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Identification of Ecosystem Services as a tool to promote environmental management of a natural park in the municipality of Natal/RN

Cynthia Valéria Barbosa Gomes Lobato[1] Maxwell Ferreira Lobato[2] Diógenes Félix da Silva Costa[3]

[1] Master. Federal University of Rio Grande do Norte – UFRN Natal, Rio Grande do Norte – Brazil. val803@hotmail.com

[2] Doctor. Federal Rural University of the Semi-Arid Region – UFERSA Angicos, Rio Grande do Norte – Brazil

[3] Doctor. Federal University of Rio Grande do Norte – UFRN Natal, Rio Grande do Norte – Brazil

Authors' notes'

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Correspondence regarding this article should be addressed to Cynthia Valéria Barbosa Gomes Lobato

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Objective: To identify the Ecosystem Services of an urban natural park as a way of assisting in the environmental management of the area.

Methodology: The identification was carried out in Dom Nivaldo Monte City Park, based on the Common International Classification of Ecosystem Services, through a review of the bibliography and face-to-face visits. Finally, a review of the Management Plan was carried out to identify how the results of the work could assist in decision-making aimed at its effective conservation.

Originality/Relevance: The Park does not have any relevant studies related to the topic, mainly as a tool that can assist in local management. Furthermore, the work becomes relevant when it is intended to present decision-makers with information about the benefits of their ecosystems with a view to the correct application of resources and, therefore, their conservation.

Results: 26 Ecosystem Services were found that are fundamental to its sustainability, in addition to serving as a contribution so that park users understand it, in fact, as a conservation unit and not just a place for leisure and sport.

Social contributions/to management: Work tends to be a guide regarding the distribution of resources, based on the urgency with which they must be invested or the type of intervention to be carried out.

Keywords: identification, ecosystem services, Dom Nivaldo Monte City Park, environmental management

Identificação dos Serviços Ecossistêmicos como ferramenta para fomentar a gestão ambiental de um parque natural no município de Natal/RN

Resumo

Objetivo: Identificar os Serviços Ecossistêmicos de um parque natural urbano como forma de auxiliar na gestão ambiental da área.

Metodologia: A identificação foi realizada no Parque da Cidade Dom Nivaldo Monte, com base na Classificação Internacional Comum dos Serviços Ecossistêmicos, através da revisão da

bibliografia e de visitas presenciais. Por fim, foi realizada uma revisão do Plano de Manejo, a fim de identificar de que forma os resultados do trabalho poderiam auxiliar nas tomadas de decisão visando a sua efetiva conservação.

Originalidade/Relevância: O Parque não possui nenhum estudo relevante relacionado ao tema, principalmente como uma ferramenta que possa auxiliar na gestão local. No mais, o trabalho se torna relevante quanto pretende-se apresentar aos tomadores de decisão informações acerca dos benefícios dos seus ecossistemas visando a correta aplicação dos recursos e, dessa forma, a sua conservação.

Resultados: Foram encontrados 26 Serviços Ecossistêmicos que são fundamentais para a sua sustentabilidade, além de servirem de aporte para que os usuários do parque o compreendam, de fato, como uma unidade de conservação e não apenas um local de lazer e esporte.

Contribuições sociais / para a gestão: O trabalho tende a ser um norteador quanto à distribuição dos recursos, sendo baseados na urgência com que eles devem ser investidos ou no tipo de intervenção a ser executada.

Palavras-chave: identificação, serviços ecossistêmicos, Parque da Cidade Dom Nivaldo Monte, gestão ambiental

Identificación de Servicios Ecosistémicos como herramienta para promover la gestión ambiental de un parque natural en el municipio de Natal/RN

Resumén

Objetivo: Identificar los Servicios Ecosistémicos de un parque natural urbano como forma de coadyuvar en la gestión ambiental del área.

Metodología: La identificación se realizó en el Parque da Cidade Dom Nivaldo Monte, con base en la Clasificación Internacional Común de Servicios Ecosistémicos, mediante revisión de bibliografía y visitas presenciales. Finalmente, se realizó una revisión del Plan de Manejo con el fin de identificar cómo los resultados del trabajo podrían ayudar en la toma de decisiones encaminadas a su efectiva conservación.

Originalidad/Relevancia: El Parque no cuenta con estudios relevantes relacionados al tema, principalmente como herramienta que pueda ayudar en la gestión local. Además, el trabajo cobra relevancia cuando se pretende presentar a los tomadores de decisiones información sobre los beneficios de sus ecosistemas con miras a la correcta aplicación de los recursos y, por tanto, su conservación.

Resultados: Se encontraron 26 Servicios Ecosistémicos que son fundamentales para su sostenibilidad, además de servir como un aporte para que los usuarios del parque lo entiendan, en realidad, como una unidad de conservación y no solo un lugar de ocio y deporte.

Aportes sociales/a la gestión: El trabajo tiende a ser una guía en cuanto a la distribución de los recursos, en función de la urgencia con la que se deben invertir o el tipo de intervención a realizar.

Palabras clave: identificación, servicios ecosistémicos, Parque Municipal Dom Nivaldo Monte, gestión ambiental

Introduction

Environmental management is a topic of great importance in today's context, especially concerning the preservation and conservation of natural resources, since these have a direct impact on the environment depending on how they are used (Liu et al., 2022; Zhang et al., 2022).

In this context, Environmental Protection Areas play a fundamental role, being carefully delimited and managed spaces to minimize harmful human impacts on the environment, and are important for maintaining research and sustainable tourism activities (Abduganiev & Makh-kamo, 2022).

In terms of research, the environmental management of these Conservation Units, which are a specific category of Protected Area (PA), governed by their own legislation and intended for conservation, has been gaining more and more ground, seeking to understand what has actually

been done to keep nature protected and to analyze their effectiveness against anthropic pressures (Feng et al., 2021; Geldmann et al, 2019; Terraube et al.,2020).

In general terms, the latest studies emphasize the importance of improving the understanding of how and when management capacity and resources affect the performance of protected areas, and it is essential to collect data that makes it possible to compare different regions and interventions, both inside and outside these areas (Geldmann et al., 2018).

That said, environmental management is a process that involves the adoption of practices and measures aimed at minimizing environmental impacts and promoting sustainability, especially in Environmental Protection Zones, such as the one surrounding the Dom Nivaldo Monte City Park, henceforth called PCDNM (*Parque Municipal Dom Nivaldo Monte*), which was the first Municipal Environmental Conservation Unit (Natal, 2020).

