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Research Article

Activity patterns and behavior of *Myocastor coypus* in a gated community in the metropolitan area of Buenos Aires (Argentina)

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Abstract

Anthropization processes confront local wildlife with a new set of conditions that may lead to local extinctions or allow the expansion of some species. This is what happens with the coypu (*Myocastor coypus*) in gated communities in the metropolitan area of Buenos Aires (Argentina), where its rapid population growth results in continuous conflicts with the local inhabitants. The aim of this study was to document the daily and seasonal activity patterns and behavior of the coypu in an urban landscape within their natural distribution range. To achieve this, we conducted a camera-trap survey within areas occupied by the species from February to November 2018. The coypu activity was mainly crepuscular and nocturnal with variations between seasons. We found that the seasons with the greatest activity patterns overlap were winter and autumn (84%), while the least overlap was observed between summer and winter (53%). During the active periods, time spent on foraging behavior was dominant. Time dedicated to vigilance was greater in summer than in winter. This result, alongside an increase in nocturnal activity during summer, shows that coypu in this urban landscape shift its behavior when exposed to an increasing human activity. This study brings up more ecological data of this species, which is key to find alternative control methods within gated communities to lead to a harmonic relationship between inhabitants and the species in its native distribution.

Key words: *Myocastor coypus*, gated community, activity patterns, behaviour

Introduction

The intense human activity with urban, recreational or productive purposes generates what is known as an anthropic environment, where the alterations of the natural environment confront the native organisms to a wide range of new conditions (Ramírez-Bautista and Pineda-López 2016). In this context, the responses of native populations depend on the inherent characteristics of the species as much as the kind and intensity

of the disturbance (Dickman and Doncaster 1987; Balcom and Yahner 1996). In some cases, anthropization process leads to local extinctions, while in other cases, new niches are created that allow the survival of some species according to their tolerance (Liciotti 2018). In many cases, these species adapt to live in artificial niches, becoming populations that bring up economic damage or behave as a plague (Wisnivesky 2003). The alteration of habitat due to the urbanization process is the most drastic among anthropogenic modifications and it is currently growing (Marzluff and Ewing 2001).

The coypu (*Myocastor coypus*) is a semi-aquatic rodent, native to the southeast of South America (Porini et al. 2019). This species represents a natural resource of great social and economic importance for the quality of its meat and fur in many areas of its natural distribution (Bó et al. 2006). Today, wild populations are established at a global level because of previous introductions in different regions (Bertolino et al. 2012). In the last few years, coypu populations have begun to establish in urban habitats (Sheffels 2013), even in their natural distribution. Much likely, in Argentina, the establishment of coypu populations in urban areas is associated with the new features of urbanization (Corriale and Arenas 2016, 2017).

Since the decade of 1990, an accelerated expansion of the metropolitan area of Buenos Aires (Argentina) took place, one of the four megapolis of Latin America with more than 10 million inhabitants. At that time, there was an increase of the gated community's construction on wetland in the lower basin of the rivers (Fernández et al. 2010; Randado Díaz 2010). The construction of this type of gated communities, known as 'closed polderized housing development' (CPHD), implies the elevation of the land through filling of flood-prone areas, the construction of artificial ponds and the deviation of natural water streams, modifying the wetland system (Fernández et al. 2010; Pintos and Sgroi 2012). Because of this, CPHDs generate an anthropic environment that affects the ecosystem and population dynamic of the area where these are established, producing ecological and social impacts (Pintos and Sgroi 2012).

