THE CHALLENGE OF AQUATIC ENVIRONMENTS CONSERVATION AND CONTINUITY OF ENVIRONMENTAL SERVICES IN URBAN GREEN AREAS: THE CASE OF CANTAREIRA STATE PARK*

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Introduction

Mankind has always benefited from the environmental services provided by natural ecosystems. However, the concern with this issue was only intensified in the mid-20th century with the awareness of the eminent loss of these services as a result of anthropogenic pressures on ecosystems. This discussion led to the Millennium Ecosystem Assessment, requested by the Secretary-General of the United Nations, in order to assess the consequences of ecosystem changes on human well-being and establish actions to ensure the conservation and sustainable use of ecosystems (MA, 2005). The resultant reports recognize the existence of four categories of ecosystem services:

– *Supporting*: services represented by natural processes that affect the existence of the other services as nutrient cycling, solo formation and primary production;
– *Regulating*: services resulting from natural processes that affect the environmental conditions that control the human life, such as water purification, climate, flooding, and disease regulations;
– Provisioning: services related to products obtained from ecosystems as food, freshwater, fuel, wood and fibers;
– Cultural: services related to aesthetic, spiritual, educational and recreational benefits offered by ecosystems.

Forest ecosystems are clearly related to many of the benefits of these four categories, including those concerned with the maintenance of healthy aquatic ecosystems in their interior, habitat and water quality, and consequently, the aquatic biota.

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Nowadays in São Paulo State (Brasil), much of the forest formations are represented by fragments protected as conservation units. The acknowledgement of the environment services provided by those formations results from their role in the equilibrium of natural ecosystems functioning as oxygen production by plants, soil fertility, ecosystem vitality, climatic balance, thermic comfort, production of water and balance of the hydrologic cycle, among others (SILVA *et al.*, 2009). Several of these services become increasingly relevant in the case of green areas in the urban zone. This fact is not due solely to the dependence of the human population on the services, but also to the fact that the greater the proximity with this population is, the greater the threat to the green areas' maintenance will be.

Taking the last idea as a starting point, this paper will deal with the Cantareira State Park (CSP), focusing on the water bodies present in it. This is a conservation unit of integral protection created by the State Decree 41626 of 11/30/1963 and the State Law 10228 of 09/24/1968. The park is formed by one of the greatest forest fragments in the urban zone of the world (INSTITUTO FLORESTAL, 2009a) and is located in the Metropolitan Region of São Paulo (MRSP), marked by a high level of urbanization. Urban remaining forests are the reflection of the history of environment exploitation, successive economic cycles, and continuous expansion of the human population resulting in small fragments of native vegetation isolated in urban zones (HULTMAN, 1976).

Brief history of the environmental protection on the Cantareira State Park

Concern for the protection of the Serra da Cantareira, a mountain range in which lies the CSP, comes from the mid-nineteenth century, a period when the area was undergoing intense exploitation by colliers (VITOR, 1975). Aiming to study the local flora, the naturalist Albert Loefgrën created the Botanical Garden, contiguous to that mountain range in 1896. A few years later, this aim was broadened to include the forest conservation and hillsides reforestation (BRITO, 2000).

Among other processes that accelerated the destruction of the natural plant cover of São Paulo State, the coffee culture resulted in the need for the exploitation of the remaining forests, the renewal of devastated areas, and the creation of new forested areas (BRITO, 2000). Thus, in 1911, when only 35% of the original plant cover was left, the State the Forest Service was created from the Botanical Garden and Forest Reserve of Cantareira. The idea was not yet consolidated, but it represented the first step to the creation of conservation units in the state (VITOR, 1975).

Aiming to be in line with the Brazilian Forest Code of 1934, the Forest Service was legally structured in 1943 by a decree that intended to organize the monitoring and protection of forests, and the Forest Police was also created (BRITO, 2000). At that time, more than 75% of the original plant cover had been lost.

In the 1960s, several parks were created in São Paulo, among which is the CSP (Figure 1). In 1972, the Forest Service was renamed as the Forest Institute. Its organizational structure was defined to plan and select conservation units and management plans

became to be required. The CSP was one of the first units to elaborate on this document, in 1974 (BRITO, 2000).

