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Source: Journal of Mammalogy, 95(4):824-833. 2014.
Published By: American Society of Mammalogists
DOI: http://dx.doi.org/10.1644/13-MAMM-A-265
URL: http://www.bioone.org/doi/full/10.1644/13-MAMM-A-265

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Habitat suitability and anthropogenic correlates of Neotropical river otter (*Lontra longicaudis*) distribution

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The Neotropical river otter *Lontra longicaudis* is a top predator in many South and Central American aquatic freshwater systems. Its current category in the International Union for Conservation of Nature is "data deficient," which makes it imperative to determine the appropriate conservation status. We applied species distribution models to build a map of habitat suitabilities, and to identify possible anthropogenic factors that affect the presence of *L. longicaudis* in the Lower Delta of the Paraná River in the Southern Cone of South America. Presence/absence of *L. longicaudis* was obtained using 3 methodologies (sign surveys, camera traps, and interviews) and 15 environmental predictors. Habitat suitability was higher in areas with polders built for forestry, and lower in areas with human settlements and boat traffic. At present, geographic isolation and control of access on private land and reserves appear to be effective at protecting wildlife in the Paraná Delta. Our study demonstrates that species distribution models can be used for rapidly evaluating potential threats to wildlife.

Key words: flooding pulse, poaching, wetland, wildlife conservation

DOI: 10.1644/13-MAMM-A-265

Otters live in particularly fragile habitats such as wetlands, coastal marine, and riverine ecosystems. All of these systems are often unstable due to natural causes and anthropogenic effects. For example, droughts, floods, and tides regularly or sporadically change the appearance and functioning of wetlands and coastal seas (Brinson 1993; Davis and Fitzgerald 2004). Superimposed on these natural variations are anthropogenic effects. Water pollution, regulation of flows, the structural degradation of the coast, poaching, and human presence are some of the known factors affecting wildlife in coastal and riverine environments (Davis and Fitzgerald 2004; Erwin 2009).

Otters are predators located at the top of aquatic environment food webs and have large territories and habitat requirements (Parera 1996; Kruuk 2006). Most otter species are listed as endangered on the International Union for Conservation of Nature (IUCN) Red List. Kruuk (2006) conducted the most in-depth review on the ecology and conservation of otters to date. He concluded that the most important overall threat to otters is the impact of a reduction in food availability. Otters can be tolerant to human presence, structural habitat degradation, and even to a certain degree of water pollution, at least in the short term. Kruuk (2006) also found that hunting can be an important threat locally.

The Neotropical river otter, *Lontra longicaudis*, is a top predator in many South and Central American aquatic freshwater systems. It is distributed from northern Mexico (32°N) to Argentina (32°S) and is adapted to a wide variety of aquatic habitats, including seashores and elevations up to 3,000 m (Blacher 1987; Emmons and Feer 1997). Its diet is based on fish but it can include aquatic invertebrates such as crabs, crayfish and mussels, and terrestrial prey including mammals, birds, and insects (Pardini and Trajano 1999; Quadros and Monteiro-Filho et al. 2001; Chemes et al. 2010). Home range size varies from 3 to 8 km (Gallo–Reynoso 1989). It is probably the only Latin American otter species that is not at risk of extinction. However, its current category is "data deficient" with the IUCN (Waldemarin and Alvarez 2008), which makes it imperative to collect biological information on the species to assess the appropriate conservation status.

Species distribution models (SDMs) are associative models relating occurrence or abundance data at known locations of individual species (distribution data) to information on the environmental characteristics of those locations (modified from Elith and Leathwick 2009). Several publications have reviewed the available SDMs (Guisan and Thuiller 2005; Heikkinen et al. 2006; Elith and Leathwick 2009; Cassini 2011a, 2013). These reviews found that SDMs have been used with good results to characterize the natural distributions of species and that this information has been applied to investigate a variety of scientific and applied issues. SDMs have 2 main uses: identifying predictors or key factors of the environment that affect species distributions, and predicting distributions in new scenarios, assuming that the variables included in the model are relevant factors. When SDMs are used for the latter purpose, their output is normally a habitat suitability map. The 1st approach has a more theoretical focus, and considers the causal drivers of species distributions. The second approach is influenced by the strong demand for mapped products for use in conservation and land management. In recent years, several authors (Papeş and Gaubert 2007; Sepúlveda et al. 2009; Morueta-Holmes et al. 2010; Wilting et al. 2010; Cassini 2011b; Jackson and Robertson 2011, Gomez and Cassini 2013b) proposed and implemented SDMs as a useful tool for ranking key factors or threats to endangered or vulnerable species. Most current ranking of threats conducted within IUCN Specialist Groups still relies on the subjective perspectives of workshop attendees or individual experts. SDMs are ideal tools for incorporating theoretical and mathematical rigor to the ranking threat process, because they are relatively easy and fast to implement, can be used with different levels of knowledge about the species in question, and are particularly suitable for use at the geographical scale for which the IUCN Red List is designed.

