



## Research Article

## Salicaceae afforestations: advantage or disadvantage for Neotropical otter in its southernmost distribution?

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### Abstract

Anthropogenic environmental changes may affect habitat suitability for wildlife. Currently, the commercial plantation of non-native trees is one of the most important types of land-use worldwide. The Lower Paraná River Delta in Argentina is a macromosaic of wetlands of high biodiversity value, which has been modified by the afforestation with Salicaceae species. In this context, the Neotropical otter, *Lontra longicaudis* (classified as Near Threatened at world level and as Endangered in Argentina), faces new challenges related to the colonization of these afforestation landscapes. On this basis, we investigated whether these human-made habitats could be a suitable habitat for the Neotropical otter. We analyzed habitat use and selection by this species at two scales of perception (micro- and macrohabitat) and in two contrasting seasons (winter and summer). Our results show that drainage channels within the afforestation landscape provide suitable conditions for this species during winter. The most important variables at macrohabitat level (dissolved oxygen, pH, and electric conductivity) and seasonally (temperature and pH) appeared to be related to prey availability in the watercourse stretches. At the microhabitat level, the primary factor for distinguishing between used and available sites was soil hardness, possibly related to favorable edaphic conditions for digging burrows. Therefore, the survival of this species in the area will depend on the afforestation management, mainly on those actions that decrease dissolved oxygen levels of waters and increase soil hardness of banks. Under the current wetland loss scenario in the region, afforestation systems may contribute to the conservation of this species.

## Introduction

Environmental changes due to human activities related to urbanization, recreation, and production may lead to structural and functional alterations of the ecosystem. Currently, the commercial plantation of non-native trees is one of the most important types of land-use worldwide (Evans and Turnbull, 2004). Global planted forest areas increased from 1990 to 2015 from 167.5 million ha to 277.9 million ha (Payn et al., 2015). In South America, during 2015, planted forest areas covered 15000000 ha (Payn et al., 2015). Plantations usually consist of homogeneous forest stands with trees the same size and age belonging to one or a few woody species. These artificial forests support less species diversity given the limited number of available niches (Stephens and Wagner, 2007; Bremer and Farley, 2010). As a result, organisms must cope with a wide range of new conditions, and their responses depend not only on the species' intrinsic characteristics (e.g. home range, habitat specificity, life cycle, feeding, and reproductive habits) but also on the type and intensity of the alteration (Wong and Candolin, 2015). Although some wildlife species cannot survive in plantation-dominated landscapes, ecologically sustainable forest management could contribute to the conservation of biological diversity (Lindenmayer et al., 2000). In Latin America, most of the plantations concentrate in Chile and Argentina (McCarragher and Rigg, 2016). In Argentina, the plantation area reached 1.2 million ha in 2015 (SENASA, 2015) and future projections predict an increase of 15% in forestry production by the end

of 2020 (MacGregor, 2002). A large part of these plantations concentrates in wetlands, particularly in the Paraná River Delta region.

The Paraná River Delta region is a vast macromosaic of wetlands of high biodiversity value where subtropical species coexist with species from neighboring temperate areas (Malvárez, 1999; Quintana and Bó, 2010). In the Lower Delta of the Paraná River, a large proportion of natural wetlands was drained or diked (247168 ha within polders and 8893 km of levees in 2018, Minotti, 2019) for Salicaceae afforestation, which is a traditional activity dating back to the mid-nineteenth century (Fracassi, 2012) and its main use is cellulose pulp, pallets and posts. Currently, the Salicaceae afforestation is dominated by willow (*Salix* spp., 75%), followed by poplar (*Populus* spp., 25%) (Borodowski and Suárez, 2004). The resulting environmental changes had an impact on the diversity and composition of different taxonomic groups. Plants (Kalesnik, 2000; Kandus and Malvárez, 2004; Madanes et al., 2015; Krug, 2018), and arthropods (Nanni et al., 2011, 2017) diversity increased due to the incorporation of alien, mesophilic, and generalist species. These species could establish in this area due to water management practices that turned cyclical flooding ecosystems into lands free of floods similar to grasslands or forests. Other groups such as amphibians (Krug et al., 2013; Krug, 2018), and birds (Bó et al., 2010; Fracassi, 2012; Krug et al., 2013; Malzof et al., 2013; Sica et al., 2018) reduced their richness in modified habitats. Some mammals such as *Dasybus novemcinctus*, *Cerdocyon thous*, *Procyon cancrivorus* and *Axís axis* expanded their distribution to the islands of Lower Delta of the Paraná River favored by the water management practices carried out for human-made habitats (Fracassi et al., 2010). In turn, wetland wildlife species, such as capybaras (*Hydrochoerus hydrochaeris*)

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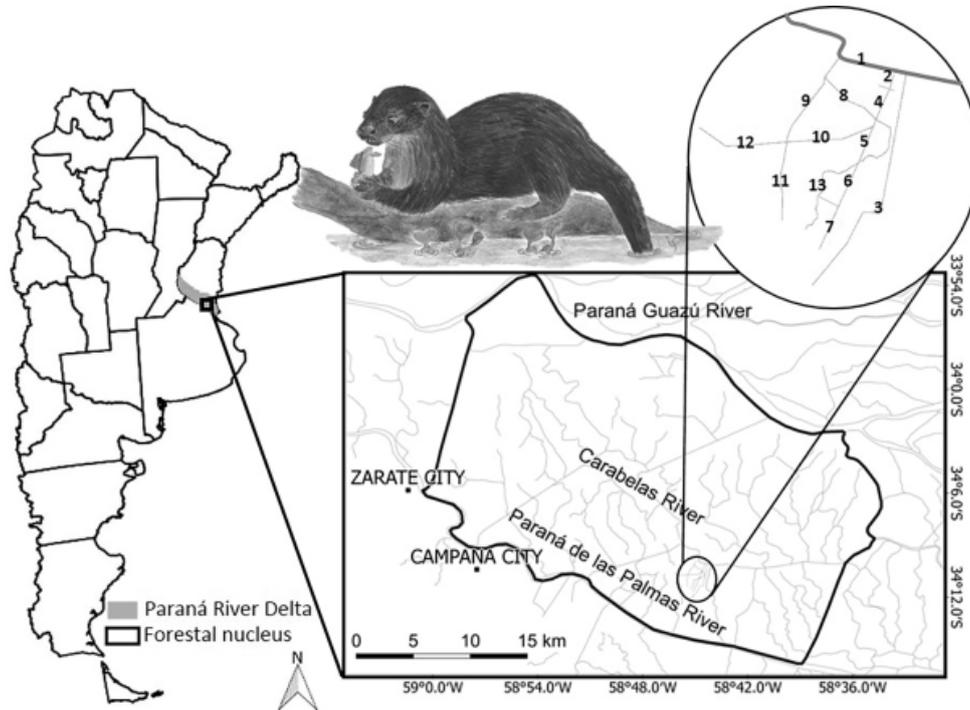