In 1986, State Decree 2534 regulated the parks of São Paulo (BRITO, 2000). In the same year, the Secretariat for Environment and the Foundation for the Conservation and Forest Production of São Paulo State, usually called the Forest Foundation, were created. The first provides and implements the state conservation policy. The second, like the Forest Institute, is subject to the Secretariat for Environment. Nowadays, the development, creation and management of programs in conservation units are responsibilities of the Forest Foundation. The assessment of research activities and the promotion and monitoring of actions to protect cultural and natural heritage and subsidize public policies and sustainable development are responsibilities of the Forest Institute (INSTITUTO FLORESTAL, 2009b).

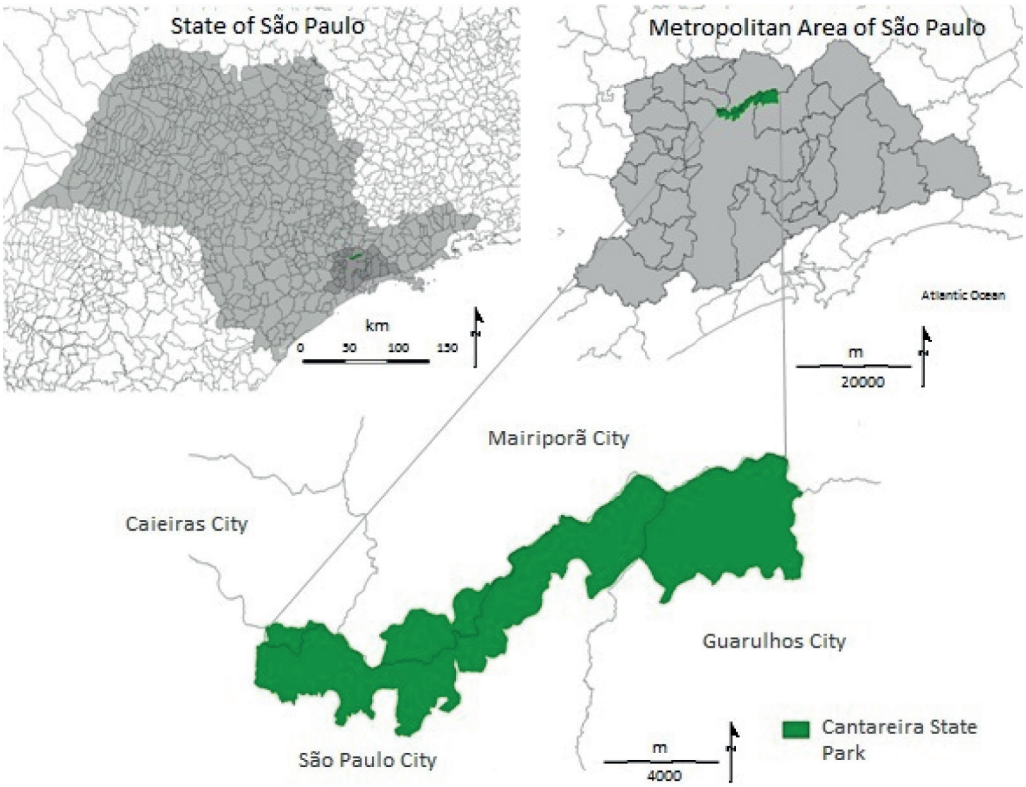

Figure 1. Location of Cantareira State Park in the Metropolitan Region of São Paulo (SP) (Source: produced with data provided by Fundação Florestal).

The evolution of the plant cover conservation system of São Paulo was concomitant to the protection structure of the Cantareira mountain range until part of it became a conservation unit of integral protection as a state park. The increase of environmental degradation in the state occurred parallel to those processes, and today only 13.9% of

the original native cover plant of the state remains (INSTITUTO FLORESTAL, 2005). In this respect, the 7,916.52 hectares of the Atlantic Forest present in the CSP are really relevant, the protection of this area being highly dependent on the feasibility of its management plan.

The current management plan was launched in 2009, resulting from the revision of the first plan of 1974. This document directs actions of managing of the park and its buffer zone, matching environmental conservation and the multiple uses of the park. That is why the plan considers the integration of actions of environmental education, ostensive policing of the area, and ordinance of soil use in the surroundings, among other actions, essential (INSTITUTO FLORESTAL, 2009b).