The PCDNM is part of the EPZ 1 Protection Zone and is an important urban green area responsible for a series of Ecosystem Services (ES), which can be defined as the contributions offered by natural ecosystems to maintain and supply the conditions necessary for the existence of human life on Earth (Daily, 1997).

This approach was also adopted by the Millennium Ecosystem Assessment (MEA, 2005), playing a key role in including the discussion of these services in countries' national political agendas (Gômes-Baggethun et al., 2010; De Groot et al., 2017).

ESs are categorized into Provision, Regulation and Maintenance, and Cultural by the Common International Classification of Ecosystem Services (CICES) (Haines-Young; Potschin, 2018) with the aim of standardizing and facilitating the establishment of environmental accounting methods, mapping, and evaluating their ES.

It is worth emphasizing that it is because of the knowledge of ES, in general, that the environmental management of a natural park needs to be performed seriously, in order to guarantee the conservation of its biodiversity, defined as the measurement of the relative diversity between organisms present in different ecosystems, as well as making it possible to make the

interaction between conservation and its use compatible (Natal, 2008b).

To achieve this goal, the PCDNM has a 2020 management plan (Natal, 2020), which establishes the guidelines for the environmental management of the area, defining permitted activities, public use areas, and conservation areas, which are divided into Lowland Semideciduous Seasonal Forest (SSF), found in areas below 100 meters above sea level; Dense Shrub Restinga (DR), which is characterized by densely intertwined shrubs and trees; Sparse Shrub Restinga (SR), dominated by herbaceous species, with exposed sandy soil; and Dunar Environment (DE), with little or no vegetation. (Natal, 2008b).

The park is an important water regulator, contributing to the infiltration of water into the soil and recharging the water table, information corroborated by Costa et al., (2012), when they mention that the park helps to prevent flooding in adjacent areas, acting as a natural sponge that absorbs excess water during periods of intense rainfall.

Another importance of the PCDNM lies in the recreational and leisure activities that make use of the trails (Maciel et al., 2017), picnic areas, living spaces, and as a tool for environmental education (Pereira et al., 2020).

In addition, the PCDNM also contributes to the conservation of local biodiversity, as its fragments of native vegetation are home to a rich diversity of species of fauna and flora, making it a haven for wildlife (Pereira, 2019).

Furthermore, taking into account the hypothesis that some of the PCDNM's Ecosystem Services are not fully perceived by a portion of managers and visitors in general, in addition to having limited knowledge about the areas of the park responsible for each service, this work is justified by the need to present decision-makers with important information for the environmental management of the Conservation Unit.

With this in mind, this study aimed to identify the Ecosystem Services present in the Dom Nivaldo Monte City Park, located in the municipality of Natal, in the state of Rio Grande do Norte, as a way of helping with the environmental management of the area.

Methodology

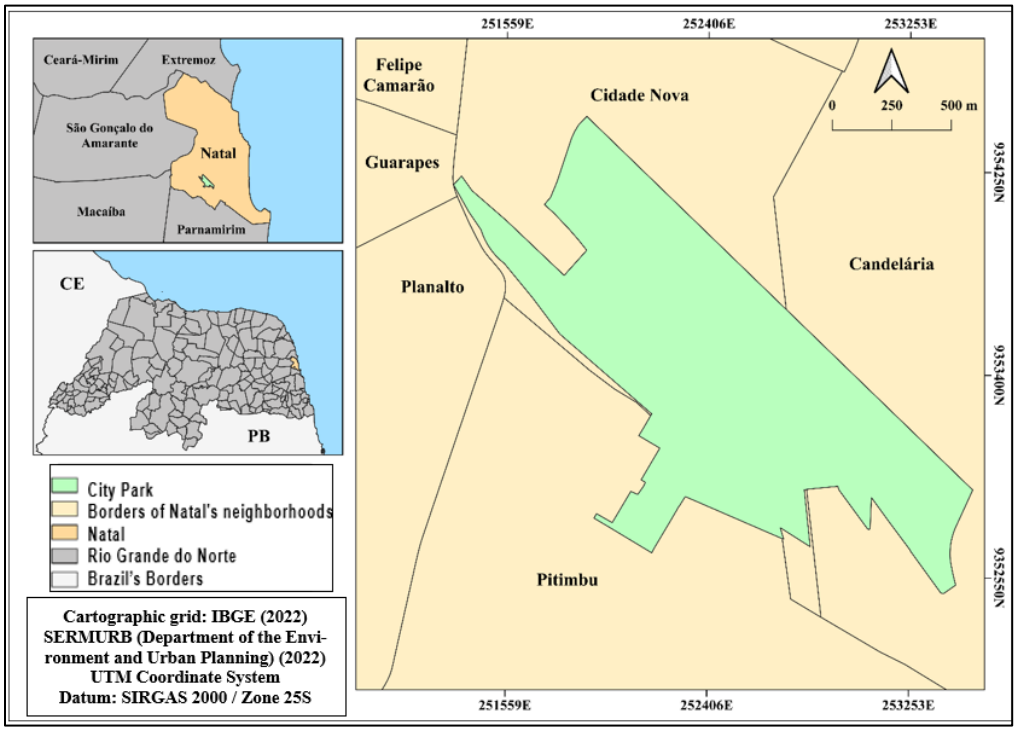
Characterization of the area

The Dom Nivaldo Monte City Park, named after the Archbishop Emeritus of Natal, was created on June 21, 2008 (Natal, 2008b) and is the first municipal conservation unit with restricted use.

The park is located between the Pitimbú, Planalto, Candelária, and Cidade Nova districts and covers a vast area of more than 154 hectares (Natal, 2020), the location of which can be seen in Figure 1.

Figure 1

Location of Dom Nivaldo Monte City Park



Source: Author

Its objective is the preservation of nature, with only the indirect use of its natural resources being authorized, which are divided into zones as follows (Natal, 2020, p. 20):

I - Intensive Use Zone - IUZ - areas designed to promote environmental education and outdoor recreation, made up of the equipment already in place in the Park (...)

II - Extensive Use Zone - EUZ - areas designed to maintain a natural or slightly altered environment, offering public access facilities for educational and recreational purposes via unpaved nature trails, with controlled visitation according to the environment's carrying capacity (...)

III - Primitive Zone - PZ - areas dedicated to the integral protection of ecosystems, genetic resources, and environmental monitoring, where there has been little or minimal human intervention, containing species of flora and fauna or natural phenomena of great scientific value.

In terms of its importance for the municipality of Natal, the PCDNM plays a crucial role in protecting the underground water source, identified by experts as one of the most significant in the city, providing around 65% of the municipality's supply (Natal, 2020).