Figure 1 – Map of the study area. The square indicates the forestal nucleus in the Lower Delta of the Paraná River. the circle shows watercourse stretches, numbered from 1 to 13.

and coypus (*Myocastor coypus*), use the numerous ditches and channels (Quintana and Bó, 2011), which used for water drainage within the afforestation (Fracassi, 2012; Fracassi et al., 2015). Only a few studies have focused on how environmental changes affect habitat use by the Neotropical otter (*Lontra longicaudis*) (Gomez et al., 2014; Trigila et al., 2016). This is the largest of the three South American species of semi-aquatic mustelid belonging to the *Lontra* genus (Bardier 1992, Chehébar 1990, Larivière 1999). It was widely distributed in northern and central Argentina until the '80s, when it was exploited, for both pelts and meat, to near extinction (Parera, 1996; Canevari and Vaccaro, 2007). In the Lower Delta region, the same situation repeated despite the prohibition on hunting since 1978 (Decreto 609/78). This is related to it is an emblematic species of the Lower Delta region. It was traditionally associated to local economy, being used by the islanders as a food and economic resource for a long time. It is classified as endangered in Argentina by the Argentine Society for the Study of Mammals (SAREM) (Ojeda et al., 2012) and as Near Threatened at world level by the IUCN (Rheingantz and Trinca, 2015). Fortunately, this species is in recovery after the implementation of conservation measures that banned the hunt and sale of derived products (CITES, 2016). However, wetlands native species face new challenges in adapting to new conditions in the Lower Delta of the Paraná River due to the development of human-made habitats. We investigated whether these human-made habitats could be a suitable habitat for Neotropical otter in the Lower Paraná River Delta. For this, we analyzed habitat use and selection by Neotropical otter at two scales of perception (micro- and macrohabitat) and in two contrasting seasons (winter and summer) in a Salicaceae afforestation landscape of the Lower Delta of the Paraná River, Argentina.

## Methods

### Sampling Design

We sampled in the afforestation facility Las Carabelas (34°10'6.32" S, 58°44'18.86" W, Fig. 1), of the Papel Prensa S.A. company, located in the forestal nucleus (935 km<sup>2</sup>) of the Lower Delta of the Paraná River (Fracassi, 2012). The afforestation was surrounded by a dike 5 m above the river level and drained by a complex system of channels to prevent flooding. It had shrub and herbaceous strata mainly composed of *Carex riparia* subsp. *chilensis*, *Rubus divaricatus*, *Trifolium repens*, *Nasella*

*hyalina*, *Ligustrum sinense*, and *Cortaderia selloana* (Bó et al., 2010; Krug, 2018).

To analyze habitat selection, we registered the presence of Neotropical otters through either direct observation or signs of activity such as feces, burrows, slides, and feeding and resting sites along the banks of watercourses (channels) within the afforestation and in the natural stream Las Piedras, which flows around the plantation facility. We followed the methodology of Christensen (1985) for *L. canadensis*, with the following modifications: within the afforestation, we defined homogeneous stretches of channels or natural streams of different lengths (150 m to 1000 m). We defined homogeneous stretches of watercourses according to their general aspects (width, depth), type and abundance of vegetation cover, and location (near or far from floodgates or pumps, etc.).

We conducted this study at two spatial scales (micro- and macrohabitats), and two temporal scales (winter and summer). Given that a multi-scale approach is fundamental in habitat selection studies, we decided to apply an approach at different spatial scales to understand the relationship between Neotropical otter and afforestation (McGarigal et al., 2016). Neotropical otter, in other places of its distribution, responds to different characteristics of the environment express at different spatial scales (Rheingantz et al., 2014; Navarro-Picado et al., 2017). Given that this species displayed different spatial distribution throughout the year in other regions (Gori et al., 2003), we compared two contrasting seasons.

### Habitat selection at macrohabitat level

We surveyed 13 stretches of watercourses (150 m to 1000 m, Fig. 1) and determined habitat use of the Neotropical otter by counts of signs or sightings. We relativized the number of signs to the length of the stretches of watercourses. We also measured the total length of each watercourse stretch of interest to analyze habitat use relative to habitat availability. Also, we randomly selected a point on each stretch where we determined the width and depth of the watercourse (structural characterization) and measured pH, water temperature, suspended solids, water transparency, dissolved oxygen, electric conductivity, and productivity (water physicochemical parameters). Productivity was estimated as the product of chlorophyll-a concentration and value of QMAX of 2 because the obtained chlorophyll-a values were typical of oligotrophic water bodies, Goodwin, 1965; Eaton et al., 2005). We

chose these variables because they could relate to the prey availability and hunting ability of the Neotropical otter. For example, high content of suspended solids or low water transparency would decrease habitat suitability for Neotropical otters by reducing visibility, and therefore prey detection. We measured all variables in both summer and winter.

**Habitat selection at microhabitat level**

We analyzed the used and available sites within the stretches of watercourses selected by the Neotropical otter based on the macrohabitat level analysis. We marked the location of the sites that showed signs of activity, using the Global Positioning System (GPS). We randomly located the available sites along line transects that ran parallel to the watercourses. We detected 25 points of use and 25 points of availability (N=50).

