, can contribute to the conservation, valuation of the protected area, generation of revenue for its management, enhanced oversight and protection, as well as employment opportunities and income increase for local populations (Amando de Barros, 2003).

Protected natural areas, therefore, represent privileged spaces for (re)connecting people with nature, combining knowledge, affectivity, imagination, and sense of belonging; elements essential for fulfilling the goals of environmental education and nature conservation (Vasconcellos, 2006). According to Cotes (2018), experiences in natural environments can contribute to the revision of values and attitudes, fostering behavioral changes in relation to the environment. In accord, the Brazilian National Environmental Education Policy defines environmental education as the processes by which individuals and collectives build social values, knowledge, skills, attitudes, and competencies aimed at conserving the environment, regarding it as a common good essential to quality of life and sustainability (National Environmental Education Policy, 2016, Art. 1º).

In practical terms, ecotourism activities should prioritize sustainable use of natural and cultural heritage, encourage their conservation, promote environmental interpretation and education, and contribute to the well-being of populations (Ministério do Turismo., 2010). In this vein, the Brazilian Ministry of Tourism's document summarizes that "Ecotourism rests upon the tripod: interpretation, conservation and sustainability" (Ministério do Turismo., 2010).

The profile of the Brazilian ecotourist, according to that same document, is predominantly between 25 and 50 years old, with higher education, medium to high purchasing power, originating from large urban centers, concerned with conservation and preferring authentic and high-quality experiences (Ministério do Turismo., 2010). Such a configuration indicates a trend of elitization of ecotourism, which demands initiatives of socialization and democratization of access for different social segments (children, elderly persons, people with disabilities, and low-income populations) in order to broaden the social and educational benefits stemming from the public use of natural areas.

Sensory trails assume a particular strategy to bring society and nature closer together by integrating playful and pedagogical elements that stimulate sensory perception (visual, auditory, olfactory, tactile). By using the landscape as a didactic resource, such trails enhance the bodily and perceptual experience of participants, promoting engagement, reflection, and learning (Vasconcellos, 2006; Oliveira & Bloomfield, V.K. Magalhães, 1999). International experiences such as the Sensory Trail Park Lancaster (Lancaster, Ohio, USA), with stations designed to stimulate the senses through textures, smells, and sounds (Fairfieldcountyparks, 2019), or the Frick Naturena Sinnespfad Trail (Kornbergweg, Switzerland), with interactive sensory stations focused on children (Swiss Family Fun, 2001), exemplify approaches that favor inclusion of people with disabilities and enhancement of the environmental experience.

In Brazil, initiatives such as Trilha da Vida (Parque Ecológico do Guarapiranga, São Paulo) (Ribeiro, 2015), the sensory trail at Núcleo Picinguaba (Parque Estadual da Serra do Mar — Ubatuba, SP) (Infraestrutura Meio Ambiente, 2020), and trails specifically designed for visually impaired persons and wheelchair users, such as in Parque Estadual da Pedra Branca, Parque Nacional da Tijuca, the Sensory Garden of Parque Nacional do Itatiaia, and the Sensory Trail & Garden at the Reserva Ecológica de Guapiaçu (REGUA) (Almeída, 2020), demonstrate the applicability and potential of sensory trails for inclusive tourism and environmental education in the Brazilian context. In view of these examples, a close relationship between sensory trails and inclusive tourism becomes evident, sensory trails being an initial step toward developing adapted trails that promote inclusion of people with disabilities.

2. Materials and methods

This study adopted an action-research approach with an empirical character and interpretative reflections, combining bibliographic research (secondary data) and primary data collection obtained in the field. Data analysis was conducted using quantitative procedures (basic descriptive statistics) and qualitative techniques (discourse analysis and thematic interpretation), following the methodological frameworks of Silverman (2007) and the epistemological orientation of (Feyerabend, 2011).