A management plan evolves stepwise, having the flexibility to aggregate acknowledgment to enhance and to deepen management actions of resources in protected areas. This feature is relevant, especially in CSP. Theoretically, the protection of this relevant Atlantic Forest fragment has the potential to conserve its water bodies. This assumption is really important as the park is plenty of springs and streams of three subbasins of the Upper Tietê River Basin that has serious troubles related to the water demand and supply. Important rivers of the MRSP, whose waters run into the Tietê River, arise in the CSP south face, including Cabuçu de Baixo, Cabuçu de Cima, and Baquirivu. In the north, the water from micro basins Ribeirão Santa Inês, Ribeirão Águas Claras, and Ribeirão São Pedro flows into the Paiva Castro Reservoir, the last reservoir of the Cantareira water supply system (Figura 2).

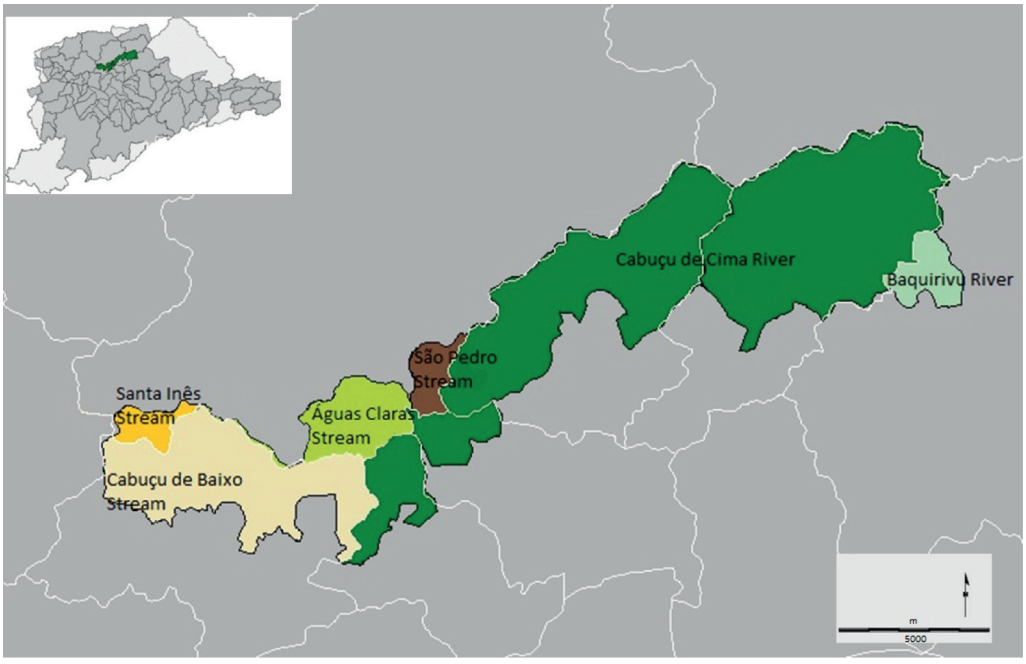

Figura 2. Sub-basins that are part of Cantareira State Park (SP) (Source: produced with data provided by Comitê de Bacia Hidrográfica do Alto Tietê and Fundação Florestal).

Environmental services provided by the Cantareira State Park

According to the emphasis attached to the CSP bodies of water in this paper, the environmental services related to these ecosystems will be subsequently examined.

Conservation of biodiversity

Biodiversity in an integral protection area is mainly related to the support services because both nutrient cycling and primary production depend on the species in the ecosystem. Cultural services have the potential to be threatening to the conservation of biodiversity. Therefore, in conservation units they are profited just in areas where visitation is allowed.

The role of CSP in the conservation of terrestrial and aquatic biodiversity is fundamental; the park is a significant fragment of the Atlantic Forest, one of the main repositories of biodiversity in the planet. Although only 7% of its original cover remains, this forest still has a high biodiversity (CONSERVAÇÃO INTERNACIONAL DO BRASIL, 2011; FUNDAÇÃO SOS MATA ATLÂNTICA, 2011). It has high plant and animal endemism, being a world hotspot of biodiversity (Myers *et al*., 2000). Moreover, the Atlantic Forest Biosphere Reserve (AFBR) is the biggest and one of the major reserves of the UNESCO world network (KIBRIT, 2010).

