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Factors to be considered in the creation of Protected Areas: the case of Descobrimento National Park Prado, Bahia – Brazil.

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Abstract

The creation of protected areas is one of the most useful strategies for protecting biodiversity against constant and growing threats. Accordingly, the aim of the present study was to analyze conservation biology concepts and assess their application to the creation and expansion of Descobrimento National Park (Bahia, Brazil) by using primary and secondary data and geoprocessing tools. The creation of the protected area was basically guided by the opportunity to acquire the area, and great opportunities for biodiversity conservation in the region were disregarded in the process. The reliability of the planning tools of the conservation unit are discussed, as are the situations involving their application in the buffer zone.

Keywords: Conservation biology. Park management. Biodiversity Conservation.

Introduction

The establishment of protected areas has been used as a global strategy for conserving biodiversity, a process that is affected by multiple important variables, ranging from conservation biology to conservation opportunities (PÁDUA; CHIARAVALLOTI, 2012). However, the creation and management of Protected Areas (PAs) have been based on a variety of different theories. Therefore, different conservation efforts have prioritized the protection of specific species at small scales (WELNER, 1995), habitats, in order to ensure the protection of multiple taxa (MARGULES et al., 1981), hotspots, which harbor high

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biodiversity and are severely threatened (MYERS et al., 2000), and phylogenetic diversity, as strategy for maintaining diverse ecosystems and, thereby, ensuring an effective global supply of ecosystem services (CADDOTTE; DAVIES, 2010; SRIVASTAVA et al., 2012).

Brazil's federal government created, in 1999, the Pau Brasil and Descobrimento National Parks (in the municipalities of Porto Seguro and Prado, respectively) in the extreme southern region of Bahia, in allusion to the 500th anniversary of the arrival of the Portuguese to the coasts of Bahia. The two areas were acquired from the Brasil Holanda Company and were considered of extreme biological importance for the conservation of biodiversity (MMA, 2000; BRASIL, 1999). The Descobrimento National Park (DNP), in particular, encompasses a large expanse of dense ombrophilous forest that harbors high levels of biodiversity (ICMBio, 2014). The importance of the park for the conservation of biodiversity, at both the local and regional levels, has already been demonstrated by several studies (e.g., DOMINGUES, 2000; MARCHIORO, 2003). However, the region is subject to strong anthropogenic interferences, such as hunting, deforestation, fire, invasion, use, and irregular occupation, which negatively affect biodiversity, and these pressures have put in question the effectiveness of the DNP as a PA (PONTES JUNIOR, 2016).

Accordingly, the aim of the present study was to analyze the process of establishing the DNP, to determine whether key conservation concepts were considered during the decision-making process, to contribute to the discussion about the effectiveness of protected areas in the conservation of biodiversity, and to broaden the discussion about the processes of establishing PAs.