In practice, the development of the work comprised the following stages: a bibliographic survey on central topics (nature–society relationship; public use in protected natural areas; ecotourism; sensory trails; inclusive tourism); identification and analysis of similar experiences and studies in national and international contexts; systematization of methodological procedures applied in the two university extension projects; technical visits and fieldwork to adapt routes; application of evaluation instruments (semi-structured questionnaires) and organization of discussion circles after the field activities to assess and improve the methodologies; and, finally, systematization and discussion of the results obtained.

The instruments for primary data collection included attendance and participation records, evaluation forms completed by participants (profiles and perceptions), field reports from monitors, photographic documentation, and dissemination materials. Quantitative data were processed using simple descriptive statistics (frequencies, percentages), while qualitative information from participants' comments, reports, and observations were organized into thematic categories for purposes of analysis and interpretation.

3. Results and discussion

Overall, both projects were designed to foster a more harmonious relationship between society and nature, articulating actions of environmental education, perception, and social inclusion through tourism. The following section presents a detailed description of the historical background, methodological procedures, and main indicators that highlight the results achieved by each initiative between 2016 and 2024.

3.1. University Extension Project "Partiu Trilha UERJ – DTUR: Ecotourism and the Nature–Society Relationship"

Linked to the Department of Tourism at UERJ and initiated in 2016, the project aimed primarily to stimulate social practices fostering a more balanced and sustainable nature–society relationship, bringing both tourists and residents closer to the remaining natural areas of the state of Rio de Janeiro. To this end, itineraries, activities, and events in ecotourism and adventure tourism were designed in Natural Parks of the metropolitan and mountainous regions of the state, offered free of charge and directed toward diverse audiences (national and international tourists, local residents, senior groups, and children/adolescents aged 6 to 18), thereby promoting social interaction, health, quality of life, and, through environmental education, the dissemination of sustainable visitation practices as well as democratization of ecotourism.
The state of Rio de Janeiro offers a wide range of Natural Parks (municipal, state, and federal) that allow for hiking, trekking, climbing, and other public-use activities throughout the year. In this context, methodological procedures included initial bibliographic research on public use and ecotourism, followed by technical visits to the parks for mapping and designing itineraries adapted to each group's specificities. Outreach and audience engagement were carried out through social media and institutional communication channels.

Groups were organized via prior scheduling, with an average of 20 participants per group and a team of four monitors (including at least one licensed tour guide). The average frequency proposed was at least two activities per semester. After each itinerary, a discussion circle was conducted with participants to evaluate the experience, collect suggestions, and continuously

adapt methodologies; a process of reflection and adjustment maintained throughout the project's development.

Considering the profile of the Brazilian ecotourist (Brasil, 2008), characterized by a relatively narrow demographic and socioeconomic range, the free offering of activities allowed for greater access and democratization of practices traditionally restricted to limited groups.
The data summarized in Table 1 illustrate the indicators used to analyze the project's evolution between 2016 and 2024.

Based on Table 1, a progressive increase can be observed in the number of activities conducted, from only 2 in 2016 to 8 in 2024, totaling 55 activities over the period. This growth was directly reflected in the number of people involved, which also rose significantly: from 48 participants in 2016 to 148 in 2024, reaching 986 people in total.

The diversity of natural parks also expanded, from 2 units in 2016 to a peak of 5 units in several years, totaling 8 parks overall, demonstrating the territorial expansion of the project. Regarding group profiles, there was a gradual increase from 1 profile in 2016 to 3 distinct profiles in multiple years, including university students, elementary/high school students, and open groups (residents/tourists). In academic terms, the project featured 30 presentations at scientific events during the period, while student monitor involvement remained relatively stable, totaling 22 students.