There are over 700 integral protection conservation units constituting the core zones of AFBR. CSP is one of these zones, besides being one of the core zones of the São Paulo City Green Belt Biosphere Reserve. The last was named a special biosphere reserve in 1994. It comprises 73 cities and is part of the AFBR (KIBRIT, 2010).

According to Rylands (2005), conservation units are the foundation for the protection of the Brazilian biomes. Direct exploitation of natural resources is forbidden in integral protection conservation units such as the CSP. However, the indirect use of these resources is allowed, with some exceptions provided by Law 9985 07/18/2000, which instituted the National System of Nature Conservation Units (BRASIL, 2000).

Protection of aquatic environments by the forest

The protection of the bodies of water of CSP is imperative as this area is a relevant water source. Thus, it would ensure the continuity of environmental services related to the availability and quality of water. This is relevant to the human population and biota living in or depending on the aquatic environments of the park.

First-order streams are differential bodies of water because, in general, they receive water directly from slope runoff (DUNN *et al*., 2011). The chemical quality of the water from low-order streams, like those occurring in CSP, is influenced by several landscape factors related to vegetation, climate, geology, and topography (ANDERSSON and NYBERG, 2009). These streams are very susceptible to soil cover changes because the riparian vegetation enables temperature variation in a narrow range and supplies detrital organic matter to them. Terrestrial woody debris are relevant, as they are food resources

to organisms in the streams which depend mainly on allochthonous sources of energy (TABACCHI *et al.*, 1998).

The analysis of soil cover on macroscale landscape assessment is the first step in the creation of sustainable management in catchment areas. Thomson *et al.* (2012), studying the influence of arboreal vegetation and climatic variation on watersheds, verified that stream conditions are the best under extensive stretches of arboreal vegetation, as for water quality as for aquatic habitats. Those authors also pointed out the potential to manage this vegetation to reduce negative impacts of extreme climatic changes on aquatic ecosystems, as the benefits of its presence persisted during dry periods.

Besides its role on macroscale, vegetation is also important on the scale of riparian zones, i.e., regions adjacent to streams, where the runoff from higher areas is connected to the surface and underground flows. Even though these zones normally occupy a small fraction of the landscape, many times they play a significant role on the chemical control of water, enabling the exchange between the surrounding land and the stream system (NRC, 2002; BURT and PINAY, 2005). Therefore, the influence of riparian vegetation over the aquatic environments is fundamental. Besides, this vegetation has a relevant function as an ecological corridor, making possible the circulation of organisms. Fragmentation of riparian vegetation restricts circulation and can consequently result in animal and plant species suppression (HEARTSILL-SCALLEY and AIDE, 2003). Moreover, this vegetation buffers the flows from adjacent soil, retaining sediments, nutrients, and contaminants that otherwise enter the water bodies (CAROTHERS,1977). The banks' lack of stability due to the riparian vegetation removal increases light availability, propitiates soil erosion and sedimentation, and changes the water flow, the thermic regime, nutrient cycles, and microhabitats. Furthermore, the reduction of vegetation results in a decrease of woody debris input in streams, contributing to habitat degradation and affecting the whole lotic ecosystem (JOHNSON *et al.* 1995).

The soil cover by natural vegetation in riparian zones, as in the total drainage basin, affects stream conditions carrying out a regulating environmental service concerning water purification (Heartsill-Scalley e Aide, 2003). Because vegetation changes potentially affect the structure and processes within these water bodies, other environmental services related to these ecosystems will also be threatened.

Water source for the MRSP

CSP water bodies provide a relevant provisioning environmental service since they have been contributed for a long time to the water supply of cities of MRSP.

From the beginning of the nineteenth century, the Cantareira mountain range had a relevant role in the water production for São Paulo city and region, and this was the original motive for its preservation. At that time, the water company implanted the system of intake and treatment of potable water for public supply using the water of Cantareira, which was the main water source to the region (MARTINS, 2003). However, this system was not enough to meet the increasing water demand resulting from the increase of the population of São Paulo city. At the end of the same century, the São Paulo State cre-

ated the Water and Wastewater Office (WWO) dispossessing farms in an area of 5,000 hectares, where CSP is located nowadays (INSTITUTO FLORESTAL, 2009b). Several signs of small dam edifications that are part of WWO are still visible in that site.