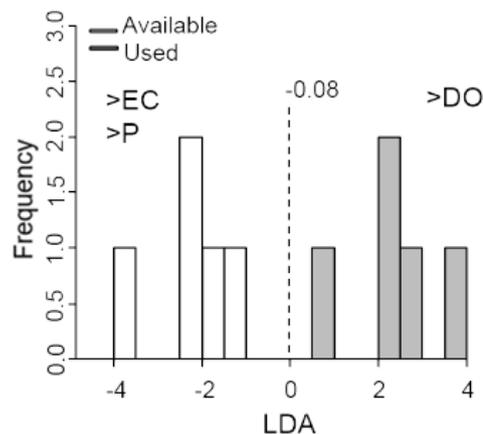
On each of these sites, we determined the width and depth of the watercourse, bank slope, cover of floating, rooted and bank vegetation, cover of canopy, cover of bare soil on the bank of the watercourse, soil hardness on the bank of the watercourse and water transparency. We chose these variables because they could relate to the habitat suitability for Neotropical otters. For example, soil hardness on the watercourse bank could affect its ability to dig burrows.

**Comparison of habitat selection between contrasting seasons (summer-winter)**

To evaluate the temporal selection of the Neotropical otter, we compared the watercourses used in two contrasting seasons: winter (presence of Neotropical otter) and summer (absence of Neotropical otter). We used the same variables used to determine habitat selection at the macrohabitat level.

**Data analysis**

To minimize collinearity between variables, we performed Pearson’s correlations, and we excluded from the analysis those with  $r > 0.6$ . We used eighty percent of data to train the models, while we used the remaining data for their validation. To test for significant differences between used and available watercourses sites or stretches at both spatial scales and between seasons, we used multivariate analysis of variance — MANOVA — and a discriminant stepwise analysis – DA — (Lee, 1971; Williams, 1981). We included variables in the DA according to their importance in univariate ANOVAs and the capacity of discrimination between used and available watercourse sites or stretches. To evaluate the significance of the final model, we used the Wilks’ Lambda test. To verify if the variables were correctly rejected by univariate ANOVAs, we repeated the analyses using all possible combinations of the removed variables. Then we compared the significance of the discriminant functions and the performance of the models and evaluated their biological implications. To select the final model, we based on parsimony, i.e., the model that explains most of the variation with the least number of necessary variables and has an overall classification error rate lower than 10%. In all cases, we assessed the assumption of multivariate normality using the Shapiro multivariate normality test in the `mvnornmtest` package (Jarek, 2012), while we tested multivariate homoscedasticity using the Bartlett test and the Figger test in the `stats R` package (R Core Team, 2018). If the normality assumption was not met, we transformed the data either as  $\ln$ - or square root. If only one variable was left, we used the general linear model (`glm`) for the comparison, after checking the validity of the assumptions. We used a Chi-square goodness-of-fit test to evaluate the use vs. availability at macrohabitat scale (Manly et al., 2007). To prevent from violating the assumptions for this test, we combined similar sites to increase the expected frequencies. Thus, we grouped sites 1–2 and 5–6 by similarity and proximity (Fig. 1). We grouped the watercourse stretches 1 and 2 because they were the only ones connecting directly with the Carabelas River, while we grouped the watercourse stretches 5 and 6 because they were placed one after the other along the same channel. The Chi-square table was partitioned to detect watercourses responsible for the overall differences in the frequencies between use and availability (Siegel and Castellan, 1988). We considered watercourse stretches as selected if



**Figure 2** – Linear Discriminant Analysis for the training group at the macrohabitat level. Histogram of discriminant scores for each watercourse stretch by use. Dotted line=cutoff point. Available stretches: white bars; used stretches: grey bars. DO: dissolved oxygen; EC: electric conductivity; P: productivity.

**Table 1** – Variables considered in the analysis of habitat selection by the Neotropical otter at the macrohabitat level in the Lower Parana River Delta (mean±SE).

Variable	Watercourse	
	Available	Used
Depth (m)	0.81 ± 0.18	2.15 ± 0.26
Width (m)	7.54 ± 0.88	21.03 ± 6.17
pH	6.61 ± 0.09	6.78 ± 0.17
Electric conductivity (µS)	195.71 ± 16.40	175.00 ± 12.05
Suspended solids (mg/l)	4.14 ± 1.10	15.00 ± 2.30
Water transparency (cm)	52.86 ± 9.17	26.17 ± 1.42
Dissolved oxygen (mg/l)	4.83 ± 0.40	8.69 ± 0.54
Productivity (µg/h)	5.54 ± 1.00	4.00 ± 0.91
Temperature (° C)	17.29 ± 0.42	19.67 ± 0.42

they were used in a significantly greater proportion to their availability and as avoided if they were used in significantly less proportion to their availability. When there were no significant differences, we considered them to be used in proportion to their availability. We did all analyses with the `stats R` package (R Core Team, 2018), `RStudio` (Rstudio Team, 2015) and `Infostat` (Di Rienzo et al., 2018).

**Results**

**Habitat selection at macrohabitat scale**

Six of the 13 watercourse stretches surveyed exhibited signs of activity by Neotropical otters. The variables width and depth of the watercourse, water transparency, suspended solids, and temperature were excluded from the analyses because they were highly correlated ( $r > 0.8$ ) with each other and with dissolved oxygen. We decided to conserve the dissolved oxygen above the other mentioned variables because it relates to the fishes abundance, and the eutrophication of the watercourse stretches. The mean values for all the variables considered are shown in Tab. 1. The final model included the variables electric conductivity, productivity and dissolved oxygen and allowed to discriminate between used and available stretches (Wilks’  $\lambda = 0.13135$ ,  $p = 0.01983$ , Fig. 2) with an accuracy of 100%, based on data separated for model validation.

Dissolved oxygen values were higher in used than in unused watercourse stretches, while electric conductivity and productivity values were higher in unused than in used watercourse stretches (Tab. 1). Overall, there were significant differences in habitat use relative to availability among watercourses ( $\chi^2 = 7.87$ ;  $df = 3$ ;  $p < 0.0487$ ). Habitat analysis of the 6 watercourses used by neotropical otters indicated that sites 3, 4 and 5+6 (Fig. 11) were used in proportion to availability, while the site 1+2 (Fig. 1) was used in a proportion greater than its availability ( $\chi^2 = 6.43$ ;  $df = 1$ ;  $p = 0.0112$ ).