Table 1. Indicators of the Evolution of the Extension Project "Partiu Trilha UERJ – DTUR: Ecotourism and the Society–Nature Relationship" (2016–2024)

Criteria	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total
Total Number of People Involved in the Activities	48	83	118	163	38	115	132	141	148	986
Number of Natural Parks Where the Activities Were Carried Out	2 (A;C)	3 (A; B; C)	5 (A; B; C; D; E)	5 (A; B; C; D; E)	2 (C; F)	3 (B; C; F)	5 (B; C; D; E; G)	5 (C; D; E; G; H)	4 (C; D; E; G)	8
Group Profiles**	1 (I)	2 (I; K)	3 (I; J; K)	3 (I; J; K)	1 (I)	2 (I;K)	3 (I; J; K)	2 (I; K)	3 (I; J; K)	3
Project Presentation in Lectures and Scientific Events	1	2	3	4	5	4	3	4	4	30
Number of students involved (Monitors)	2	3	3	3	3	2	2	2	2	22

*** Natural Parks**
A) Parque Natural Municipal Montanhas de Teresópolis (PNMMT) – Teresópolis, RJ
B) Parque Nacional da Serra dos Órgãos (PARNA-SO) – Teresópolis, RJ
C) Parque Nacional da Tijuca (PNT) – Rio de Janeiro, RJ
D) Parque Natural Municipal da Prainha (PNMP) – Rio de Janeiro, RJ
E) Parque Natural Municipal de Grumari (PNMG) – Rio de Janeiro, RJ
F) Parque Natural Municipal Marapendi (PNMM) – Rio de Janeiro, RJ
G) Parque Estadual do Grajaú (PEG) – Rio de Janeiro, RJ

H) Parque Natural Municipal Bosque da Barra (PNMBB) – Rio de Janeiro, RJ
**** Group Profiles**
I) University Students
J) Elementary and High School Students (children and adolescents aged 6–18)
K) Open Groups (residents, tourists, and visitors)

It is worth noting that in early 2020, specific itineraries were developed for senior groups at the Tijuca National Park, adapting the duration and difficulty levels to this demographic's needs. However, due to the COVID-19 pandemic, these activities were temporarily suspended, particularly given the elderly population's classification as a risk group. Safety, health, and well-being thus guided all decisions, leading to the adaptation of methodologies to comply with sanitary norms and existing protocols. In-person activities in natural parks gradually resumed later in 2020 (Figure 1).

Figure 1. Overview of activities in the Partiu Trilha UERJ – DTUR Project". (Source: Own elaboration)

Continuous growth in all monitored indicators (number of participants, diversity of profiles, and territorial scope) demonstrated that the project successfully achieved its objectives of democratizing ecotourism and strengthening society–nature connections.

3.2. University Extension Project "Sensory Trails and Routes as Instruments of Environmental Perception and Education in the State of Rio de Janeiro"

Initially conceived as an internal internship project within the Department of Tourism at UERJ in 2016, the work was consolidated as an extension project in 2018. The sensory trails were proposed as pedagogical instruments of high educational value, emphasizing playful and non-formal learning strategies while also fostering social inclusion. These routes constitute distinctive tourist attractions, with the potential to strengthen local economies and expand environmental awareness among residents and visitors, while simultaneously promoting the inclusion of people with disabilities in ecotourism activities (Pereira & Ghisoni, 2017).

The methodological stages included an initial bibliographic review and discussions on environmental history, nature–society relationships, ecotourism, environmental education, sensory trails, and inclusive tourism. This was followed by fieldwork in various natural parks across the state of Rio de Janeiro (and one in the state of São Paulo) to identify suitable routes, target audiences, durations, and difficulty levels for sensory activities. After these assessments, group schedules were arranged, and activities were disseminated through social media, lectures, and participation in scientific events.

During the bibliographic review, it became evident that discussions about sensory trails in Brazilian natural parks remained incipient and that academic production on the topic was relatively scarce; thus, the project's innovative character was justified. Between 2016 and 2017, methodologies were adapted for university students and open groups; in 2018, pedagogical strategies were designed for elementary and high school students; and in 2019, specific adaptations were introduced for groups of people with disabilities (Down Syndrome), in partnership with the Down Syndrome Association (ASSIND) in Teresópolis (RJ).