The CPHD represents new niches with physical and biological characteristics that allow the coypu to satisfy its requirements, making them an ideal environment in terms of forage and refuge (Corriale and Arenas 2016, 2017). However, the population rise of the coypu in CPHDs generates a continuous conflict with their inhabitants, mainly because of burrow building on the edges of the ponds and due to the foraging behavior that leaves big patches of bare ground on the gardens (Corriale and Arenas 2016). To reduce conflicts, the correct management of this native rodent of South America (Porini et al. 2019) might require actions based on the species ecology. Still, little is known about the behavior of the coypu in urban habitats inside area of its natural distribution. It has been observed that human activity has a strong influence on the behavior and activity patterns of animals (Kitchen et al. 2000; Ditchkoff et al. 2006; Kamler et al. 2007; Rubiano Pérez 2019). Animals that live in urban settings tend to reduce their activity periods, increasing nocturnality (Gaynor et al. 2018; Shamoon et al. 2018) and, therefore, reducing their foraging time (Presley et al. 2009). By time segregation, animals minimize the risk associated with human contact (Gaynor et al. 2018). Previous studies of the coypu in urban habitats show wider areas of action and larger displacements outside the bodies of water than those observed in natural environments (Corriale et al. 2006; Corriale and Arenas 2016, 2017; Hilts et al. 2019), which demonstrates that the coypu shift its behavior in anthropic environments.

The coypu activity pattern is mainly crepuscular and nocturnal though it may present variations depending on the climatic–hydrologic characteristics and the presence of predators (Chabreck 1962; Palomares et al. 1994; Hernández 2009). As an invasive species, in urban habitats, the coypu presents a diurnal activity pattern associated with the availability of food left by humans (Meyer et al. 2005), while in nonurban habitats, its activity is more variable with diurnal activity during low temperatures, mostly during cold winters (Gosling et al. 1980; Gosling 1981). This proves a great behavior plasticity of this species when dealing with external factors, such as extreme weather conditions, forage availability and/or human presence.

The aim of this study was to analyze the activity patterns and behavior of the coypu in a CPHD in the metropolitan area of Buenos Aires (Argentina). First, we hypothesize that the coypu reduces its activity period with respect to that observed in studies conducted in nonurban habitats, but that at the same time, it increases its activity during the night. Second, we hypothesize that there are seasonal shifts in the activity patterns and in the times dedicated to different behaviors, similar to those observed in areas where the coypu was introduced. This study increases the ecological information of this species in urban habitats within its natural range that might contribute to design adequate management measures that enable a harmonic relationship with the local inhabitants.

Methods

Study site

The study was conducted at a gated community located in Belén de Escobar, in Buenos Aires province, Argentina (34°20′S 58°44′W; Fig. 1). The gated community has an area of 500 ha and is divided into four connected neighborhoods. Inside the gated community, there are 44 artificial ponds (Corriale and Arenas 2017). The mean area of the plots is around 800 m^2, 65% of the plots or properties have direct access to the ponds. Although most ponds lack aquatic vegetation, around its edges, native marsh vegetation can be found, such as *Schoenoplectus californicus*, *Zizaniopsis bonaerensis* and *Cortaderia selloana*, and some exotic plants such as *Iris pseudacorus*. In the upper areas, landscaped gardens predominate with dominance of low graminoids, among which dominates *Axonopus compressus* and ornamental plants.

The gated community is influenced by the phytogeographical region of Rolling Pampa and shares a border with the ecoregion Delta and Paraná Islands, which brings together a wide biological diversity. It is located in the basin of the Luján, along other 54 residential developments of the type CPHD. All these types of development have the same urban structure that consists in a landscape with artificial ponds typically connected to the main channel of the Luján River (Pintos 2017). The climate is moist temperate, with mean annual temperatures of 16.5°C (maximum mean temperature of 29.9° in summer and minimum mean temperature of 7.4° in winter) and rainfall of around 1000 mm per year, though it varies greatly through each season. The driest month is July with 55 mm, while the rainiest is March with 115 mm (Climate data 2017).

Data collection

To investigate the activity patterns and behavior of coypus, 52 infrared-triggered camera stations were installed at different sites during February to November 2018 ranging from 42 to