**Table 2** – Variables considered in the analysis of habitat selection by the Neotropical otter at the microhabitat level in the Lower Parana River Delta (mean±SE).

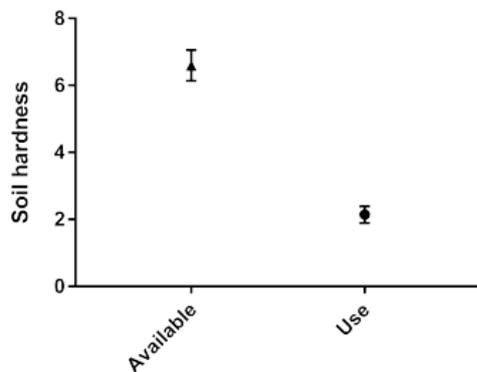
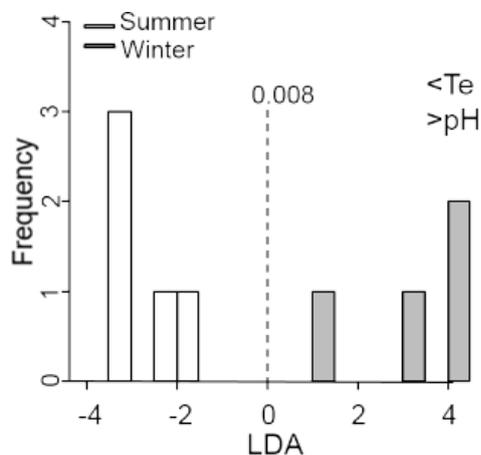
Variable	Use	
	Available	Used
Water transparency (cm)	29.00 ± 1.04	24.00 ± 1.74
Depth (m)	33.28 ± 3.94	35.21 ± 3.18
Width (m)	11.96 ± 0.65	17.46 ± 2.06
Floating vegetation cover (%)	30.90 ± 7.21	51.30 ± 5.87
Rooted vegetation cover (%)	20.60 ± 5.99	3.00 ± 1.31
Bank vegetation cover (%)	46.20 ± 4.77	61.60 ± 4.65
Canopy cover (%)	25.00 ± 5.60	13.80 ± 5.31
Soil hardness (cm)	6.60 ± 0.46	2.14 ± 0.25
Bank slope (°)	32.00 ± 4.07	27.80 ± 2.16
Bare soil cover on the bank (%)	32.20 ± 4.47	26.90 ± 4.52

**Table 3** – Variables used for seasonal comparison of habitat selection by Neotropical otters in the Lower Paraná River Delta (mean±SE).

Variable	Winter	Summer
Depth (m)	2.15 ± 0.26	2.01 ± 0.26
Width (m)	21.03 ± 6.17	19.37 ± 6.19
pH	6.78 ± 0.17	6.17 ± 0.10
Suspended solids (mg/l)	15.00 ± 2.31	15.17 ± 2.18
Dissolved oxygen (mg/l)	8.69 ± 0.54	5.76 ± 0.85
Temperature (° C)	19.68 ± 0.42	24.67 ± 0.42

### Habitat selection at microhabitat level

To the analyses, we did not include the variable cover of bank vegetation (BV) because it was highly correlated with the cover of bare soil

**Figure 3** – Soil hardness (mean±SE) in used and available sites for Neotropical otters.**Figure 4** – Linear Discriminant Analysis for the training group for contrasting seasons. Histogram of discriminant score for each watercourse stretch by seasons (summer and winter). Dotted line=cutoff point. Summer: white bars; winter: grey bar. Te: water temperature.

(BS). We prefer to conserve the cover of bare soil because it relates to soil erosion. The cover of rooted vegetation (RV) was not included because it had a large number of zeros. The mean values of the variables considered in the analyses are given in Tab. 2. Soil hardness (SH) was sufficient for discriminating between used and available watercourses ( $F_{1,72.88}; p < 0.0001$ ; 90% accuracy), with higher values for the latter (Fig. 3).

### Comparison of habitat selection between contrasting seasons (summer-winter)

Electric conductivity (EC), water transparency (WT) and productivity (P) were not included in the analyses by being highly correlated with pH, depth of the watercourse (DC) and temperature (Te). We decided to conserve these three variables above the other mentioned variables because they relate to the abundance and activity of fishes, the main prey of the Neotropical otters. The mean values of the variables considered in the analyses are shown in Tab. 3. Ln- and square root-transformations were applied to the width of the watercourse (W) and suspended solids (SS) data, respectively, to meet assumptions of multivariate normality. The final model included temperature (Te) and pH and allowed to discriminate used from available watercourses (Wilks'  $\lambda = 0.083666$ ;  $p = 0.00059$ , Fig. 4), with an accuracy of 100%, based on data separated for model validation. The used watercourses showed lower temperature and higher pH values than the available ones (Tab. 3).

### Discussion

In the current context, where afforestation is one of the most important type of land-use worldwide (Evans and Turnbull, 2004), knowing the consequences of natural landscapes transformations into human-made landscapes is essential to understand how threatened wildlife species can adapt to these new environmental conditions and, therefore, provide guidelines for their conservation. In this paper, we identify the key factors that influence habitat selection of Neotropical otter in a deep-modified wetland landscape. Our results show that, at least during one season, drainage channels with certain environmental features in Salicaceae afforestation provide suitable conditions for this species. However, further intensification of anthropogenic impacts on the original landscape structure may lead to the fragmentation and quality loss of the species' habitat. In this regard, Ottino et al. (1995) stated that habitat fragmentation and the number of feeding resources are key factors conditioning the presence of the European otter (*Lutra lutra*).