In addition, its vegetation, characterized as a remnant of the Atlantic Forest, including some species typical of the Cerrado and Caatinga, represents a refuge area for wildlife, contributing to the conservation of biological diversity and genetic resources within the municipality (Natal, 2020).

The fauna and flora are rich, sheltering a wide variety of species native to the region, such as sabiá, turtledoves, hawks, and lizards, as well as plant species such as trees, shrubs, grasses, and herbaceous plants, especially palm trees, cacti, bromeliads and orchids.

Finally, the relief of the Dom Nivaldo Monte City Park is characterized by gentle undulations and plains, typical of the coastal region, and the soil is predominantly sandy, due to its location in an area of dunes.

In addition, the architectural design of the City Park was drawn up by the renowned architect Oscar Niemeyer, who left his unmistakable mark with a 45-meter tower housing the city's memorial (Natal, 2008a), as well as a lookout point, allowing visitors to contemplate much of the

surrounding natural beauty.

Identification of Ecosystem Services

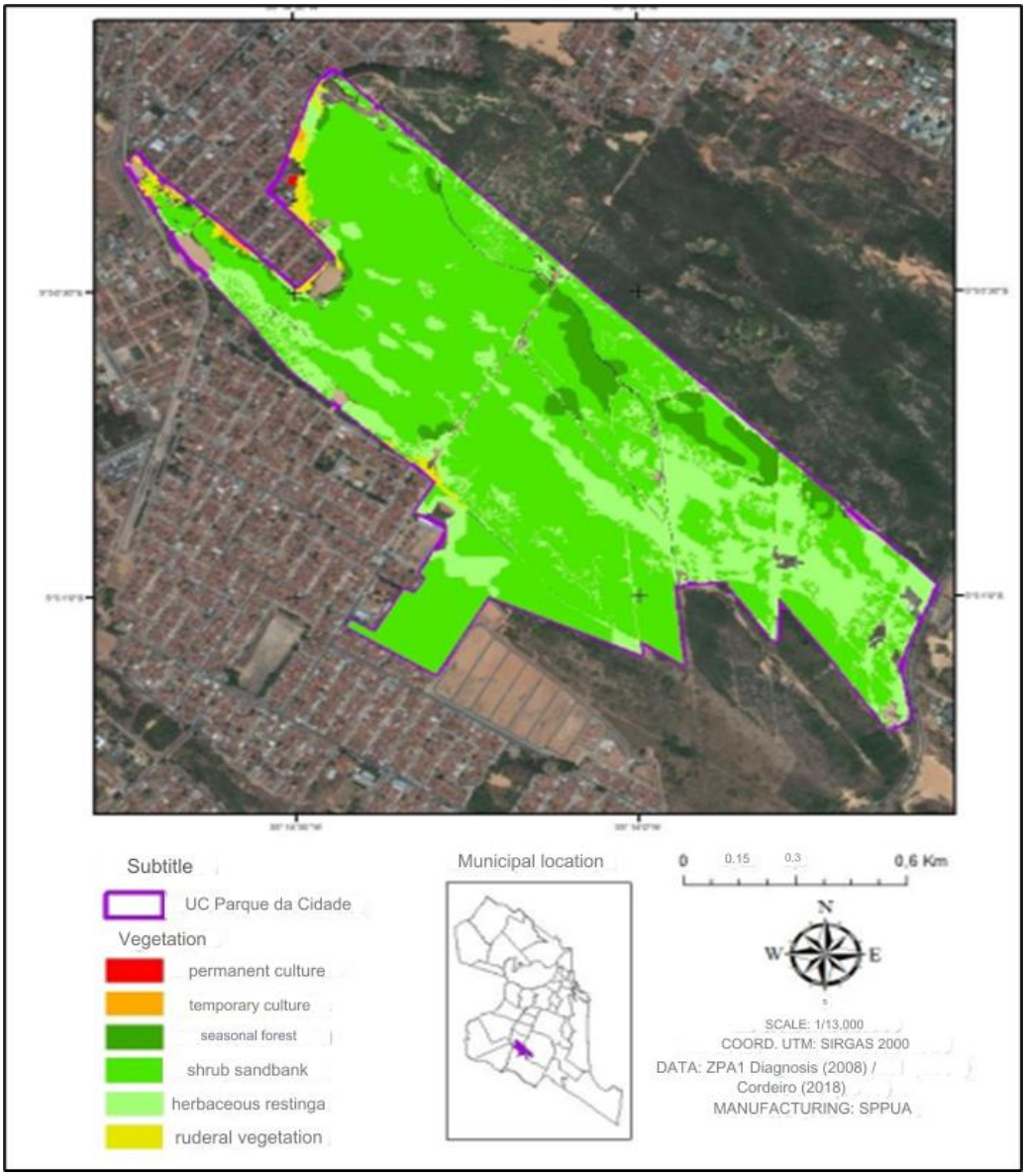
Ecosystem services were identified in person using the Checklist Method, recording the presence of these services in the park for each category analyzed (Provision, Regulation and Maintenance, and Cultural). In addition, a literature review was carried out and public information made available by the Natal City Government was analyzed to support the results found.

In addition, the Checklist was created using the tables proposed by the Common International Classification of Ecosystem Services (CICES) (Haiines-Young & Potshchini, 2017), in addition to identifying indicators that indicate their existence in order to complement the information already present.

Finally, information was also added on the areas of vegetation in the park responsible for the Services found, including SSF, DR, SR, and DE, the distribution of which can be seen in Figure 2, and the features through examples collected on site, as shown in Figure 3.

Figure 2

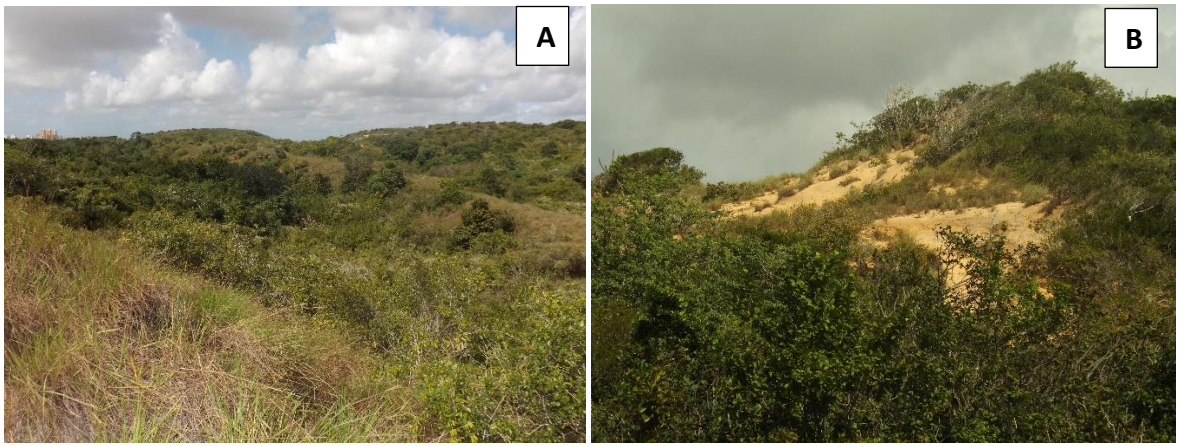
Vegetation map of the PCDNM



Source: Natal (2020)