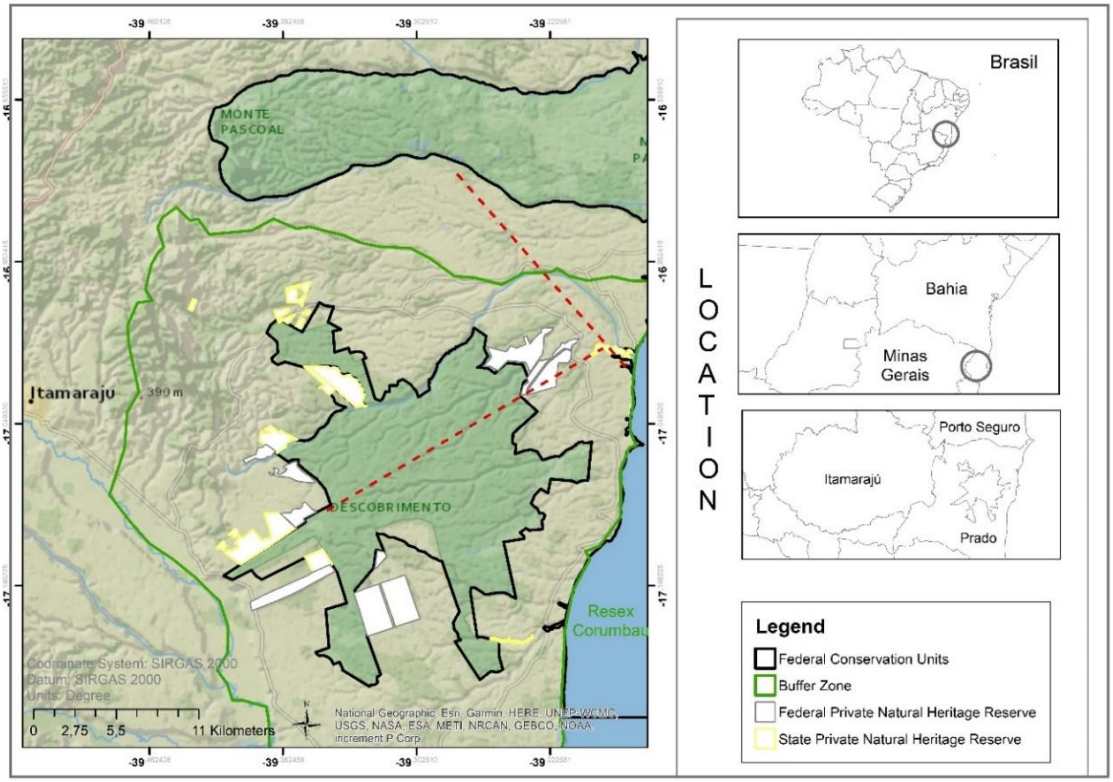
Material and Methods

Study area

The study was conducted within the DNP and its buffer zone, which are located in the municipality of Prado, Bahia, Brazil (Figure 1).

The present study evaluated the geology, size, shape, quality, landscape implantation, ecosystem representativeness, management plan, and buffer zone of the forest fragments, using ArcGIS 10.3 to calculate distances, areas, and perimeters and to identify PAs and other forest fragments, hydrography, roads, and other landscape elements. Shapefiles of the above attributes were obtained from the authors and the PA managing body. The Patch Analyst extension of ArcGIS was also used to calculate landscape metrics, which were defined according to Metzger (2001), and Trackmaker was used to access data that was obtained using GPS devices, such as the locations of roads and internal DNP tracks. The analysis was based on images from the ArcGIS database, using the Datum SYRGAS 2000 Geographic Coordinate System for georeferencing.

Figure 1 - Location of the Descobrimento National Park. Source: The authors.



Results and Discussion

Geology

The protection of relevant geological, geomorphological, speleological, archaeological, paleontological, and cultural characteristics are also objectives of the National System of Conservation Units, as determined by Art. 4 of Law 9.985/2000 (BRASIL, 2000). In this context, it is interesting to note that the current landscape of the extreme southern region of Bahia, southern boundary of the São Francisco Craton, was shaped by a series of transformations that involved erosion of the kinzigitic complex, where the remains are Monte Pascoal and the Serra da Gaturama (MARTIN et al., 1980). According to Domingues (2000), the erosion of the kinzigitic complex and the slow deposition of sediments gave rise to the tablelands of the Barreiras Group, the sandy sediments of which cover the crystalline basement with an average thickness of 70 m in the Cumuruxatiba region.

The hydrography of the area was molded into the Barreiras tablelands, excavating the terrain, being affected by the marine transgression and regression that were caused by alternation between periods of glaciation and higher temperatures, which caused the formation of cliffs and the emergence of coral reefs, in addition to the west-east direction of the rivers (MARTIN et al., 1980).

Domingues (2000) reported that parallel geological faults caused neotectonic

movements, such as the sinking of entire blocks of rocks, thereby creating broad and deep valleys (grabens) with flat thalwegs, where rivers drain through meanders (as in the Jucuruçu valley) or of those that resulted from the movement due to faults in the pre-Cambrian structure, such as the Salto da Divisa - Barra do Cahy fault, the process of which strongly altered the orientation of the hydrography in the affected area. Such geological faults are indicated as dashed red lines in Figure 1.

In the above context, it is important to highlight the creation of geoparks, under the protection of UNESCO, which represents a new conservation strategy that combines geoconservation with the sustainable development of the populations that inhabit it, always focusing on interrelations with the rest of the natural and cultural heritage. According to Rocha et al. (2017), 87 geoparks have been established worldwide, and even though there is only one geopark in Brazil, the Araripe Geopark, there are indications that a national network of geoparks will be established, which would be an additional opportunity to consider for the region under study.

Size

The DNP originally encompassed 21,149 ha (BRASIL, 1999) and was expanded to 22,693.97 ha in 2012 (BRASIL, 2012). In addition, 19 private natural heritage reserves have been juxtaposed to its limits, between 2008 and 2014 (PONTES JUNIOR, 2016). Together, the DNP and private natural heritage reserves encompass a combined total of 27,257.51 ha of legally protected Atlantic Forest. However, there are also ~4000 ha of legal reserves and permanent preservation areas adjacent to the unit (ALMEIDA et al., 2006). Thus, the area legally protected by the DNP, adjacent PAs, and another adjacent protected area encompasses ~30,000 ha (Figure 1).