The WWO system of water uptake and treatment was organized for small size attending by small reservoirs in the Cantareira mountain range, including Engordador, Barrocada and Cabuçu, all located in the site where the CSP is now. Water going to the distributor system was directed by gravity to consumer centers. However, this structure was inefficient during times of drought, as the water volume was too small to be transported by gravity. To this was added the increased demand for potable water resulting from São Paulo's demographic growth potentiated by industrialization. Thus, the search for other sources to make possible the supply became necessary as the use of some protected water zones and preexistent reservoirs before destined to other uses, as Billings and Guarapiranga (ALVES, 2010).

Due to the continuous human population increase, hydric deficit proceeded in the Upper Tietê basin that is nearly totally in the MRSP, and the available water being insufficient to supply the region. Thus, it started the import of 32.3 m3/s of water from adjacent basins by water producing systems (COMITÊ DA BACIA HIDROGRÁFICA DO ALTO TIETÊ, 2009; ANA, 2010). Among these systems, Cantareira System, set out in the 1970's, stands out as being responsible nowadays for 50% of the total water used to supply MRSP. Although with the same denomination, this system transposes the Cantareira mountain range (ALVES, 2010) and almost nearly does not use water from CSP. In MRSP, the hydric availability *per* inhabitant was 201 m^3/year in 2003 (PORTO, 2003), an amount considered extremely low according the UNO recommendation of 2,500 m^3/year. This water scarcity is related to the MRSP location on a region of river headwaters. In relation to the unity of management of Upper Tietê specifically, the water demand is considered critical and continues increasing (SSRH/CRHi, 2011).

In this situation of low water availability in the MRSP, the Cantareira mountain range plays a relevant role as it houses springs of several micro basins. Some of them have slopes directed to the Paiva Castro reservoir, contributing indirectly to Cantareira System. Moreover, it contributes to the supply of Guarulhos City through the Cabuçu reservoir that is operated by the Autonomous Service of Water and Wastewater of Guarulhos (ASWWG).

According to data on instantaneous flow measured in points more representative of CSP, the park contributes around 902 L/s. Two sites stand out: the micro basin of Águas Claras stream with a flow of 188.7 L/s and Cabuçu reservoir with a mean value of 184.2 L/s of water uptake by ASWWG (INSTITUTO FLORESTAL, 2009b).

Anthropogenic pressures on the PEC as threats to the aquatic ecosystems

The region in which CSP is inserted has attributes of areas tending to vulnerability as it is associated with nearly uncontrolled processes of urbanization and activities in the different economic segments. This situation comes with a social debt that is expressed by the precarious conditions of dwelling of part of the population, occupancy of risk areas,

besides the shortcomings of urban and social infrastructure. In this context, the natural environment is subject to the features resulting of large metropolitan regions as the pressure on the environmental heritage that makes protected areas vulnerable (EMPLASA, 2012).

CSP comprises lands of Caieiras, Mairiporã, Guarulhos and São Paulo. Therefore, these cities characterized by a high level of urbanization (Table 1) have a direct influence on the park, and in general neighbourhoods at the borderline of CSP have a lack of basic infrastructure and are occupied by a population with low level of instruction.

Table 1. Area, population, urbanization level, and water supply of cities with lands in the Cantareira State Park (SP).

	Area (km^2)	Area inserted in CSP (%)	Population (ind.)	Urbanization Level (%)	Water Supply (% of access)
Ano	2012	2009	2011	2010	2000
Caieiras	95,89	1,43	88,122	97,52	97,89
Mairiporã	321,48	2,60	83,206	100,00	65,06
Guarulhos	318,01	8,01	1.236,884	87,39	94,69
São Paulo	1.522,99	2,84	11.377,021	99,10	99,42

Sources: Fundação SEADE (2012); Instituto Brasileiro de Geografia e Estatística (2012); Instituto Florestal (2009b).

The Index of Social Vulnerability of São Paulo State is a tool that helps to understand the living conditions of the population in those cities. This index allows to differentiate areas according the exposition of people to diverse levels of social vulnerability as it results from synthetic indicators of socioeconomic and demographic dimensions (FUNDAÇÃO SEADE, 2012). In that case, it is understood that vulnerability refers to the possibility that an individual, family or social group has to control external forces affecting its welfare. According Fundação SEADE (2012), excepting São Paulo, more than 50% of the population living in the cities which have lands in the CSP were in medium, high and very high categories of vulnerability in 2000. Considering that in general the less the income and access to education, the higher the deleterious effects of the population on the environment, one has an idea about the pressure of that situation on CSP.