At the macrohabitat level, Neotropical otters selected watercourse stretches with higher dissolved oxygen concentration. Indeed, it is one of the most important determinants for the diversity and abundance of many organisms (ACUMAR, 2009) such as fish (Goodman and Campbell, 2007; Essington and Paulsen, 2010; Parker et al., 2016), which are the primary prey item for the Neotropical otter (Parera, 2002; Chemes et al., 2010; Cruz-García et al., 2017; González and Castillo, 2017). Neotropical otter used channels potentially having the largest number of fish (Minotti, 1988) and were absent in stretches where mean dissolved oxygen concentration was below the level required for fish (ACUMAR, 2009). Studies on this otter carried out in other regions within its distribution area have reported prey availability as one of the most relevant factors for habitat selection (Melquist and Hornocker, 1983; Cortés et al., 1998; Gori et al., 2003). In line with this, we found that the channel stretches more used than expected by chance were related to those constantly connected to the Carabelas River (and therefore with higher prey abundance), and without anthropogenic disturbances. In contrast, the stream Las Piedras, which also was connected to the Carabelas River, was used in proportion to its availability because of the constant traffic of boats and the presence of houses along the streamside. Habitat suitability for Neotropical otters seems to be decreased with the increase of human disturbances (Rheingantz et al., 2014). In this regard, Gomez et al. (2014) pointed out that habitat suitability for this otter was higher in afforestations within polders than in human-disturbed areas.

Besides, the offer of prey in channels inside the dike depends on their hydrologic level (deficit or excess), which varies with the frequency of water discharge from the reservoir. Stretches of watercourses close to the dike gates would provide Neotropical otter with better environmental conditions given the higher dissolved oxygen levels due to increased rates of water replacement. This may explain the absence of Neotropical otters in channel stretches distant from the gates, containing low oxygenated standing water. Moreover, it is expected that a high content of suspended solids decreases habitat suitability for Neotropical otter by reducing visibility and therefore prey detection. However, the presence of Neotropical otter in stretches with higher values of this variable may be explained by the fact that this species uses whiskers to detect fish movements (Quadros and Monteiro-Filho, 2001; Melquist et al., 2003).

Cortés et al. (1998) found a significant correlation between water quality and the distribution and abundance of the European otter (*Lutra lutra*). In agreement, our results indicated that the Neotropical otter used stretches with the lowest conductivity values (attributable to lower concentration of ions), reflecting better water quality (CEANID, 2009).

At the microhabitat level, soil hardness on the bank of the watercourse was the most important factor for distinguishing used from available sites. In contrast to other otter species, Neotropical otter digs burrows near the watercourses as shelters (Nowak and Walker, 1999; Pardini and Trajano, 1999), thus avoiding very hard soils. This factor is particularly relevant in afforestations, where productive tree species are planted along the banks of channels and cut down after some years. This implies the use of heavy machinery which may compact soils, harming this otter.

Temperature and pH allowed to discriminate between watercourses used by Neotropical otters in winter and summer. Temperature is known to be crucial for the growth and distribution of aquatic organisms (Garrabou et al., 2009; Alabaster and Lloyd, 2013; Mccauley et al., 2015). Indeed, an increase in temperature increases the rate of chemical and biological reactions and decreases oxygen solubility, among other effects (Margalef, 1983). In summer, this may contribute to the depletion of dissolved oxygen, which, together with changes in pH, could lead to increased fish mortality (ACUMAR, 2009; Alabaster and Lloyd, 2013). Although no decrease in pH was detected in summer, there is evidence suggesting the existence of a threshold value for the presence of otters (e.g. European otters were found in water bodies with pH values lower than 5.5) (Mason and Macdonald, 2009). The direct effect of both variables on fish communities from the study area would be supported by Brancolini (2009), who recorded lower fish richness and abundance in the internal channels of the studied afforestations in summer.

In winter, lower temperatures result in a decrease in fish activity. In this regard, otters are opportunistic and feed on less active fish species because they are easier to catch (Wise et al., 1981; Stenson et al., 1984; Kruuk and Moorhouse, 1990; Rheingantz et al., 2012; González and Castillo, 2017). In particular, *L. canadensis* shows an inverse relationship between the capture frequency of fish species and swimming speed (Toweill and Tabor, 1982; Serfass et al., 1990; Canevari and Vaccaro, 2007). Therefore, an increase in fish activity resulting from higher water temperatures in the channels during summer may have an additional negative impact on Neotropical otters. Another possible explanation for the absence of this otter during summer may be that in the native aggressive piranhas (*Serrasalmus maculatus*, *Serrasalmus marginatus* and *Puygocentrus natterii*) are more active during this season than winter (Menni, 2004). Certainly, in the Iberá wetlands (Corrientes province, Argentina), Neotropical otters usually moves in summer from the shores of the Iberá Lake to areas with floating marshes as a strategy for avoiding these predators (Gori et al., 2003).

According to Martínez-Abraín and Jimenez (2015), human action may lead to the unintended generation of artificial habitat types that functionally resemble the essential features of the original habitat and thus wildlife species could find a suitable habitat in them. It is crucial that this happens for threatened species, such as Neotropical otter, because the increase in extension of human-made habitats in detriment

of natural ecosystems is a worldwide phenomenon. The current afforestation landscape in the Lower Paraná River Delta is the result of profound changes in the original wetlands, which may have positive or negative impacts on wildlife. As for Neotropical otter, channels in Salicaceae afforestations provide a suitable habitat, at least in part of the year. However, the survival of the Neotropical otter in the studied area will depend on the afforestation management, mainly those actions that decrease dissolved oxygen levels of waters and increase soil hardness of banks. In addition, the labors for maintenance and harvest in the plantations usually cause the fragmentation of suitable areas for this species, leading to a decrease in the habitat quality of the remnant patches. According to Trigila et al. (2016), this is likely to affect Neotropical otter populations by the loss of genetic diversity as well.