Figure 3

Sample of Semideciduous Seasonal Forest and dense Shrub Restinga interspersed with sparse Shrub Restinga (A); Dunar Environment (B)



Source: Author.

Finally, a review was carried out of the chapter on the environmental management of the PCDNM, contained in its Management Plan (Natal, 2020), in order to identify what has been proposed for the monitoring and control of natural resources and how the identification of Ecosystem Services can assist in decision-making and control aimed at their effective conservation.

The results were presented in the form of tables, produced using Microsoft Excel, and an Alluvial Diagram, using the free RAWgraphs software.

Results and discussion

Identification of Ecosystem Regulation and Maintenance Services (ERMS)

The results of the identification of Regulating and Maintaining Ecosystem Services, which are crucial to ensuring that ecosystems continue to function in a balanced manner, ensuring the sustainability of the communities of living beings that depend on them, are shown in Table 1.

Table 1

Ecosystem Regulation and Maintenance Services (ERMS)

Section	Division	Group	Class	Type of class	Park Area	Ecosystem Services	Indicators
Regulation and Maintenance (Biotic)	Transformation of biochemical or physical inputs in ecosystems	Mediation of waste or toxic substances of anthropogenic origin by living processes	Bioremediation by microorganisms, algae, plants, and animals	By type of living system or by type of waste or livelihood	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga**	**Remediation of contaminated soils**	**Presence of the plant species *Ricinus communis L e Apuleia leiocarpa* (phytoremediator)**
Regulation and Maintenance (Biotic)	Transformation of biochemical or physical inputs into ecosystems	Mediation of disturbances of anthropogenic origin	Odor reduction	By type of living system	**Sparse Restinga**	**Reduction of odors, especially those caused by hydrogen sulfide gas**	**Presence of the plant species *Mimosa misera***
Regulation and Maintenance (Biotic)	Transformation of biochemical or physical inputs in ecosystems	Mediation of disturbances of anthropogenic origin	Noise attenuation	By type of living system	**Semideciduous Seasonal Forest**	**Attenuation of noise coming from the city.**	**Presence of trees native to the Semideciduous Seasonal Forest (e.g. *Paubrasilia echinata*)**
Regulation and Maintenance (Biotic)	Regulation of physical, chemical, and biological conditions	Regulation of baseline flows and extreme events	Control of erosion rates	By risk reduction, protected area	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga**	**Mitigating the erosion process**	**Vegetation coverage**
Regulation and Maintenance (Biotic)	Regulation of physical, chemical, and biological conditions	Regulation of baseline flows and extreme events	Hydrological cycle and water flow regulation (including flood control and coastal protection)	By depth/volumes	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga**	**Retention of rainwater by vegetation and its slow release.**	**Efficiency of the adjacent region's drainage system**
Regulation and Maintenance (Biotic)	Regulation of physical, chemical, and biological conditions	Regulation of baseline flows and extreme events	Wind protection.	By risk reduction, protected area	**Semideciduous Seasonal Forest**	**Reducing the speed of air movement**	**Use of windbreaks**

Section	Division	Group	Class	Type of class	Park Area	Ecosystem Services	Indicators
Regulation and Maintenance (Biotic)	Regulation of physical, chemical, and biological conditions	Maintenance of the life cycle, habitat, and protection of the gene pool	Pollination (or dispersal of 'gametes' in a marine context)	By quantity and pollinator	**Seasonal Semideciduous Seasonal Forest/Restinga densa/Restinga esparsa**	**Provide a habitat for native pollinators**	**Presence of native bees (e.g. Mamangava)**
Regulation and Maintenance (Biotic)	Regulation of physical, chemical, and biological conditions	Maintenance of the life cycle, habitat, and protection of the gene pool	Seed dispersal	By quantity and dispersal agent	**Seasonal Semideciduous Seasonal Forest/Restinga densa/Restinga esparsa**	**Provide regeneration of plant species in the Conservation Unit**	**Presence of the species Solanum paniculatum L (Jurubeba)**
Regulation and Maintenance (Biotic)	Regulation of physical, chemical, and biological conditions	Maintenance of the life cycle, habitat, and protection of the gene pool	Maintenance of nursery populations and habitats (including protection of the gene pool)	By quantity and origin	**Semideciduous Seasonal Forest**	**Provide habitats for wild plants and animals**	**Presence of the species Coleodactylus natalensis (leaf lizard)**
Regulation and Maintenance (Biotic)	Regulation of physical, chemical, and biological conditions	Regulation of soil quality	Decomposition and fixation processes and their effects on soil quality	By quantity/concentration and origin	**Seasonal Semideciduous Seasonal Forest/Restinga densa/Restinga esparsa**	**Decomposition of plant waste**	**Plant litter**
Regulation and Maintenance (Biotic)	Regulation of physical, chemical, and biological conditions	Atmospheric composition and conditions	Regulation of the chemical composition of the atmosphere and oceans	By contribution of type of living system to quantity, concentration, or climate parameter	**Seasonal Semideciduous Seasonal Forest/Restinga densa/Restinga esparsa**	**Carbon sequestration by the Park's plant species**	**Methodology used by Amaro et al.(2013)**
Regulation and Maintenance (Biotic)	Regulation of physical, chemical, and biological conditions	Regulation of soil quality	Regulation of temperature and humidity, including ventilation and transpiration	By contribution of type of living system to quantity, concentration, or climatic parameter	**Semideciduous Seasonal Forest**	**Evaporative cooling provided by urban trees**	**Local temperature measurement**

Source: Adapted from Haines-Young & Potschin (2017).