Areas of >20,000 ha have the potential to sustain viable populations (~500 individuals) of mammals weighing >1 kg (CHIARELLO, 2000). However, at least 100,000 ha are needed to sustain populations of large mammals (>50 kg; REDFORD et al., 1991; TERBORG, 1992; NEWMARK, 1995; PAVIOLO et al., 2009). Therefore, the area encompassed by the DNP and neighboring private natural heritage reserves is acceptable for conserving part of the area's biodiversity, but alternative strategies, such as the creation of new protected areas, implementation of ecological corridors, and ordering of productive activities in the buffer zone, will be needed to ensure satisfactory levels of environmental protection.

Form

The design of the PA, with several areas extending into the surroundings, is responsible for the wide expanse of the perimeter, which was 157 km at the time of the PA's creation and has since decreased to 156.59 km with the expansion of the area. Elongated fragments, clipped perimeters, or additions from the surrounding matrix in the natural area harbor less biodiversity than more circular fragments (HELZER et al., 1999; WILLIANS et al., 2005).

Circular shapes are the most appropriate for protected areas since they possess the smallest perimeter:area ratio and larger central areas (core areas), which undergo less interference from the surrounding matrix, thereby facilitating the conservation of biodiversity (DIAMOND, 1975).

The core area of the DNP, which is defined here as the total area located ≥100 m away from the park's borders (PAULA et al., 2016), was 22,299.82 ha, or 394 ha (almost 2%) less than the DNP's total area. This situation calls for a revision of land-use planning along the PA's border areas, either by changing boundaries to increase the protected area or by managing the agrosilvopastoral activities that are conducted in the immediate vicinity to favor those that have smaller impacts on biodiversity conservation, such as the implantation of agroforestry systems with organic management in border environments to the detriment of traditionally managed pastures or crops.

Perimeter:area ratio

The ratio of the PA's perimeter to its area is important for the preservation of biodiversity because it is directly related to the edge effect, an ecological process related to changing environmental conditions at boundaries that have a higher solar and wind incidence, reduction of soil moisture, and greater contact with the surrounding matrix (TABARELLI et al., 2008). This process directly affects the biota, favoring generalist and opportunistic species to the detriment of specialist species in closed forest environments (TABARELLI et al., 2012).

The perimeter:area ratio of the DNP indicates that for each hectare of PA there are ~7 m of boundary. This ratio indicates that the PA design is not appropriate since the ideal PA would be circular, with a perimeter-area ratio close to three.

To improve the shape of the DNP, i.e., to make the PA more round, it would be necessary to add more land between the extensions of the park's boundaries into the landscape, thereby doubling the park's area. With such an increase in area, the perimeter:area ratio of the DNP (156.59) would be 3.45, which is much closer to the desired ration of π (~3.14; CARVALHO, 2011).

Ecosystems covered

The DNP originally encompassed 21,149 ha of a forest fragment of >30,000 ha, basically covering the physiognomy of tablelands covered by dense ombrophilous forest, and its boundaries are made by paths that have been traced within the forest and that separate the park from other forested properties. The park's interior contains substantially degraded areas and small patches of *muçununga*, which is a type of ecosystem that is generally associated with the dense rain forests of southern Bahia and sandy, hydromorphic soil (MEIRA NETO et al., 2005), whereas the areas immediately surrounding the DNP include several fragments of Atlantic Forest in advanced stages of regeneration, highland forests, and large areas of *muçununga*, *restinga*, mangroves, and even coral reefs. Thus, there is a strong indication that the creation of the PA was not

based solely on conservation biology criteria and that it, instead, was mainly based on the opportunity presented by the Brasil Holanda Company to Brazil's federal government, namely to acquire the Bralanda Hum Farm (PONTES JUNIOR, 2016). Indeed, several opportunities to maximize the conservation value of the PA not considered. For example, the park could have been created to include a mosaic of PAs, to guarantee both environmental preservation and the development of the region. In other words, the DNP could have been designed to cover the entire forest fragment in which it is located, including large areas of *muçununga*.