Our results allowed us to answer the question posed in the title of this paper. Afforestation systems appear as suitable sites for this species, at least in winter, with drainage channels playing an important role in the provision of food and shelter resources. This emphasizes the importance of afforestation landscapes for its conservation in the Lower Paraná River Delta, in the context of the rapid wetland loss that has characterized the region over the last years (Sica et al., 2016). A remaining challenge is to encourage afforestation managers to take actions improving water and habitat quality in the channels during summer, which would favor Neotropical otters all year round. ☞

## References

- ACUMAR, 2009. Environmental sanitation plan for the Matanza Riachuelo watershed. Authority of the Matanza-Riachuelo watershed, Buenos Aires, Argentina.
- Alabaster J.S., Lloyd R.S., 2013. Water quality criteria for freshwater fish. 2<sup>nd</sup> edition. Elsevier.
- Bó R.F., Quintana R.D., Courtalón P., Astrada E., Bolkovic M.L., Coco G.L., Magnano A., 2010. Efectos de los cambios en el régimen hidrológico por las actividades humanas sobre la vegetación y la fauna silvestre del Delta del Río Paraná. Endicamientos y tertraplenes en el Delta del Paraná. Situación, efectos ambientales y marco jurídico. Buenos Aires: Fundación Humedales/Wetlands International. [in Spanish]
- Borodowski E.D., Suárez R.O., 2004. El cultivo de álamos y sauces: su historia en el Delta del Paraná. SAGPyA Forestal 32: 5–13. [in Spanish]
- Brancolini F., 2009. Estructura y composición de los ensambles de peces en arroyos de la zona deltaica de Bajos del Temor (Provincia de Buenos Aires, Argentina) Universidad CAECE, Buenos Aires, Argentina. [in Spanish]
- Bremer L.L., Farley K.A., 2010. Does plantation forestry restore biodiversity or create green deserts? A synthesis of the effects of land-use transitions on plant species richness. Biodiversity and Conservation 19: 3893–3915.
- Canevari M., Vaccaro O., 2007. Guía de mamíferos del sur de América del Sur. Iola Buenos Aires. [in Spanish]
- CEANID, 2000. Muestreo y análisis de las aguas del río Pilcomayo y sus afluentes. Oficina Técnica Nacional de los Ríos Pilcomayo y Bermejo. [in Spanish]
- CITES, 2016. Apéndices I, II y III. Convención sobre el comercio internacional de especies amenazadas de fauna y flora silvestres. [in Spanish]
- Cortés Y., Fernández-Salvador R., García F.J., Virgós E., Llorente M., 1998. Changes in otter *Lutra lutra* distribution in Central Spain in the 1964–1995 period. Biological Conservation 86: 179–183.
- Cruz-García F., Contreras-Balderas A.J., García Salas J.A., Gallo-Reynoso J.P., 2017. Dieta de la nutria neotropical (*Lontra longicaudis annectens*) en Pueblo Nuevo, Durango, México. Revista mexicana de biodiversidad 88: 701–709. [in Spanish]
- Chemes S.B., Giraud A.R., Gil G., 2010. Dieta de *Lontra longicaudis* (Carnívora, Mustelidae) en el Parque Nacional El Rey (Salta, Argentina) y su comparación con otras poblaciones de la cuenca del Paraná. Mastozoología neotropical 17. [in Spanish]
- Christensen K., 1985. The linear interval method for determining habitat selection of riparian wildlife species. In: USDA Forest Service, General Technical Report RM-120 of the First North American Riparian Conference, Tucson, Arizona, USA. 101–104.
- Decreto 609/78. 1978. Caza deportiva — Normas a cumplimentar por los cazadores — Zonas habilitadas — Períodos de caza. La Plata, Buenos Aires. [in Spanish]
- Di Rienzo J., Casanoves F., Balzarini M., Gonzalez L., Tablada M., Versión C., 2018. Infostat versión 2018. Grupo InfoStat, FCA, Universidad Nacional de Córdoba Córdoba, Argentina. [in Spanish]
- Eaton A., Clesceri L., Rice E., Greenberg A., Franson M., 2005. Standard methods for the examination of water and wastewater. 21<sup>st</sup> Ed. Port City Press, Pikeville, Washington DC.
- Essington T.E., Paulsen C.E., 2010. Quantifying Hypoxia Impacts on an Estuarine Demersal Community Using a Hierarchical Ensemble Approach. Ecosystems 13: 1035–1048.
- Evans J., Turnbull J.W., 2004. Plantation forestry in the tropics: The role, silviculture, and use of planted forests for industrial, social, environmental, and agroforestry purposes. 3<sup>rd</sup> edition. Oxford University Press, UK.
- Fracassi N., 2012. Diversidad de mamíferos y aves en forestaciones y pajonales de Salicáceas del Bajo Delta del río Paraná. Tesis de Magister en Recursos Naturales, Escuela de Graduados “Alberto Soriano”, Facultad de Agronomía, Universidad de Buenos Aires (FAUBA), Buenos Aires, Argentina. [in Spanish]
- Fracassi N.G., Buchter W.M., Pereira J.A., Borodowski E.D., Somma D., 2015. Determinants of capybara presence in afforestations of the lower delta of the Paraná river, Argentina. Studies on Neotropical Fauna and Environment 50: 229–237.
- Fracassi N.G., Moreyra P.A., Lartigau B., Teta P., Landó R., Pereira J.A., 2010. Nuevas especies de mamíferos para el bajo delta del Paraná y bajos ribereños adyacentes, Buenos Aires, Argentina. Mastozoología neotropical 17: 367–373. [in Spanish]