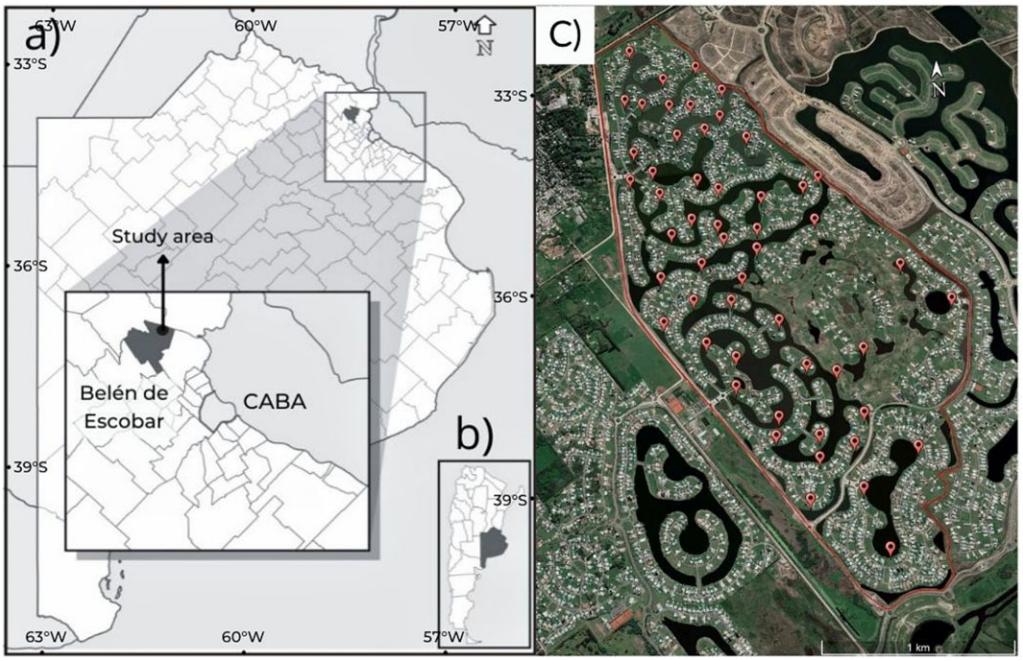

Figure 1: Location of the study area, Belen de Escobar District (dark gray) (a), Buenos Aires Province, Argentina (b). The gated community (outlined in red) and location of camera stations (red point) (c) (Google Earth Pro 2019)

92 days per season. Each station was located on empty lots (without houses) where signs or presence of coypus were evident (e.g. footprints, feces, feeding ground, nests, caves). In non-urban habitats close to the study area, daily movements were restricted within the first 10 m of the coastline, either in or out of the water (Guichón 2003; Guichón et al 2003). In our study area, we have observed that these movements can be greater, up to 50 m. Therefore, to avoid spatial pseudo-replication, the camera stations were settled more than 400 m from each other (Ridout and Linkie 2009). Records of multiple individuals were considered as a single record of the species. The camera traps were set up to record a 2-min video each time the IR sensors were activated and a time lag of 15 min, for 14 days. The cameras were upheld with a wooden stake to a height of 30–40 cm from the ground and 3 m from the coastline to cover the activity range of the species (Guichón et al. 2003). Each video registered date, time and environmental temperature.

Data analysis

To estimate the annual and seasonal activity patterns of coypus, we used the kernel density analysis, which is a non-parametric method for evaluating the probability density function of a random variable (Worton 1989; Ridout and Linkie 2009). Alongside, an overlap analysis was made with the object of describing the similarity between seasonal activity patterns of the coypus based on Kernel densities (Ridout and Linkie 2009). For this, we used a coefficient of overlapping (Δ), taking the minimum of the density functions from two sets of samples (in our case two seasons). Overlap was assumed as the area lying under both density curves. The coefficient of overlapping ranged from 0 (no overlap) to 1 (complete overlap) (Ridout and Linkie 2009). The analyses were performed in R environment 3.4.4 (R Development Core Team 2017) using the 'overlap' R-package (Meredith and Ridout 2016). The species behavior was described in two seasons with contrasting climate-hydrologic characteristics (winter and summer). To this end, a continuous focal sampling technique was conducted, which consists of recording the exact behavior of an individual and the time at which it occurs, indicating start time and end time of each behavior. The ethogram construction and further analysis were made with the Behavioral Observation Research Interactive Software, version 7.9.7 program (Friard and Gamba 2016) (Table 1). This program allows us to record the times dedicated to the different behaviors in a simple way. A total of 53 focal individuals were analyzed (25 in summer and 28 in winter). Because it was not possible to differentiate among individuals, we analyzed only one focal individual per camera station or two focal individuals if they appeared in the same video. The seasonal variation of the proportion of time spent on each behavior over the total time of observation was analyzed using a generalized linear mixed model with a Beta error distribution and a log link function (Zuur et al. 2009). Beta function is highly recommended for modelling proportions of continuous variables that may fall inside the interval (0–1) (Ferrari and Cribari-Neto 2004). The site or camera station was included in the model as a random factor to contemplate the lack of independence between individuals of the same social group. The total observation time for each focal was variable because it depends on the amount of time a coypu stays in front of the camera, once activated. Then, the total observation time was included in the model as 'offset'. All these analyses were carried out with the statistical program R version 3.4.4 (R Development Core Team 2017, 'glmmTMB' library).