Meanwhile, in the mountain region between the DNP and Monte Pascoal National Park, the creation of a natural monument, or even the officialization of the ecological corridor, could be envisaged. In the coastal zone, wildlife refuges could be created in areas of *restinga* and mangrove, given the continued threat of extinction for many species, including sea turtles, which use the region's beaches to lay eggs (ICMBio, 2014). Furthermore, the Corumbau Marine Extractive Reserve, which is a sustainable use PA, the limits of which coincide with those of the DNP's buffer zone, could benefit from being expanded to include terrestrial areas, thereby ensuring the permanence of the fisherman in the area that is undergoing intense real estate speculation (BUCCI, 2009). Finally, integrated protection units could be created on the coast, in order to protect coral reefs, which have suffered from disordered tourism and fishing (MARCHIORO, 2003).

Opportunities to maximize the conservation value of the park were also disregarded during the expansion of the PA, which included more altered areas than forested areas, thereby transferring the costs of environmental recovery from the affected landowners to the ICMBio.

Insularity

A total of 65 forest fragments, with a combined area of 14,773.20 ha, were identified in the DNP and MPNP (74,100 ha in total) using the Patch Analyst extension of ArcGIS. Therefore, ~20% of the area of the two PAs is covered by forest fragments (PONTES JUNIOR, 2016).

Fragmentation is generally considered one of the main causes of biodiversity losses in the area since it creates "forest islands" that are surrounded by farmland, often leading to the isolation of forest habitats (TERBORGH, 1992; FAHRIG, 2003; TABARELLI et al., 2005). Under these circumstances, the biotic communities of small and isolated forest fragments may be more affected by the effects of fragmentation than by the intrinsic factors of the communities, such as predation and competition (CHIARELLO, 2000).

Accordingly, this isolation, together with the edge effect, should be considered in efforts to preserve the Atlantic Forest (TABARELLI et al., 2008). Indeed, the analysis of fragmented landscapes is used to measure the degree to which ecological areas are impaired and, as such, are essential for establishing biodiversity preservation and conservation models (RIBEIRO et al., 2009).

The largest and best-preserved forest fragments in the study area were concentrated near a forest mass to the West of the PAs (DNP and MPNP). These fragments encompassed a set of mountains with great relevance to biodiversity conservation, both owing to previous reports of rare specimens from the fragments (ICMBio, 2014) and because the fragments practically form a natural ecological corridor between the DNP and MPNP.

Quality of the forest area

The DNP is not exclusively composed of dense ombrophilous forest. On the contrary, 9245 ha of early and mid-regeneration areas, which are derived from historical disturbances, are found in the park's interior (PONTES JUNIOR, 2016).

Usage history

The forest fragment that includes the DNP already included a number of deforested areas in the 1970s during the process of use and occupation by about 80 properties, before the area was acquired by the Brasil Holanda Company (PONTES JUNIOR, 2016). A number of deforested *muçununga* sites from that time persist today as degraded areas, apparently demonstrating a certain freezing in the process of vegetation succession, which has also been reported to occur in *muçununga*s of the extreme southern region of Bahia by Meira-Neto et al. (2005), who reported that fire and grazing are the main factors affecting biodiversity in the peculiar ecosystem. The situation can indicate that the level of aggression has overtaken the resilience of the ecosystem, i.e., the capacity of the ecosystem to return to equilibrium after a disturbance. In such scenarios, anthropic interference is needed to ensure recovery (RODRIGUES, 2013).

Selective extraction

The extraction of ~300,000 m^3 of wood by the Brasil Holanda Company from the Bralanda Hum Farm has also reduced the quality of the forest (PONTES JUNIOR, 2016). Indeed, areas from which wood was selectively extracted differ substantially from areas of dense ombrophilous forest, with vegetation exhibiting the characteristics of early and mid-regeneration, such as the prevalence of generalist species that are not associated with forested environments (PONTES JUNIOR, 2016; ICMBio, 2014).

Forest fires

Forest fires represent another source of disturbance in the degraded areas of the DNP interior. Most notably, a fire that occurred at the end of 1994 destroyed about 19,000 ha in the region, including 7000 ha in the interior of the Bralanda Hum Farm area, which was later incorporated into the DNP (PONTES JUNIOR, 2016). A number of smaller fires have also occurred in the PA since then and have inflicted similar deleterious effects on the forest ecosystem. Both the forest fire records of the PA and the analysis of heat sources registered by INPE indicate that fires have destroyed ~2000 ha of forest since the PA was created. In

addition, many of the fires have occurred successively in the same areas, effectively preventing environmental regeneration and resulting in large portions of the PA being covered by initial vegetation for a long time (PONTES JUNIOR, 2016).