This research identified 12 Ecosystem Services of Regulation and Maintenance. The first, related to the ability to remediate contaminated soils, is indicated by the presence of the plant species *Ricinus communis L* (castor bean) and *Apuleia leiocarpa* (*Grápia*), which can act as phytoremediators in the possible decontamination of the soil by heavy metals such as lead, as researched by some authors (Rodríguez-Ortiz, et al., 2006; Silva et al., 2015; Vieira et al., 2019).

An ERMS was also found related to the reduction of odors, especially those caused by hydrogen sulfide gas, which generally comes from microbiological degradation, with the presence of the plant species *Mimosa caesal-piniifolia* (*Sabiá*) as an indicator, which, according to Angeoletto et al. (2020), can be part of a plant barrier to improve the local microclimate, contributing to the mitigation of odors.

Another significant service was that related to the attenuation of noise coming from the city, which can be confirmed by Oliveira, Biondi, and Reis (2022) in their work on the importance of urban green areas in reducing noise pollution when they explain that vegetation was effective in reducing noise due to its density and the number of trees.

The attenuation of the erosion process, whose indicator is the Park's vegetation cover, was also an ERMS identified and is directly linked to another Service, that of water retention by vegetation, whose indicator is the efficiency of drainage in the surrounding area during rainfall.

This is especially important in densely populated urban areas, where increased soil sealing due to urbanization can lead to flooding, and the PCDNM is an important player in preventing flooding and reducing the negative impacts associated with extreme weather events.

Two other ERMSs found were the reduction in the speed of air movement, which could be indicated by the values measured through a windbreak; and the accommodation of a habitat for native pollinators, which was indicated by the species *Xylocopa spp*, known as the Mamangava bee (NATAL, 2008b).

The ability of species to regenerate through seed dispersal was also a ERMS found, with the presence of *Solanum paniculatum L* (Jurubeba) as an indicator, which was cited in the work

by Ramalho & Pimenta (2010, p. 76).

During the construction of the park, unsterilized gravel was used on the paved trails, which introduced a bank of exotic seeds to the native forest, such as the *Solanum paniculatum L* tree (known as Jurubeba), from the *Solanaceae* family. These germinated and proliferated in the Conservation Unit.

The ninth service found was related to the park's ability to provide habitats for wild plants and animals, with one of the indicators being the presence of the *Coleodactylus Natalensis* species (leaf lizard), which generally lives in the shadows of trees native to the Atlantic forest and caatinga (Lisboa & Freire, 2012), while the tenth was related to the decomposition of plant residues that influence soil quality, with the PCDNM's own vegetation as an indicator

This information is corroborated by Faria et al. (2019, p. 12) when "the natural environment has important transitional vegetation present in both the Atlantic Forest, Caatinga and Cerrado" is mentioned, as seen in Figure 4.

Figure 4

Transitional vegetation of the PCDNM

Source: Author

The last two services found are directly related to microclimate regulation, especially carbon sequestration, since the plant species present in the park act as sinks for this chemical

element, playing an important role in mitigating climate change. As an indicator, models proposed in the literature can be used to estimate the amount of CO_2 sequestered in natural parks (Amaro et al.2013; Rocha et al.2017).

Finally, regarding the management of the PCDNM, the identification of Ecosystem Regulation and Maintenance Services is important, as it reinforces to decision-makers the importance of climate monitoring in the region, as stated in its Management Plan (Natal, 2020).

Finally, another important aspect is the reaffirmation of the need to monitor water resources, which are also already included as objectives in the Management Plan for that area, some of which are the abstraction of water from the Pitimbu River Basin, which supplies 2/3 of the population of the city of Natal and has suffered from environmental problems for years, such as silting up, garbage disposal on its banks, *in natura* sewage disposal, among others (IDEMA, 2023).

Identification of Cultural Ecosystem Services (CES)

Cultural ecosystem services, as already mentioned, are those that have a subjective value and are related to people's psychological and emotional well-being, including recreation and tourism in natural environments, the aesthetic value of nature that inspires art and culture, and the strengthening of cultural identities through the use of natural resources in traditional practices. These services play a significant role in the quality of life of societies, promoting an emotional connection with nature and fostering a sense of belonging and care for the environment.

That said, the results collected are shown in Table 2.

Table 2

Cultural Ecosystem Services (CES)

Section	Division	Group	Class	Type of class	Park Area	Ecosystem Services	Indicators
Cultural (Biotic)	Direct, outdoor interactions with living systems that depend on their presence in the environment	Physical and experiential interactions with the natural environment	Characteristics of living systems that enable activities that promote health, recovery, or pleasure through active or immersive interactions	By type of living system or environmental scenario	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Using the park environment for sport and recreation**	**Number of visitors seeking the park for sport and recreation**
Cultural (Biotic)	Direct, outdoor interactions with living systems that depend on their presence in the environment	Physical and experiential interactions with the natural environment	Characteristics of living systems that enable activities (...) passive or observational interactions	By type of living system or environmental scenario	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Observing plants and animals where they live; using nature to de-stress**	**Number of visitors seeking the park for hiking trails**
Cultural (Biotic)	Direct, *in situ*, and outdoor interactions with living systems that depend on their presence in the environment	Intellectual and representative interactions with the natural environment	Characteristics of living systems that enable scientific research or the creation of traditional ecological knowledge	By type of living system or environmental scenario	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Using the park for scientific research and learning about the environment and nature**	**Cavalcante et. al (2017); Ramalho & Pimenta (2010); Laurentino et al.(2021)**
Cultural (Biotic)	Direct, *in situ*, and outdoor interactions with living systems that depend on their presence in the environment	Intellectual and representative interactions with the natural environment	Characteristics of living systems that enable education and training	By type of living system or environmental scenario	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Practicing environmental education**	**Pereira *et al*.(2020); Maciel et al.(2017)**

Section	Division	Group	Class	Type of class	Park Area	Ecosystem Services	Indicators
Cultural (Biotic)	Direct, *in situ*, and outdoor interactions with living systems that depend on presence in the environment	Intellectual and representative interactions with the natural environment	Characteristics of living systems that enable aesthetic experiences	By type of living system or environmental scenario	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Artistic inspiration**	**Photographs taken in the park and posted on social media**
Cultural (Biotic)	Indirect, remote, often internal interactions with living systems that do not require presence in the environment	Spiritual, symbolic, and other interactions with the natural environment	Elements of living systems that have symbolic meaning	By type of living system or environmental scenario	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Recognition of the Park from species characteristic of the area**	**The leaf lizard and other species found in the park**
Cultural (Biotic)	Indirect, remote, often internal interactions with living systems that do not require presence in the environment	Other biotic features that have a non-use value	Characteristics of living systems that have an existence value	By type of living system or environmental scenario	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Conservation of wild areas**	**Park's Primitive Zone**
Cultural (Abiotic)	Direct, *in situ*, and outdoor interactions with natural physical systems that depend on presence in the environment	Physical and experiential interactions with natural abiotic components of the environment	Natural and abiotic features of nature that enable active or passive physical and experiential interactions	Quantity per type	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Active or passive physical and experiential interactions**	**Number of visitors who come to the park to connect with nature**