Guarulhos and São Paulo are in the park south side and in relation to the last city borderline neighbourhoods are Jaraguá, Brasilândia, Cachoeirinha, Mandaqui and Tremembé. In these sites, clandestine settlements arise at the expense of local vegeta-

tion. These areas that already passed by a relevant process of vegetation suppression give support to an intense process of urbanization, reinforcing the Silva and Grostein's understanding that the two phenomenona are closely related (SILVA and GROSTEIN, 2007).

In the micro basin of Cabuçu de Baixo stream, in the borderline region between the CSP and São Paulo city, specifically in Bananal, Bispo and Guaraú streams, intense deforestation from 1986 to 2000 was observed, and the vegetation was replaced by urban occupation along those water bodies. Besides illegal occupations, in the borderline areas of the park there also are housings as Taipas built by the Metropolitan Company of Housing and Vila Brasilândia built by the Company of Urban and Housing Development. In relation to these housings, Silva and Grostein (2007) highlight that the public power replicates patterns of unsustainability comparable to that observed in clandestine settlements and slums.

In relation to São Paulo, specifically, the borderline areas had functioned as a protection barrier to the CSP until the end of 1990 decade, during the process of expansion of urban densification. In the face of this situation, Silva and Grostein (2007) pointed out the threatening invasion of park edges due the urban area if this dynamic of occupation continues.

The proliferation of precarious housing settlements is also observed in the boundary between CSP and Guarulhos City, as well as in the Jardim Monte Alto, Jardim Novo Recreio, and Recreio São Jorge settlements (INSTITUTO FLORESTAL, 2009b).

In Caieiras and Mairiporã, located on the north side of CSP, urban occupation has taken place mainly through closed condominiums and small residential farms. This way of occupation keeps higher levels of vegetation than others. However, it was responsible for the fragmentation and deforestation of significant sections of vegetal cover between 1960 and 1990, corresponding to 1,485.81 hectares (SILVA E GROSTEIN, 2007; INSTITUTO FLORESTAL, 2009a).

Concluding remarks

As explained, the Cantareira State Park has environmental troubles related to the precarious living situation of a large portion of its neighbouring population. These troubles can advance to the interior of the park as it is a leisure option related to the environmental services provided by a great green area that is easily accessible.

Among those services, specifically to aquatic environments as streams, waterfalls and reservoirs, are reported the cultural ones represented by recreational and spiritual benefits. The first ones are related to use for fishing and bathing which are closely connected to the failure of options for a population lacking leisure infrastructure and income to seek for other alternatives. The second benefits are related to religious practices as the area is intensively searched with this goal, the countless vestiges of these activities being within the CSP. The utilization of these cultural services has a great problem related to its potential to affect, negatively, the aquatic habitat and water quality and many times this occurs illegally in sites of the park where the public access is restricted.

The illegal use of the environmental service of water provision by the clandestine water uptake by inhabitants of surroundings is also a common practice in CSP (INSTITUTO FLORESTAL, 2009b). This fact can be confirmed by the presence of water hoses in the park, and this practice can contribute to the decrease of water availability there. The impact of this practice can get worse as urbanization advances in the park borders as springs and streams in CSP have a relatively low volume.

Illegal practices inside CSP are also related to the general low educational and information levels of the people living in the surroundings. It is presumable that people know the prohibition to access some CSP areas but do not understand the motive for this, which results in disrespect to the rules.

From this perspective, the prevailing environmental and socioeconomic state of the surroundings of CSP is an obstacle to aquatic biota conservation, its related supporting services, and the good quality water supply due to the uncontrolled urbanization. On the other hand, because of its status as a legally protected area where activities are restricted, its location in a mountain range, and the difficult access to more conserved sites, the degradation of this relevant urban green area and its ecosystems is minimized. Moreover, its location favours the conservation of water bodies because it virtually does not receive tributaries from the outside area, preventing the input of allochthonous pollutant loads.