Internal paths

The quality of forested areas of the DNP is also affected by existing internal paths in the PA, given their construction and maintenance, as well as the similarity with the areas affected by various disturbances. There are 99.71 km of paths inside the DNP, all of which were constructed before the creation of the PA and which possess a mean width of 3 m (PONTES JUNIOR, 2016). Given an edge effect for vegetation in 100 m at each side (PAULA et al., 2016), there is a constant width of 0.20 m for paths inside the DNP, which suggests an area of 1995 ha (99.71 km extension multiplied by 0.20 m wide) that is affected by the presence of these paths. This value corresponds to ~10% of the area of the PA but must be relativized since the paths cross degraded areas, which likely have a greater effect on the ecosystem than the paths, as reported by Santos et al. (2010).

Roads and trails are often reported to facilitate invasion by exotic species (GELBARD et al., 2003; CHRISTEN et al., 2009; BARBOSA et al., 2010), entrance by people and environmental wrongdoings (CHIARELLO, 2000), grounding and separation of populations, and the creation of new habitats, such as the damming of watercourses, which can interfere with amphibian populations, known to have low dispersal ability and to prefer more humid areas (PONTES et al., 2013).

When considering the influence of internal paths, the area of the DNP that is affected by disturbance is increased to a total of 11,240 ha (9245 ha of degraded areas + 1995 ha of area influenced by internal paths). This is nearly half the total area of the DNP (22,697.69 ha). Therefore, the management body of the PA needs to determine whether all the paths and trails inside the protected area are needed or if some should be closed and recovered.

Participation in biodiversity conservation

The PAs should be implanted in the whole context of dialog, which aims to strengthen the strategies for biodiversity conservation. Participation in the network is important given that the perpetuity of conditions suitable for life on the planet will only persist if a set of measures, including the construction of a network of protected areas, are taken at the global level. Such a vision can be easily perceived by highlighting the cross-border conditions that involve the species, such as migrations or even climatic conditions, where, for example, rain that falls in a particular locality originates in another region (NOBRE, 2014).

The Biosphere Reserve, which was created within UNESCO's Man and the Biosphere Programme during the 1970s and envisaged by Law 9.985/2000, is one of these models and has been the main instrument of this program, as a worldwide network established to promote cooperative research,

natural and cultural heritage conservation, and sustainable development.

The Mata Atlântica Biosphere Reserve was first developed in the extreme southern region of Bahia in 2000, during phase IV, and the DNP was part of all discussions pertaining to the subject, as in the case of those related to the central corridor of the Atlantic Forest, with great importance for external financing arising from the Ecological Corridors Program, which was responsible, among other activities, for financing the PA's Management Plan, the meetings and workshops for establishing the Advisory Council, and the inflow of material resources (e.g., vehicles; ICMBio, 2014).

Planning

The creation of protected areas is essential to the conservation of biodiversity, but both require good planning. This premise was defined by the Convention on Biological Diversity, by its ultimate decision-making body, the Conference of the Parties, as set out in the Aichi Targets (MARCO et al., 2015). According to the definition written in Law 9.985/2000, PAs must have a management plan that incorporates the main PA area, as well as its buffer zone and ecological corridors, including measures to promote their integration into the economic and social life of neighboring communities.

Dourojeanni (2003) reported that ~55 plans already existed in Latin America by 1976 for the management of PAs, many having been produced in the 1960s. However, the first management plan to be established in Brazil was only constituted in 1976 by the Brazilian Institute for Forestry Development, for the Brasília National Park, and according to D'Amico (2016), less than half of the federal PAs in Brazil have management plans, most of them developed from secondary data.

In the DNP, the field studies that underlie the management plan were conducted in 2009 using rapid ecological assessment (REA) methods, which, according to Sayre et al. (2003), combine the simultaneous work of researchers from several areas in the same locations, observing the methodology of each area but ensuring the integration of the results, in order to understand the ecological relationship between these groups. However, because REA methods do not address population bias, the results of the methodology should be interpreted with caution, given the importance of population studies in elucidating the actual state of species conservation (BARRYMAN, 2002).

In addition to the methodological definition, the data used to establish the DNP's management plan have certain weaknesses. For example, the data is a decade old and, therefore, outdated. In addition, the faunal studies only address vertebrate species, and the zoning of the unit indicates that the buffer zone as of small dimensions and is located in an area with intense past use and also that there are no Executive Plans, therefore, low execution of what was planned (PONTES JUNIOR, 2016). It is important to note that the DNP belongs to a select group of PAs with management plants, which also provide a good score in management effectiveness methodologies (IBAMA, 2007;

ICMBio, 2010). However, as described above, this data should be viewed with great caution since the information generated by them may be outdated, misinformed, and not even put into practice.