Section	Division	Group	Class	Type of class	Park Area	Ecosystem Services	Indicators
Cultural (Abiotic)	Indirect, remote, and usually internal interactions with physical systems that do not require presence in the environment	Spiritual, symbolic, and other interactions with abiotic components	Natural and abiotic features of nature that allow spiritual, symbolic and other interactions	Quantity per type	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Spiritual reflection**	**Number of visitors seeking the park for spiritual reflection**
Cultural (Abiotic)	Indirect, remote, and generally internal interactions with physical systems that do not require presence in the environment	Other abiotic features with non-use value	Natural and abiotic features or characteristics of nature that have existence, option or legacy value	Quantity per type	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Natural and abiotic spaces in nature that can be used by future generations**	**Unpaved trails**

Source: Adapted from Haines-Young and Potschin (2017)

In terms of ecosystem services in Natural Parks, cultural services (CES) are uniquely important, as they directly affect visitors, who seek outdoor spaces for leisure, recreation, and contemplation. However, despite this importance, CESs are still given little priority in public policy management and decision-making (Pinto et al., 2019).

In addition, protected areas gain importance in this context precisely because they are the main strategy for protecting terrestrial and marine ecosystems, and are responsible for experiences associated with tourism, leisure, health and contemplation of natural landscapes (Pivoto et al., 2022).

That said, among the 10 Cultural Ecosystem Services (CES) identified in the PCDNM, special attention is given to those related to recreation and sports activities, since the park has ample green areas and spaces for practicing sports, as can be seen in Figure 5.

Figure 5

Paved trails

Source: Author

One indicator is the number of visitors who come to the park to exercise, a figure that reached 260,000 a year on average before the pandemic (Natal, 2017).

Another CES identified is related to the observation of plants and animals where they live, with the indicator being the number of visitors who come to the PCDNM to use the trails.

As the Park is made up of green areas, forests, and other natural elements, creating an atmosphere of tranquillity and scenic beauty that attracts visitors, the opportunity to be in contact with nature in its purest form is valued by many, providing an experience of connection with the environment and a sense of well-being, as corroborated by Rebouças, Grilo, and Araújo (2015).

In addition, the park's scenic landscape is also a source of inspiration creativity, serving as a backdrop for activities such as photography, painting, and other forms of artistic expression (Natal, 2015b).

Another significant CES is related to research activities and knowledge of nature, making it possible to carry out scientific studies and collect data on biodiversity and other aspects of the local environment (Cavalcante et al., 2017; Laurentino et al., 2021; Ramalho & Pimenta (2010), environmental education (Pereira et al., 2020), such as interpretive trails (Maciel et al., 2017), exhibitions and lectures (Natal, 2022b), contributing to environmental awareness and sensitization of visitors. Indicators include the number of academic papers that have been carried out on the site and that are available on various research platforms and journals.

In addition to those already identified, another important CES was the one that aims to promote people's recognition of its cultural, historical, and iconic character, which is linked to living systems that have a symbolic meaning. Indicators include some plant species, such as the Coroa-de-frade, which is native, as well as animals considered symbols of the region, such as the leaf lizard.

Another CES identified was related to the conservation of wild areas that have existence value, with the Park's own Primitive Zone as an indicator, the division of which is presented in its Management Plan (Natal, 2020).

Finally, the last CES identified was the one related to the natural and abiotic characteristics of nature that can be used by future generations and whose indicator is the trails and green areas themselves.

In short, the identification of Cultural Ecosystem Services serves to reinforce the

information that is explicit in the Management Plan, which establishes an Extensive Use Zone, as explained below:

> I - Extensive Use Zone - EUZ - areas designed to maintain a natural or slightly altered environment, offering public access facilities for educational and recreational purposes by means of unpaved nature trails, with controlled visitation and in accordance with the environment's carrying capacity (Natal, 2020, p.20).

Identification of Provisioning Ecosystem Services

These services, defined later, are the material benefits that people can derive from ecosystems, however, as the PCDNM is part of the Conservation Unit Group with Integral Protection in the National Park category, according to the National System of Conservation Units (NSCU), "its objective is to preserve nature, with only indirect use of its natural resources being allowed, subject to the rules and restrictions provided for by law" (Natal, 2020, p. 20).

As a result, Table 3 provides information on Ecosystem Provision Services, despite all the Park's limitations, which are also relevant for decision-making regarding the maintenance and protection of the site.

Table 3

Provisioning Ecosystem Services (PES)

Section	Division	Group	Class	Type of class	Park Area	Ecosystem Services	Indicators
Provision (Biotic)	Genetic material of all biota (including production of seeds, spores, or gametes)	Genetic material from plants, algae, or fungi	Seeds, spores, and other plant materials collected to maintain or establish a population	By species or varieties	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Collection of seeds from parent plant species to produce seedlings of Atlantic Forest species.**	**Replanting of native Atlantic Forest trees on the main avenues of Natal/RN**
Provision (Biotic)	Genetic material of all biota (including production of seeds, spores, or gametes)	Animal genetic material	Animal material collected for the purpose of maintaining or establishing a population	By species or varieties	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Collection of animal genetic material for research and disease control purposes**	**Wild animals contaminated with Toxoplasmosis**
Provision (Biotic)	Genetic material of all biota (including seed, spore, or gamete production)	Animal genetic material	Wild animals (whole organisms) used to create new strains or varieties	That can be used to maintain populations or develop new varieties	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Provision of genetic material from plant and animal species for the preservation of endangered species.**	**Sightings of endangered plant species, animals, or chicks.**
Provision (Biotic)	Water	Groundwater for use in nutrition, materials, or energy	Underground (and subsurface) drinking water	By amount, type, and source	**Semideciduous Seasonal Forest/Dense Restinga/Sparse Restinga/Dune Environment**	**Supplying water to the Barreiras Aquifer**	**Information found in the literature (Natal, 2018b; Natal, 2020, Righetto & Rocha, 2005)**

Source: Adapted from Haines-Young and Potschin (2017)

Four Ecosystem Services were identified, with the supply of water to the Dunas/ Barreiras Aquifer being one of the most fundamental, as it contributes to its preservation since it supplies part of the municipality. The Management Plan for the Park and EPZ 1 (Natal, 2018b; Natal, 2020) can be used as an indicator, as can Righetto and Rocha (2005), who cite the importance of this aquifer for the Park and the city of Natal.