The maximum number of participants per activity varied according to the carrying capacity of each environment and the characteristics of each group. Activities addressed environmental education content in a playful and inclusive manner, also incorporating historical and geographical aspects, nature– society relationships, health, quality of life, social inclusion, and best practices for visiting natural areas. Activities and methodologies were designed for tropical environments, especially the Atlantic Forest, but could be adapted to other biomes and ecosystems with low cost and minimal trail interventions.

At the end of each activity, semi-structured questionnaires were applied to capture participant profiles and perceptions of the practices developed, as well as to collect information for evaluating the methodologies adopted. Table 2 provides a summary of the principal stages involved in the implementation of sensory trails within the project.

Table 2. Basic steps for conducting sensory trails and routes

Basic steps for conducting sensory trails and routes	
Step I – Before the sensory trail	
In the origin place	Detail to the interested group what are the sensory trails and how they work.
Arrival of the group at the place of the activity	1) Icebreaker activity aiming to integrate the individual with the group; the group with the group; and the group with the environment. 2) Basic stretching aiming to prepare the individual physically and mentally before the activities.
Step II – During the sensory trail	
Environmental education	Familiarize the group with the ecological characteristics of the site as well as on the relevance of the debate on the environmental issue by different actors and at different temporal and spatial scales.
Sensory Activities	Experience of the perception of the human senses: sight, hearing, touch, and smell through a bank of activities defined according to the participating group.
Step III – After the sensory trail	
Debate / Discussion	It aims to fix the knowledge gained during the activity, and also to exchange experiences with the other members of the group.
Data collection	Questionnaire application.
Relaxation activities	Preparation for returning for the place of origin.

According to Table 3, continuous growth was observed in the indicators: a greater number of people reached, expansion of group profiles, increased use of natural areas, growth in the number of students involved, and increased presence at scientific events.

Over the period, 56 activities were conducted, starting with 4 in 2016 and reaching 8 in 2024 (Fig. 2). The total number of participants reached 947, with 2019 standing out for having 170 participants, the highest annual total.

The number of natural parks used increased from 1 park in 2016 to up to 6 parks in some years, totaling 11 different units overall, indicating greater geographic diversity.

Group profiles also expanded, including not only students and visitors but also people with disabilities starting in 2019, representing significant progress in terms of social inclusion. There were 34 presentations at scientific events and 23 student monitors involved, peaking at 5 students in 2018 and 2019.

In 2020, plans were made to broaden participation among groups with disabilities, focusing on individuals with Down Syndrome, visual and hearing impairments, mobility disabilities, and autism; an effort temporarily interrupted by the COVID-19 pandemic. In response, new protocols were developed to adapt sensory trails to the realities of physical distancing and health regulations. Later in 2020, in-person activities were resumed, initially focusing on the university's student community.

Table 3. Indicators of the Evolution of the Extension Project "Sensory Trails and Routes as Instruments of Environmental Awareness and Education in the State of Rio de Janeiro" (2016–2024)

Criteria	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total
Total Number of People Involved in the Activities	56	110	85	170	32	68	125	136	165	947
Number of Natural Parks Where the Activities Were Carried Out	1 (A)	1 (A)	5 (A; B; C; D; E)	6 (A; B; C; D; E; F)	3 (A; B; C)	3 (C; H; I)	5 (B; C; D; E; J)	6 (C; D; E; G; J; K)	4 (C; D; E; G)	11
Group Profiles**	1 (L)	2 (L; M)	3 (L; M; N)	4 (L; M; N; O)	1 (L)	2 (L; N)	4 (L; M; N; O)	3 (L; N; O)	3 (L; M; N)	4
Project Presentation in Lectures and Scientific Events	1	3	4	5	5	5	4	4	3	34