Results

A total of 3198 capture events were recorded in the gated community (summer, $N = 265$; autumn, $N = 1842$; winter, $N = 846$; spring, $N = 245$). Considering the entire period of study, coypus at the gated community presented a unimodal activity pattern, with a substantial crepuscular and nocturnal activity, starting

Table 1: *Myocastor coypus* ethogram

Categories	Description
Effective consumption	The individual nibbles on grass
Search	The individual lowers its head (steady or moving) and sniffs around without consuming grass
Foraging	The individual carries out consumption or search behavior
Displacement	The individual moves from one point to another (excluding the time in which the focal is searching for food) (Altmann 1974)
Social	Allogrooming, persecution among two or more individuals or sexual behavior
Vigilance	Individual steady, with its head held high. State of alert
Grooming	The individual proceeds to groom itself or scratches with its mouth or limbs

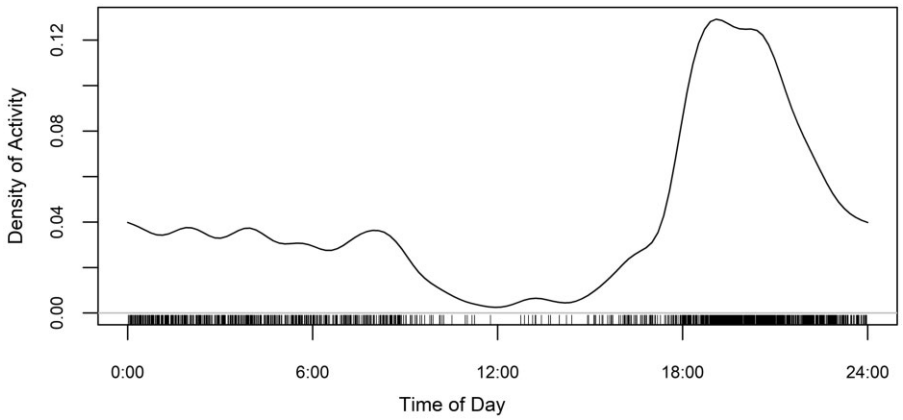

Figure 2: Annual activity pattern of the *Myocastor coypus* in a gated community in the metropolitan area of Buenos Aires (Argentina)