Regarding water supply, the dunes are of unique importance for the preservation of the aquifer, information that can be confirmed by the EPZ 1 Management Plan, when it explains that "they function as a receiving unit for rainwater, which is transferred vertically through infiltration to the underlying Barreiras aquifer (Natal, 2008, p.28).

Another PES identified concerns the controlled collection of seeds from parent plant species to produce seedlings of Atlantic Forest species, the indicator of which is the project to replant native Atlantic Forest trees on the main avenues of Natal/RN, according to the Planta Natal project (Natal, c2022 b; Natal, 2023).

Another important aspect of identifying this PES is to monitor the use of ornamental species, which also contribute to improving the urban environment, but which need to be monitored to prevent them from being harvested illegally, as explained in the Management Plan:

> *Cattleya granulosa* (orchid) and *Melocactus violaceus* (wreath) are species that are usually collected for sale, as they are ornamental, so they should be included in specific flora monitoring programs to minimize threats to these species. (Natal, 2020, p.11).

This information is also corroborated by Ramalho and Pimenta (2010), who explain that the Dom Nivaldo Monte Natural Park is home to a remnant portion of the Atlantic Forest, is located in the Environmental Protection Zone-1 (EPZ-1) of Natal, and faces the challenge of illegal trade due to the exploitation of plants, specifically an endemic and endangered species of orchid.

Another PES identified was related to the collection of genetic material from animals for the purposes of research and disease control, which is indicated by scientific studies that have collected this material to identify diseases in local fauna (Fournier et al., 2014; Lopes et.al., 2018).

The collection of this material is significant for the conservation of the region's biodiversity since the presence of different species of plants and animals in the park contributes to maintaining healthy and resilient ecosystems, as well as serving scientific research.

Costa (2014), for example, studied genetic diversity in natural populations of *Hancornia speciosa* Gomes (mangaba tree) in the state of Rio Grande do Norte, and Rêgo (2019) analyzed and morphologically and genetically characterized specimens from populations of *Coleodactylus natalensis* (leaf lizard) in forest remnants of Rio Grande do Norte, such as the PCDNM.

Finally, the last PES identified was the supply of genetic material from plants and animals for research or preservation of endangered species, the indicator being the sighting of these species by visitors and staff, as indicated in the Management Plan itself (Natal, 2020).

That being said, it can be concluded that the identification of Ecosystem Services is relevant and important for managers and the general population to know since these material goods are the ones that suffer most from their clandestine exploitation.

Furthermore, another important result obtained from the above-mentioned identifications is the need to strengthen the monitoring of flora, fauna, and the general physical environment, which is already included as a strategic action in the Management Plan (Natal, 2020).

With regard to monitoring the flora of the PCDNM, the Management Plan provides for a bimonthly analysis, with the aim of checking whether any type of plant species is being removed or whether there are fires or deforestation.

To this end, at least 10 individuals of the specific species of Orchid and Brazilwood are identified, located, and monitored every month, as well as any others that are considered important (Natal, 2020).

When it comes to fauna, a survey is carried out every two years with the population around the Conservation Unit to identify whether there are any wild animals in the urbanized area, as well as a bimonthly analysis of the identification of dead animals, seizures, collections, captures or receipt of animals from the Conservation Unit and a survey every two years of the local mammal

and bird fauna (Natal, 2020).

Finally, monitoring the physical environment consists of mapping vegetation cover and land use in a given area every 5 years, checking the spatial evolution of vegetation patches, urban expansion, conflicting occupations, and assessing the state of conservation (Natal, 2022).

Influence of park areas on the provision of identified ecosystem services

By identifying the ecosystem services provided by the PCDNM, it was possible to present the relationship between these services and the areas of the park, in order to better visualize the importance of these spaces in terms of their benefits for the population.

The SSFs were coded in order to plot an Alluvial Diagram, relating the Ecosystem Services identified to the areas in which they were found.

To this end, a table (Figure 6) was produced containing the Ecosystem Services, the acronyms for each type of ES, and the services identified in the previous tables, which were coded as SR (Regulation and Maintenance Services), SP (Provision Services) and SC (Cultural Services).

Figure 6

Code for identifying ecosystem services

ACRONYM		Id	SERVICES	CODE
REGULATION E MANUTENÇÃO	SR	1	Remediation of contaminated soils	SR1
		2	Odor reduction	SR2
		3	Noise attenuation	SR3
		4	Mitigating the risk of erosion	SR4
		5	Retention of rainwater by vegetation	SR5
		6	Reduction in the speed of air movement	SR6
		7	Habitat for native pollinators	SR7
		8	Regeneration of plant species	SR8
		9	Habitat for wild plants and animals	SR9
		10	Decomposition of plant waste	SR10
		11	Carbon sequestration	SR11
		12	Evaporative cooling	SR12
CULTURAL	SC	13	Recreation	SC13
		14	Landscape contemplation	SC14
		15	Scientific research	SC15
		16	Environmental education	SC16
		17	Artistic inspiration	SC17
		18	Symbolic meaning	SC18
		19	Conservation of wild areas	SC19
		20	Physical and experimental interactions	SC20
		21	Symbolic and spiritual interactions	SC21
		23	Legacy value	SC22
PROVISION	SP	24	Seed collection	SP23
		25	Collecting animal genetic material	SP24
		26	Animal monitoring and preservation	SP25
		27	Groundwater flow	SP26

Source: Author.