* **Natural Parks**
A) Parque Natural Municipal Montanhas de Teresópolis (PNMMT) – Teresópolis, RJ
B) Parque Nacional da Serra dos Órgãos (PARNA-SO) – Teresópolis, RJ
C) Parque Nacional da Tijuca (PNT) – Rio de Janeiro, RJ
D) Parque Natural Municipal da Prainha (PNMP) – Rio de Janeiro, RJ
E) Parque Natural Municipal de Grumari (PNMG) – Rio de Janeiro, RJ
F) Reserva Guapiaçu (REGUA) – Cachoeiras de Macacu, RJ
G) Parque Estadual da Serra do Mar - Núcleo Picinguaba (PESM) – Ubatuba, SP
H) Parque Natural Municipal Marapendi (PNMM) – Rio de Janeiro, RJ
I) Parque Natural Municipal Chico Mendes (PNMCM) – Rio de Janeiro, RJ
J) Parque Estadual do Grajaú (PEG) – Rio de Janeiro, RJ
K) Parque Natural Municipal Bosque da Barra (PNMBB) – Rio de Janeiro, RJ
** **Group Profiles**
L) University Students
M) Elementary and High School Students (children and adolescents aged 6–18)
N) Open Groups (residents, tourists, and visitors)
O) People with disabilities (Down Syndrome)

Overall, the projects' results revealed impacts in three dimensions: social (environmental education and inclusion), environmental (conservation and society–nature relations), and economic (development of distinctive tourist products and appreciation of local culture).

Figure 2. Examples of sensory activities developed by the project Source: Pereira (2021)

4. Conclusion

By addressing public use in protected natural areas through ecotourism, sensory trails, and inclusive tourism, the projects analyzed here directly engaged with the concept of sustainability and the implementation of the 2030 Agenda in the tourism sector. A direct correspondence was observed with several Sustainable Development Goals (United Nations [UN], 2015, p. 14), among which the following stand out:

• SDG 3 — Good Health and Well-being: through the organization of physical and sensory activities in natural environments for diverse groups, including people with Down Syndrome.

• SDG 4 — Quality Education: via environmental education activities aimed at elementary, high school, and university students, as well as work with people with disabilities.

• SDG 10 — Reduced Inequalities: through free visitation activities in natural parks, democratizing access to ecotourism.

• SDG 15 — Life on Land: by promoting sustainable public use in natural areas, contributing to biodiversity conservation.

• SDG 16 — Peace, Justice, and Strong Institutions: through engagement with local communities and participation in natural park advisory councils.

The case studies demonstrated that university extension initiatives can contribute to sustainability in the tourism sector by fostering ecotourism democratization, promoting public use in natural parks, and advancing inclusive tourism through sustainable practices, such as free itineraries and sensory trails. These initiatives encourage environmental education (playful and non-formal), promote social inclusion of people with disabilities, enhance local cultures, and create distinctive, low-cost tourist attractions.

The COVID-19 pandemic directly impacted both projects, requiring methodological revisions and the development of protocols for the safe resumption of activities, prioritizing participant health and well-being while maintaining ecosystem conservation. Nevertheless, the accumulated experiences and the gradual resumption of in-person activities provide methodological insights and empirical evidence supporting the continuity, adaptation, and replication of these practices in other territorial contexts.

In conclusion, the actions described successfully stimulated social practices fostering a more harmonious and sustainable relationship between society and nature, bringing human populations closer to the remaining natural areas in the state of Rio de Janeiro, promoting social inclusion, and supporting public use associated with biodiversity conservation.

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Conflict of interest

The authors declare no conflict of interest.

Author Contributions

T. Ferreira Pinheiro Dias Pereira: Defined and conceptualized the research topic, participated in the methodological design, collaborated in the development and application of the instruments, and conducted the research. In addition, drafted the first version of the scientific article and contributed to the final review and editing of the manuscript.

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