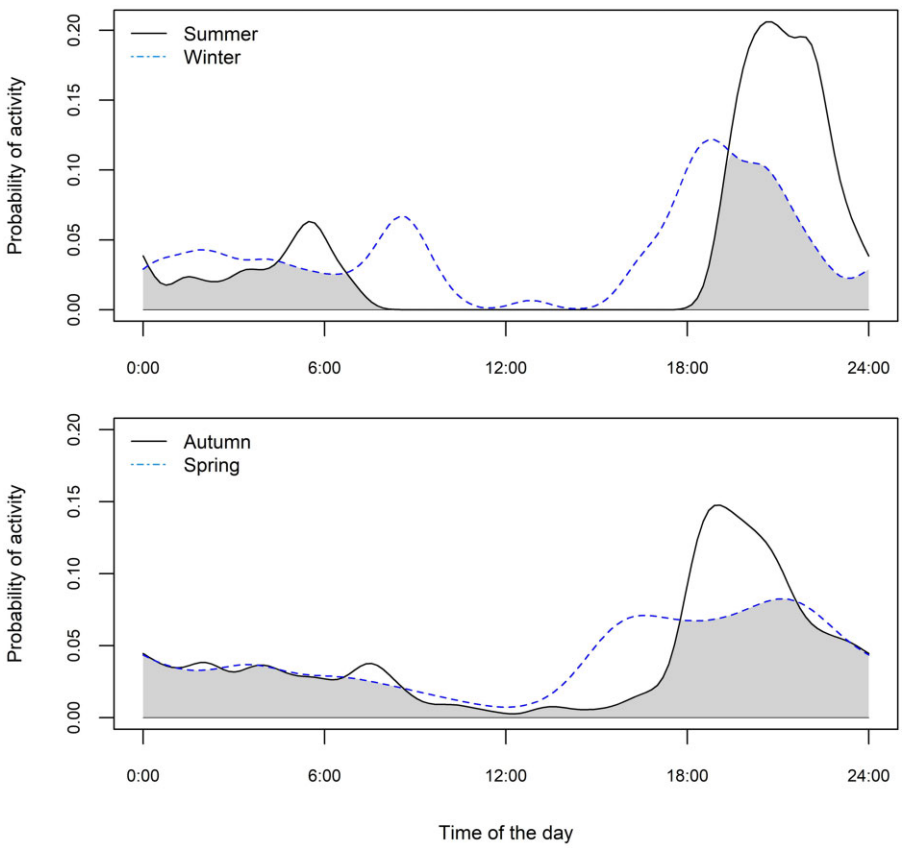

Figure 3: *Myocastor coypus* activity density per hour a day and its overlap between summer and winter (upper panel) and autumn and spring (lower panel) in a gated community in the metropolitan area of Buenos Aires (Argentina)

from 18 h and remaining active for 15 h (Fig. 2). However, the activity pattern varied through different seasons. The lower overlap index of activity patterns was registered between summer and winter with a value of 53% (Fig. 3 and Table 2). Although the patterns were very similar, a delay of 4 h of the activity peak at dawn and 2 h advance of the afternoon peak was observed from the winter activity pattern to the one of summer. Major overlap was registered between autumn and winter with an index of 84%, followed by a 78% between autumn and spring (Fig. 3 and Table 2). During summer and winter, two activity peaks were observed at twilight, although during summer the coypu's activity was mostly concentrated at that time than the rest of the seasons. In autumn and spring, there was not an increase of activity around dawn. In turn, activity during spring showed a more irregular pattern, with more daytime activity than in the other seasons. During daytime, coypus were usually resting alone or in groups over the edge of the body of water, except in spring where they were seen active.

Foraging was the dominant behavior during their activity periods (Fig. 4), which included both searching and effective consumption of food. Foraging accounted for 67.8% of the total observation time during winter and 58.6% during summer. There were no significant differences in the proportion of time dedicated to the foraging behavior between seasons ($z = -0.49$, $P > 0.05$) nor in the time spent on search of food ($z = -1.78$, $P < 0.1$) (Fig. 4). However, the time dedicated to vigilance was higher during summer than winter ($z = 3.27$, $P < 0.01$). Vigilance accounted for 12.9% in summer and 7.9% in winter (Fig. 4).

Table 2: Overlapping index between seasonal activity patterns of coypus (*Myocastor coypus*) in a gated community in the metropolitan area of Buenos Aires (Argentina)

Season	Summer	Autumn	Winter	Spring
Summer	–	53	63	56
Autumn	–	–	84	78
Winter	–	–	–	77