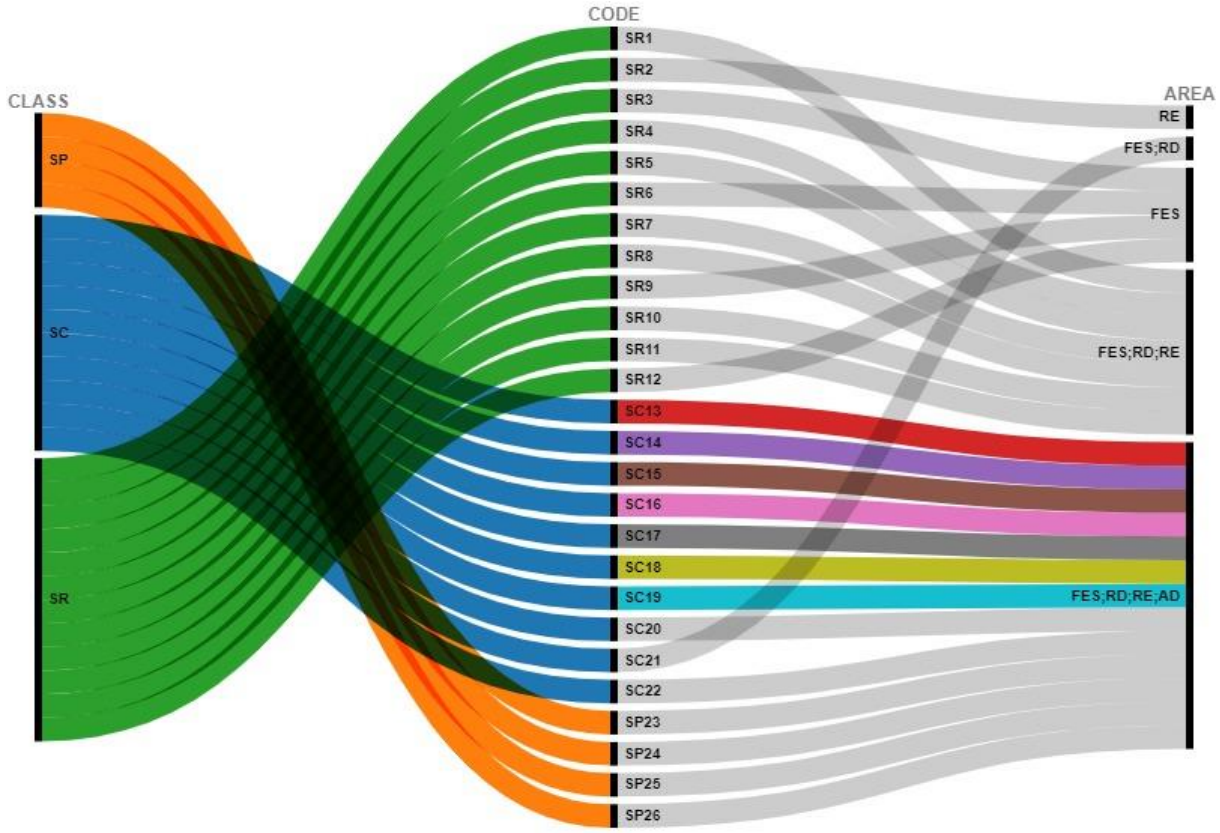
As can be seen, 12 Regulating and Maintaining Ecosystem Services (RS), 10 Cultural Ecosystem Services (CS), and 4 Provisioning Ecosystem Services (PS) were identified, totaling 26. In addition, the areas of the park were coded as SR (Sparse Restinga), SSF (Semideciduous Seasonal Forest), DR (Dense Restinga) and DE (Dune Area).

To visualize the relationship between the park's areas and its ecosystem services, an

Alluvial Diagram was created, divided into classes related to the ES identified (Regulation and Maintenance, Provision and Cultural), the code of these services, corresponding to the ES identified and the areas themselves, as shown in Figure 7.

Figure 7

List of ecosystem services provided in the PCDNM's natural areas



Source: Author.

Figure 7 shows that the SR was responsible for only one Ecosystem Service (Regulation), related to the reduction of odors, which can be explained by the fact that the plant species of the genus *Mimosa*, which occurs in open degraded areas of shrub vegetation (Dourado et al., 2013), is part of this type of habitat, which is characterized by an irregular occurrence of low and

branched trees, as defined by CONAMA Resolution No. 437 of December 30, 2011 (Brazil, 2011).

The SSF alone was responsible for four other regulating ecosystem services: noise attenuation, reduction of air movement speed, habitat for plants and wildlife, and evaporative cooling. This can be explained by the characteristics of this type of forest, which is made up of large trees, such as the species of indisputable historical value: *Caesalpinia echinata Lam*, known as brazilwood (IBGE, 2012).

The DR and the SSF were together responsible for the cultural ecosystem service related to symbolic and spiritual interactions, since the park's greatest symbols of fauna and flora, such as the leaf lizard, the cattleya orchid, and the crimson crown, have this type of vegetation as their natural habitat (Ramalho & Pimenta, 2010).

The regulation services responsible for soil remediation, erosion risk mitigation, water retention, habitat for pollinators, decomposition of plant residues, and carbon sequestration were identified in the SSF, DR, and SR areas, i.e. covering all of the park's vegetation.

Finally, all the other cultural ecosystem services related to re-creation, landscape contemplation, scientific research, environmental education practices, artistic inspiration, symbolic meaning, wilderness conservation, physical and experimental interactions, and legacy value, as well as those related to seed collection, collection of animal genetic material, monitoring and preservation of animals and groundwater flow were found in all areas of the park, showing its importance for leisure, recreation, nature contemplation, sport and providing material goods for the population, as recommended in the Management Plan (Natal, 2020).

In summary, the SSF was responsible for 25 services identified, the SR and DR separately for 21, and the DE, which has no vegetation cover, for 13, indicating the importance of vegetation for the purpose of the park, which is to combine sustainability with human interaction.

Conclusions

The main contribution of this study was the detailed identification of the Ecosystem Services of Regulation and Maintenance, Culture, and Provision offered by the PDCNM, which can be used as a strategy to help managers make decisions.

The Park's administrators will be able to use this work to constantly monitor these services in order to verify the pressures that the Conservation Unit is suffering or will suffer as a result of negative anthropic actions.

In addition, decision-makers will be able to consult it in order to plan the allocation of their human and financial resources, based on those Services that can be considered most relevant to visitors and the population in general, as well as understanding the importance that each area of the park has on the provision of these ES, promoting targeted monitoring of those that are most vulnerable to anthropic actions.

At the same time, as the management of the PCDNM requires infrastructure and a technical team capable of managing any negative impact that may occur in that environment and thus reducing the distance between the abstract concept of sustainability and decision-making in the operational development process, the aforementioned identification of Ecosystem Services can be a facilitator with regard to the distribution of these resources, based, for example, on the urgency with which they should be invested, whether to monitor a parameter or correct a problem related to the anthropization of the area.

In this context, the work emerges as a tool to strengthen actions aimed at preserving green areas, promoting a holistic approach that recognizes the interdependence between man and the environment.

Finally, the results of this study reinforce the importance of effectively understanding the PCDNM so that investments in conservation, monitoring, and mitigation of negative impacts can be applied assertively, with a view to ensuring the sustainability of the Park, as well as other

similar natural spaces, as part of the commitment to protecting the environment and promoting human well-being.

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