- Garrabou J., Coma R., Bensoussan N., Bally M., Chevaldonné P., Cigliano M., Díaz D., Harmelin J.G., Gambi M.C., Kersting D.K., Ledoux J.B., Lejeune C., Linares C., Marschal C., Pérez T., Ribes M., Romano J.C., Serrano E., Teixido N., Torrents O., Zabalá M., Zuberer F., Cerrano C., 2009. Mass mortality in Northwestern Mediterranean rocky benthic communities: effects of the 2003 heat wave. *Global Change Biology* 15: 1090–1103.
- Gomez J.J., Túnez J.I., Fracassi N., Cassini M.H., 2014. Habitat suitability and anthropogenic correlates of Neotropical river otter (*Lontra longicaudis*) distribution. *Journal of Mammalogy* 95: 824–833.
- González-Christen A., Delfín-Alfonso C.A., Sosa-Martínez A., 2013. Distribución y abundancia de la nutria neotropical (*Lontra longicaudis amnctens* Major, 1897), en el Lago de Catemaco, Veracruz, México. *Therya* 4: 201–217. [in Spanish]
- González L., Castillo O., 2017. Tendencia trófica de la nutria (*Lontra longicaudis*) en el río Ospino, Portuguesa, Venezuela. *Revista Unelvez de Ciencia y Tecnología* 30: 24–28. [in Spanish]
- Goodman L.R., Campbell J.G., 2007. Lethal levels of hypoxia for gulf coast estuarine animals. *Marine Biology* 152: 37–42.
- Goodwin T.W., 1965. Chemistry and biochemistry of plant pigments. Academic Press, London & New York.
- Gori M., Carpaneto G.M., Ottino P., 2003. Spatial distribution and diet of the Neotropical otter *Lontra longicaudis* in the Ibera Lake (northern Argentina). *Acta Theriologica* 48: 495–504.
- Jarek S., 2012. *mvnrmtest*: normality test for multivariate variables. R package version 0.1–9. R Foundation for Statistical Computing. <https://CRAN.R-project.org/package=mvnrmtest>
- Kalesnik F.A., 2000. Relación entre las comunidades vegetales de los neoeosistemas de Albardón y la heterogeneidad ambiental del Bajo Delta del Río Paraná: Tendencias sucesionales y proyecciones sobre la composición futura. Facultad de Ciencias Exactas y Naturales. Universidad de Buenos Aires. [in Spanish]
- Kandus P., Malvárez A.I., 2004. Vegetation patterns and change analysis in the lower delta islands of the Paraná River (Argentina). *Wetlands* 24: 620–632.
- Krug C.P., 2018. Integridad ecológica de los humedales del Bajo Delta del Río Paraná bajo diferentes modalidades productivas. Buenos Aires. [in Spanish]
- Krug C.P., Sica Y., Nanni A., Quintana R., Gavier P., Gregorio Cicchino A., 2013. Forestaciones de salicáceas del Bajo Delta del Río Paraná como hábitat para aves, anuros y coleópteros (carabidae y aphodiidae). In II Jornadas Nacionales de Ambiente 2014 Tandil, Buenos Aires. [in Spanish]
- Kruuk H., Moorhouse A., 1990. Seasonal and spatial differences in food selection by otters (*Lutra lutra*) in Shetland. *Journal of Zoology* 221: 621–637.
- Lee, Y.-s., 1971. Asymptotic formulae for the distribution of a multivariate test statistic: Power comparisons of certain multivariate tests. *Biometrika* 58: 647–651.
- Lindenmayer D.B., Margules C.R., Botkin D.B., 2000. Indicators of Biodiversity for Ecologically Sustainable Forest Management. *Conservation Biology* 14: 941–950.
- MacGregor J., 2002. Trade of forest products and services. In FAO Expert Consultation on Trade and Sustainable Forest Management: Impact and Interactions, Roma.
- Madanes N., Quintana R.D., Kandus P., Bó R.F., 2015. Species richness and functional groups of angiosperms from the Paraná River Delta region (Argentina). *Check List* 11: 1803.
- Malvárez A.I., 1999. El Delta del Río Paraná como mosaico de humedales. Tópicos sobre humedales subtropicales y templados de Sudamérica. 35–54. [in Spanish]
- Malzof S.L., Bolkovic M.L., Thompson J.J., Quintana R.D., 2013. Habitat occupancy of the Dusky-legged Guan in the lower delta of the Paraná River, Argentina. *Bird Conservation International* 23: 83–90.
- Manly B.F.L., McDonald L., Thomas D.L., McDonald T.L., Erickson W.P., 2007. Resource selection by animals: statistical design and analysis for field studies. Springer Science & Business Media, USA.
- Margalef R., 1983. *Limnología*. Omega I, Barcelona.
- Martínez-Abraín A., Jiménez J., 2015. Anthropogenic areas as incidental substitutes for original habitat. *Conservation Biology* 30(3): 593–598. doi:10.1111/cobi.12644
- Mason C.F., Macdonald S., 2009. Otters: ecology and conservation. Cambridge University Press, USA.
- McCarragher S., Rigg L.S., 2016. Temperate Forest Ecosystems. *International Encyclopedia of Geography: People, the Earth, Environment and Technology: People, the Earth, Environment and Technology*: 1–14.
- Mccauley S.J., Hammond J.L., Frances D.N., Mabry K.E., 2015. Effects of experimental warming on survival, phenology, and morphology of an aquatic insect (Odonata). *Ecological Entomology* 40: 211–220.
- McGarigal K., Wan H.Y., Zeller K.A., Timm B.C., Cushman A.A., 2016. Multi-scale habitat selection modeling: a review and outlook. *Landscape ecology* 31: 1161–1175.
- Melquist W.E., Hornocker M.G., 1983. Ecology of River Otters in West Central Idaho. *Wildlife Monographs* 3–60.
- Melquist W.E., Polechla P.J., Towell J.D., 2003. River Otter. In: Feldhamer G.A., Thompson B.C., Chapman J.A. (Eds.) *Wild Mammals of North America*. The Johns Hopkins University Press, USA.
- Menni R.C., 2004. Peces y ambientes en la Argentina continental. *Monografías del Museo Argentino de Ciencias Naturales*. [in Spanish]
- Minotti P., 1988. Fauna acuática. Análisis preliminar de especies presentes, situación y uso. UBACyT N° 135, UBACyT, Buenos Aires, Argentina. [in Spanish]
- Minotti P., 2019. Actualización y Profundización del Mapa de Endicamientos y Terraplenes de la Región del Delta del Paraná. 2018. Buenos Aires, Argentina. [in Spanish]
- Nanni A., Magnano A., Carpintero D., 2011. Los Heteroptera (Insecta: Hemiptera) edáficos del INTA Delta del Paraná (partido de Campana, Buenos Aires). Variación espacial y temporal del elenco de las especies en distintos usos de la tierra. *Revista del Museo Argentino de Ciencias Naturales nueva serie* 13: 27–39.