Discussion

The annual activity pattern of coypus at the study area shows mainly a crepuscular and nocturnal activity (from sunset to sunrise), revealing an extended pattern compared to that observed at nonurban habitats in its natural distribution. Palomares et al. (1994) registered a 12-h-long activity that was mainly nocturnal. In comparison to the pattern they obtained, our study revealed that the activity of coypu was less nocturnal than expected with a total activity duration of 15 h which suggests that in this environment the species is exposed to a minor subset of stressors. With regard to the seasonal variations in activity patterns, the results are consistent with our hypothesis, showing a bimodal pattern for solstice seasons and a unimodal pattern for equinoxes. In turn, the start time of the activity peaks varied between summer and winter. At first hand, this relates with variations of circadian rhythms due to the change of sunrise and sundown between these seasons, which implies a temporal shift of approximately 2 h. However, the 4-h shift in the morning winter peak regarding the one in summer may also be related to the low winter temperatures, bearing in mind that the lowest during a day is registered shortly after sunrise (Picquart and Morales 2017). The influence of low temperatures over the activity patterns has also been observed in countries where the coypu was introduced (Gosling 1981; Mori et al. 2020). These results reveal that in the study site the coypus adjust its daily patterns seasonally and it takes advantage of twilight period to satisfy its energetic requirements, a common strategy in many other nonhibernating small mammals that do not store food supplies (Bozinovic and Merrit 1991). The great activity concentration during twilight registered in summer could be associated not only with raising temperatures during the day but also with stress conditions produced by human activity. During summer, people make greater use of green areas and outdoor facilities often in family groups and in the company of dogs. This increase in human activity during the day might limit the species' activity, as it has been proposed in suburban areas where the coypu was introduced (Mori et al. 2020). It is interesting that the pattern obtained in winter (Fig. 3) differs from that obtained in the natural habitats in Buenos Aires (Palomares

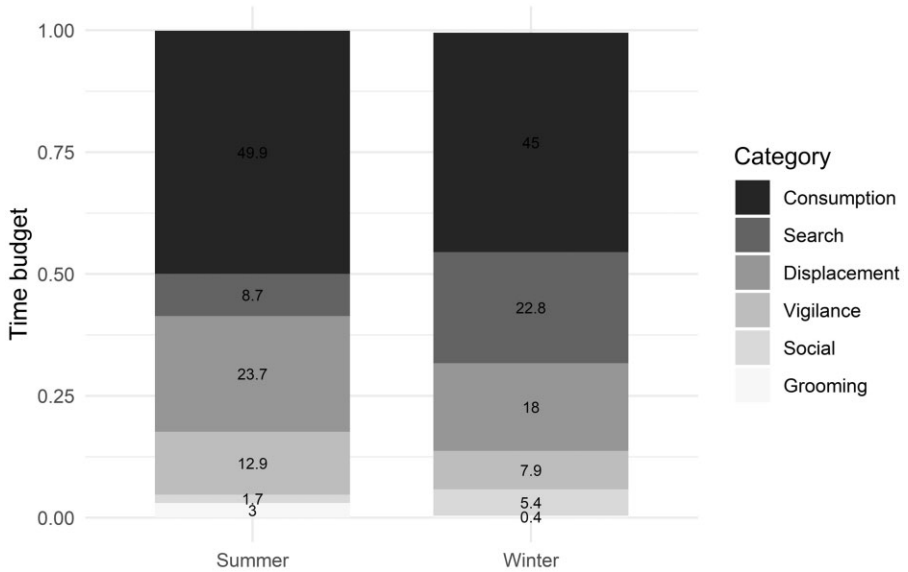

Figure 4: Time budget for each behavior of *Myocastor coypus* during summer and winter in a gated community in the metropolitan area of Buenos Aires (Argentina)

et al. 1994). The activity peak at dawn registered by these authors happens 2 hours before sunrise (between 4 and 6 am) in contrast to the peak observed in our study that takes place just after sunrise (between 8 and 9 am). This difference might be associated with the lack of natural predators and the low circulation of people during early winter mornings.

Most of the active time was destined to searching and feeding, both in winter and summer, coincident with the expected and observed behaviors reported in previous studies within the natural habitats in Buenos Aires (D'Adamo et al. 2000; Guichón et al. 2003) and in artificial aquatic habitats in Uruguay (Hernández 2009). Time devoted to foraging is closely linked with the animals need to satisfy their energetic requirements (Grier and Burk 1992; Foley and Cork 1992; Gómez-Posada 2009). Regarding social behavior, such as grooming and foraging with their bodies in contact, prevailed over agonistic behaviors. Similar conclusion has been drawn in previous studies carried out in natural habitats (Guichón 2003). Among aggressive behaviors, we observed individuals chasing off others, which could be related to the territorial behavior of the dominant male against young maturing males within the group or mature males from other groups (Gosling and Baker 1989; Guichón et al. 2003).