Although quoted aspects minimize direct impacts on CSP and, consequently, the water bodies, they do not ensure the total protection of these environments. Most of the water bodies are fed by rainwater and have good or very good water quality (RARES, 2013). An exception is the Cabuçu de Cima river that enters the park with a high load of domestic wastewater. A similar situation occurs in the Jaraguá State Park (JSP), another integral protection conservation unit located in the urban zone of São Paulo City. In CSP, the Cabuçu de Cima river flows by a short distance in a boundary area, which does not dramatically affect other water bodies inside the park. However, in JSP, the entrance of a stream contaminated by domestic wastewater resulted in a severe degradation of water bodies inside the park demanding rehabilitation measures (INSTITUTO FLORESTAL, 2010).

Another relevant point is that the number of security agents of CSP is not sufficient to control the entrance of people in prohibited areas and this trouble is enhanced by the large park extension. Therefore, water quality and habitat can occur apart from the vegetation protecting function. Saunders *et al.* (2002) pointed out that terrestrial parks, many times, did not get to deal with relevant matters related to aquatic environments as hydrology, exotic species introduction, and watershed integrity. Those authors also consider that freshwater always will be affected in some degree by activities occurring outside the protected area boundaries. Abell *et al.* (2007) emphasize the relevance of considering aquatic environments on the establishment of protected areas.

Therewith, excepting the socioeconomic issues, about which a deeper discussion is out the scope of this text, it is concluded that a cooperative effort is needed in order to protect CSP water ecosystems. This effort does not demand only the compliance of the management plan of the park and the increase of qualified security staff, but also the improvement of infrastructure in the surrounding area. Thus, there will be a greater pos-

sibility to ensure the continuity of environmental services offered by park water bodies as far as legally allowed use is concerned. After all, environment services are very relevant to human welfare and survival as human activities are dependent on them. These services are also essential to the survival of other species, and their maintenance depends directly on environmental conservation and preservation, as well as on the practices that minimize anthropogenic impacts on the environment (NOVION, 2011).

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THE CHALLENGE OF AQUATIC ENVIRONMENTS CONSERVATION AND CONTINUITY OF ENVIRONMENTAL SERVICES IN URBAN GREEN AREAS: THE CASE OF CANTAREIRA STATE PARK

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Resumo: Este trabalho trata da pressão antropogênica sobre corpos de água e de sua relação com os serviços ambientais associados a estes ambientes. Para tanto, toma como base a situação observada em um dos maiores remanescentes de floresta natural em área urbana do mundo, o Parque Estadual da Cantareira. Discute a relação entre a pressão antropogênica e a condição socioeconômica da população do entorno desta unidade de conservação de proteção integral ocupada por Mata Atlântica. Além disso, chama atenção para o fato que a proteção da vegetação nem sempre resulta em proteção dos habitats aquáticos e da qualidade da água, prejudicando o uso de serviços ambientais legalmente permitidos.

Palavras-chave: Unidade de Conservação de Proteção Integral; Mata Atlântica; Ambientes Aquáticos; Serviços Ambientais.

Abstract: This paper addresses the anthropogenic pressures on water bodies and their relationship with the environmental services associated with these environments, taking as an example the reality observed in one of the largest urban fragments of natural forest in the world, the Cantareira State Park. It discusses the relationship between anthropogenic pressure and the socioeconomic status of the population surrounding this conservation unit occupied by Atlantic Forest. Furthermore, it calls attention to the fact that the protection of vegetation does not always result in the protection of aquatic habitats and water quality, harming the use of environmental services that are legally allowed.

Keywords: Integral Protection Conservation Unit; Atlantic Forest; Aquatic Environments; Environmental Services.

Resumen: En este trabajo se aborda la presión antropogénica sobre los cuerpos de agua y su relación con los servicios ambientales asociados a estos ambientes. Por lo tanto, toma

como base la realidad observada en uno de los más grandes fragmentos urbanos de floresta natural en el mundo, el Parque Estatal de Cantareira. Explica la relación entre la presión antropogénica y la situación socioeconómica de la población en torno a esta unidad de conservación integral ocupada por Floresta Atlántica. Por otra parte, llama la atención sobre el hecho de que la protección de la vegetación no siempre se traduce en la protección de los hábitats acuáticos y la calidad del agua, perjudicando la utilización de los servicios ambientales legalmente permitidos.

Palabras clave: Unidad de Conservación de Protección Integral; Floresta Atlántica; Ambientes Acuáticos; Servicios Ambientales.