Relationship with surroundings

Regardless of the strategy adopted for creating PAs, the objectives of individual PAs are unlikely to be filled if there is a lack of connection between protected areas and the surrounding landscapes or if there is a lack of balance between the current activities in the surrounding areas and those intended for the PA. Indeed, the surrounding matrix can either facilitate the achievement of PA objectives (e.g., by providing favorable environmental conditions for the local biota) or hinder such achievement (e.g., by impeding the conservation of species or either ecological or geological processes to which the PA is linked; RIBEIRO et al., 2009).

According to the definition established in Law 9.985/2000, the buffer zone is defined as area surround PAs, where human activities are subject to specific rules and restrictions, with the purpose of minimizing the negative effects of such activities on the PA.

The buffer zone of the DNP was established by the Decree of the PA Extension in 2012 and encompasses 107,239.30 ha, of which the actual PA occupies 21%. Villages, districts, agrarian settlements, small, medium, and large properties, and marine land are all included in the buffer zone (ICMBio, 2014), with this occupation distributed by a series of micro-hydrographic basins, according to Pontes Junior (2016).

The land use of the properties encompassed by the DNP's buffer zone can be characterized as a complex mosaic of economic and social activities, including forest fragments ofvarying quality and areas allocated to pasture (majority), forestry (eucalyptus), crop plantations (mainly coffee, cocoa, and pepper), fruit production (mainly passion fruit), mining (kaolin), and shrimp farming (shrimp from Malaysia), farming. There are also activities related to tourism, which are very focused on the binomial sea and sun (ICMBio, 2014).

An appropriate forum for discussing the future location of PAs is their management council, as described by in Law 9.985/2000, which may be deliberative (e.g., Extractive Reserves and Sustainable Development Reserves) or advisory (e.g., national parks; BRASIL, 2000).

Some of the duties of the management council include evaluating the PA's budget and annual financial report, deliberating over work or activities that could potentially affect the PA, proposing guidelines and actions for reconciling relationships with populations in and around the PA, and elaborating the management plan (BRASIL, 4.340/2002).

The DNP's advisory council was created in 2008. However, after more than ten years of existence, Pontes Junior (2016) argues that the council is still immature and has a long way to come of age, as defined by Immanuel Kant (NODARI; SAUGO, 2011).

Conclusions

The process of creating and expanding PAs is complex and involves several variables that must be analyzed to find the best strategies to be operational. Some of these variables were analyzed here, by using the DNP as an example.

The results presented here demonstrate that the creation of the DNP included a series of planning mishaps, which were motivated by non-ecological criteria. Indeed, despite valuable conservation opportunities, key conservation biology concepts were disregarded, thereby hindering the conservation of the region's biodiversity and even minimizing the chances of sustainable local development.

Aspects related to the management of the PA were discussed, and it was demonstrated that, despite the existence of a management plan, the plan should be viewed with caution, owing to methodological constraints, outdated data, failure to follow the plan, and a variety of inconsistencies, such as the delimitation of the buffer zone in an area with a large history of disturbances. In addition, it is crucial that efforts are made to ensure that the PA is integrated with the region where it is implanted, in order to establish harmonious relationships with others who work in the same area, by continuously aiming to develop sustainable activities. The land use of the DNP's buffer zone is relatively complex and requires excellent management in planning with such activities.

An appropriate forum for such discussions is the PA's advisory council. However, in the case of the DNP, even though an advisory council was established more than ten years ago, it still needs to extend its efforts beyond the ratification of local management acts.

Even though biodiversity conservation is not a new idea, the present study demonstrated that the practical implementation of conservation concepts is not always realized, as observed in the DNP, which is a relatively young PA (20 years old) that could have been established using all the good practices of conservation biology.

Accordingly, the aim of the present study was to contribute technical information that could facilitate deeper discussions with public managers and decision-makers, as well as with society in general, regarding the multiple planning possibilities of protected areas.

The present study highlights the importance of evaluating with clear criteria all the context that permeates the protection of biodiversity and local development, always seeking multiple analysis of situations involving the creation of protected areas in order to boost their primary objectives, the conservation of socio-geo-biodiversity, with the sustainability of the surrounding areas, a situation in which other objectives are extolled, such as those related to the provision of sustainable ecosystem services and territorial development.

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