Time dedicated to foraging behavior did not provide any differences between seasons (Fig. 5). This may be related to the high availability and quality of vegetation in the study site during the entire year favored by the permanent irrigation and mowing of terrestrial vegetation by the gated community staff (Corriale et al. 2006; Corriale and Arenas 2016, 2017). In natural habitats, the seasonal variations in the availability and quality of food lead to changes in the diet composition, particularly through an increasing consumption of terrestrial plants during winter when aquatic vegetation becomes scarce (Borgnia et al. 2000; Guichón et al. 2003; Colares et al. 2010). Although there was no diet analysis performed, the absence of aquatic vegetation and the low diversity and richness of graminoids in the study site, a might have override this strategy. Therefore, the consumption of different parts of the plant (including roots) is probably the species response to cover the nutritional requirements when facing seasonal variations in this kind of urban environment (Corriale and Arenas 2016). On the other hand, an increase in vigilance time was registered in summer compared to that in winter, which could be related to an increase in the density and activity of inhabitants during that period, alongside an increase in the presence of domestic dogs. It is worth mentioning that the vigilance behavior was registered in many cases followed by feeding and searching behavior, which may reflect an interesting tradeoff behavior between food intake and predators' detection, already studied in other animals (Cresswell et al. 2003). When vigilance increases, an individual may reduce the predation risk (Di Blanco and Hirsch 2006, Nájera-Cordero 2010). In natural environments, the consumption of aquatic plants might reduce the time dedicated to vigilance behavior as inside the water bodies the risk of being predated is strongly reduced (Borgnia et al. 2000; Guichón et al. 2003). In this way, the vigilance behavior could be positively related to foraging outside of the body of water, a behavior commonly found in this type of urban sites, where coypus that feed on terrestrial vegetation are exposed to a higher predation risk. This relation between predation risk and foraging behavior has been studied in field experiments with *Akodon azarae* where low food consumption happens in those sites deprived of vegetation, that is, with a high predation risk (Fraschina et al. 2009).

It is to be noted that this is the first approach in describing the seasonal variations of activity patterns for the coypu within its native distribution in an urban landscape; therefore, it is hard to state that recorded patterns are all impacted by the human intervention. Then, more studies should be made in other gated communities and/or urban landscape within the coypus native distribution to extend our findings. So far, we conclude that this gated community is a particular urban landscape, different from other urban habitats, with exclusive design features that give place to the singular behavior of coypus.

Conclusions

Although the coypu is generally considered a rodent of crepuscular and nocturnal habits, the information available shows a great behavioral plasticity under different environmental conditions. At the time of designing a good management plan, it is very important to analyze wildlife activity patterns, behavior and the factors that determine those variations, particularly in these environments highly modified by human activity (Hernández 2009), even more when dealing with a species with variable behavior traits (Bó et al. 2006; Hilts et al. 2019). In this study, the annual activity pattern of the coypu is coincident with those registered for introduced populations of the species in similar habitats of other countries, where it behaves as a plague (Gosling et al. 1980; Gosling 1981). Here, we found seasonal variations were found, which seem to be associated with climate factors and the influence of human activity. This is the first study to present this information within its natural distribution range. On the other hand, foraging (feeding and searching) was the most represented behavior. Variations in the time dedicated to vigilance between summer and winter were also detected, likely related to an increase in human activity within the gated community during the summer period.

The case of the coypu shows the derangement produced by mega-projects carried out without any kind of land use management. Even though the features of these kind of urban habitats seem to benefit the coypu populations, mainly by the exclusion of its natural predators and facilitating access to food supply, the profound alterations within the wetland system of Buenos Aires might have great impacts on the regional biodiversity and its capacity of providing related ecosystem services (Minotti et al. 2009). In the light of this, it becomes imperative to encourage studies that search for sustainable management techniques to guarantee the conservation of the coypu and the wetlands it inhabits challenged by the growing urban projects.

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Conflict of interest statement. None declared.

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