- Nanni A S., Quintana R.D., Fracassi N.G., Cicchino A.C., 2017. Ground beetles (Coleoptera: Carabidae) inhabiting anthropogenic habitats in the lower delta of the Paraná river, Argentina: geographic distribution and ecological characteristics. *Austral Entomology* 56: 244–254. 171
- Navarro-Picado, J., Spínola-Parallada M., Madrigal-Mora A., Fonseca-Sánchez A., 2017. Selección de hábitat de *Lontra longicaudis* (Carnívora, Mustelidae) bajo la influencia de la represa hidroeléctrica del río Peñas Blancas y sus tributarios, Alajuela, Costa Rica. *Uniciencia* 31: 73–84. [in Spanish]
- Nowak R.M., Walker E.P., 1999. *New World River Otters*. Walker's Mammals of the World. JHU Press.
- Ojeda R.A., Chillo V., Díaz G., 2012. Libro rojo de los mamíferos amenazados de la Argentina. Sociedad Argentina para el Estudio de los Mamíferos (SAREM). Mendoza. [in Spanish]
- Ottino P., Prigioni C., Vigna Taglianti A., 1995. Habitat suitability for the otter (*Lutra lutra*) of some rivers of Abruzzo Region (Central Italy). *Hystrix* 7(1–2): 265–268. doi:10.4404/hystrix-7.1-2-4079
- Pardini, R. Trajano E., 1999. Use of Shelters by the Neotropical River Otter (*Lontra longicaudis*) in an Atlantic Forest Stream, Southeastern Brazil. *Journal of Mammalogy* 80: 600–610.
- Parera A., 1996. Las “nutrias verdaderas” de la Argentina. Fundación Vida Silvestre Argentina Buenos Aires. [in Spanish]
- Parera A., 2002. Los mamíferos de la Argentina: Y la región austral de Sudamerica. 1 Edition. El Ateneo, Buenos Aires, Argentina. [in Spanish]
- Parker J., Epifanio J., Casper A., Cao Y., 2016. The Effects of Improved Water Quality on Fish Assemblages in a Heavily Modified Large River System. *River Research and Applications* 32: 992–1007.
- Payn T., Carnus J.-M., Freer-Smith P., Kimberley M., Kollert W., Liu S., Orazio C., Rodriguez L., Silva L.N., Wingfield M. J., 2015. Changes in planted forests and future global implications. *Forest Ecology and Management* 352: 57–67.
- Quadros J., Monteiro-Filho E.L.A., 2001. Diet of the Neotropical Otter, *Lontra longicaudis*, in an Atlantic Forest Area, Santa Catarina State, Southern Brazil. *Studies on Neotropical Fauna and Environment* 36: 15–21.
- Quintana R.D., Bó R.F., 2010. Caracterización general de la región del Delta del Paraná. Endicamientos y terraplenes en el Delta del Paraná: Situación, efectos ambientales: 5 [in Spanish].
- Quintana R.D., Bó R.F., 2011. ¿Por qué el Delta del Paraná es una región única dentro del territorio de la Argentina?. In: Quintana R.D. (Ed.) *El Patrimonio natural y cultural del Bajo Delta Insular del Río Paraná*. Bases para su conservación y uso sostenible. 43–53. [in Spanish]
- R Core Team, 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Rheingantz M., Trinca C., 2015. *Lontra longicaudis*. The IUCN Red List of Threatened Species 2015: e.T12304A21937379.
- Rheingantz M.L., de Menezes J.F.S., de Thoisy B., 2014. Defining Neotropical otter *Lontra longicaudis* distribution, conservation priorities and ecological frontiers. *Tropical Conservation Science* 7: 214–229.
- Rheingantz M.L., Oliveira-Santos L.G., Waldemarin H.F., Caramaschi E.P., 2012. Are otters generalists or do they prefer larger, slower prey? Feeding flexibility of the neotropical otter *Lontra longicaudis* in the Atlantic Forest. *IUCN Otter Specialist Group Bulletin* 29: 80–94.
- RStudio Team, 2015. RStudio: integrated development for R. RStudio, Inc., Boston, MA.
- SENASA, 2015. Bosques Argentinos, Actividad Forestal y Economías Regionales. Servicio Nacional de Sanidad y Calidad Agroalimentaria. [in Spanish]
- Serfass T., Rymon L., Brooks R., 1990. Feeding relationships of river otters in northeastern Pennsylvania. *Transactions of the Northeast Section of the Wildlife Society*. 43–53.
- Sica Y.V., Gavier-Pizarro G.I., Pidgeon A.M., Travaini A., Bustamante J., Radeloff V.C., Quintana R.D., 2018. Changes in bird assemblages in a wetland ecosystem after 14 years of intensified cattle farming. *Austral Ecology*.
- Sica Y.V., Quintana R.D., Radeloff V., Gavier-Pizarro G., 2016. Wetland loss due to land use change in the Lower Paraná River Delta, Argentina. *Science of the Total Environment* 568: 967–978.
- Siegel S., Castellan N., 1988. Measures of association and their tests of significance. In: Siegel S., Castellan N. (Eds.) *Nonparametric statistics for the behavioral sciences*. McGraw-Hill, New York. 224–312.
- Stenson G.B., Badgero G.A., Fisher M.D., 1984. Food habits of the river otter *Lutra canadensis* in the marine environment of British Columbia. *Canadian Journal of Zoology* 62: 88–91.
- Stephens S.S., Wagner M.R., 2007. Forest plantations and biodiversity: a fresh perspective. *Journal of Forestry* 105: 307–313.
- Towell D.E., Tabor J.E., 1982. The northern river otter. In: Chapman J.A., Feldhamer G.A. (Eds.) *Wild mammals of North America: biology, management, and economics*. John Hopkins University Press, Baltimore, MD. 688–703.
- Trigila A.P., Gómez J.J., Cassini M.H., Túnez J.I., 2016. Genetic diversity in the Neotropical river otter, *Lontra longicaudis* (Mammalia, Mustelidae), in the Lower Delta of Paraná River, Argentina and its relation with habitat suitability. *Hydrobiologia* 768: 287–298.
- Williams B.K., 1981. Discriminant analysis in wildlife research: theory and applications. In: Williams B.K. (Ed.) *The Use of Multivariate Statistics in Studies of Wildlife Habitat*. Rocky Mountain Forest and Range Experiment Station, University of Vermont. 59–71.
- Wise M.H., Linn L.J., Kennedy C.R., 1981. A comparison of the feeding biology of mink *Mustela vison* and otter *Lutra lutra*. *Journal of Zoology* 195: 181–213.
- Wong B., Candolin U., 2015. Behavioral responses to changing environments. *Behavioral Ecology* 26: 665–673.