The objectives of our study were to build a map of habitat suitability distribution, and identify possible anthropogenic factors that affect the presence of Neotropical river otters in the Lower Delta of the Paraná River, which stretches through the final 300 km of the Paraná Basin, in the Southern Cone of South America. We estimated the distribution of the species from field surveys and data were analyzed by applying conventional SDMs. The analysis included anthropogenic variables related to habitat structure (e.g., polders built or dams for forestry), human presence (density of settlements, boat traffic), land use (forestry), and pollution (chemical parameters of water such as nitrates and phosphates).

Materials and Methods

Study area.—The Paraná River delta is a large wetland located in the east-central region of Argentina, which stretches through the final 300 km of the Paraná Basin, the 2nd largest basin in South America (Bonetto 1986). The Lower Delta, the terminal area of this delta, covers approximately 17,500 km^2 (Malvárez 1997), and is located approximately between 32°05′S and 58°30′W, and between 34°29′S and 60°48′W. The Lower Delta is divided in 2 portions, 1 located in Entre Rios Province, the other in Buenos Aires Province. The south borders a populated region of the Pampas plain with several major towns, including the Buenos Aires suburbs, one of the 20 largest cities of the world. Our study area comprised the Buenos Aires portion of the Lower Delta of the Paraná River (Fig. 1). We divided it into a total of 114 cells of $0.05 \times 0.05°$, approximately 5.5 km long, which approaches the average size of the home range of *L. longicaudis* (3–8 km—Ortega et al. 2012, 6.29 $\pm$ 5.96 km—Trinca et al. 2013).

From a biogeographical point of view, this region has a high number of species of flora and fauna, more than expected for similar-latitude continental areas (Burkart 1957; Quintana 1999). Many of these species are carried by the Paraná and Uruguay rivers from subtropical areas and coexist with those from neighboring temperate areas, giving the region a unique profile (Malvárez 1997). Its hydrological regime is expressed through a fluvial–tidal gradient in the NW-SE direction, which, together with the presence of different landscape patterns, determines a marked environmental heterogeneity (Kandus et al. 2003). The islands of the Lower Delta have a bucket shape, surrounded by a peripheral levee enclosing a depressed central area. A rich riparian forest dominated the borders, but was replaced on many islands by commercial forests of *Populus* spp. and *Salix* spp. (Borodowski and Suárez 2005). Central areas represented freshwater marshes, with low species richness, dominated by graminoid and "ceibo" *Erythrina crista-galli* forests (Kandus et al. 2003).

Otter presence and environmental predictors.—Data on the presence of *L. longicaudis* was obtained using 3 methodologies: sign surveys (feces, footprints, burrows, and skins collected by local people), camera traps, and interviews. Field surveys and interviews provided information on the distribution of Neotropical river otters in 83 (65 presences/18 absences) of the 114 cells in which we had divided the study area. Most signs were obtained during 2 field campaigns conducted between December 2000 and March 2011, including 5 locations provided by B. Lartigau. Most areas were accessible by water, allowing random selection of cells. Thirty-eight camera traps were distributed in 13 cells from 2008 to 2011 as part of an additional study on the impact of forestry on wildlife, so they were distributed at random within this type of habitat. A total of 3,897 trap days was conducted. We conducted semistructured interviews (Sinzogan et al. 2008; Anadón et al. 2009) with the inhabitants of the Lower Delta Island. A total of 224 interviews was conducted. They provided information on several social and environmental factors and on the presence or absence of otters in the neighborhood. Most interviews were conducted with people arriving from all parts of the Delta to the central port, so they also were a representative sample of the study area.

Following Guisan and Zimmermann (2000), we were especially careful in the selection of environmental predictors. We preferred to use fewer variables with high biological

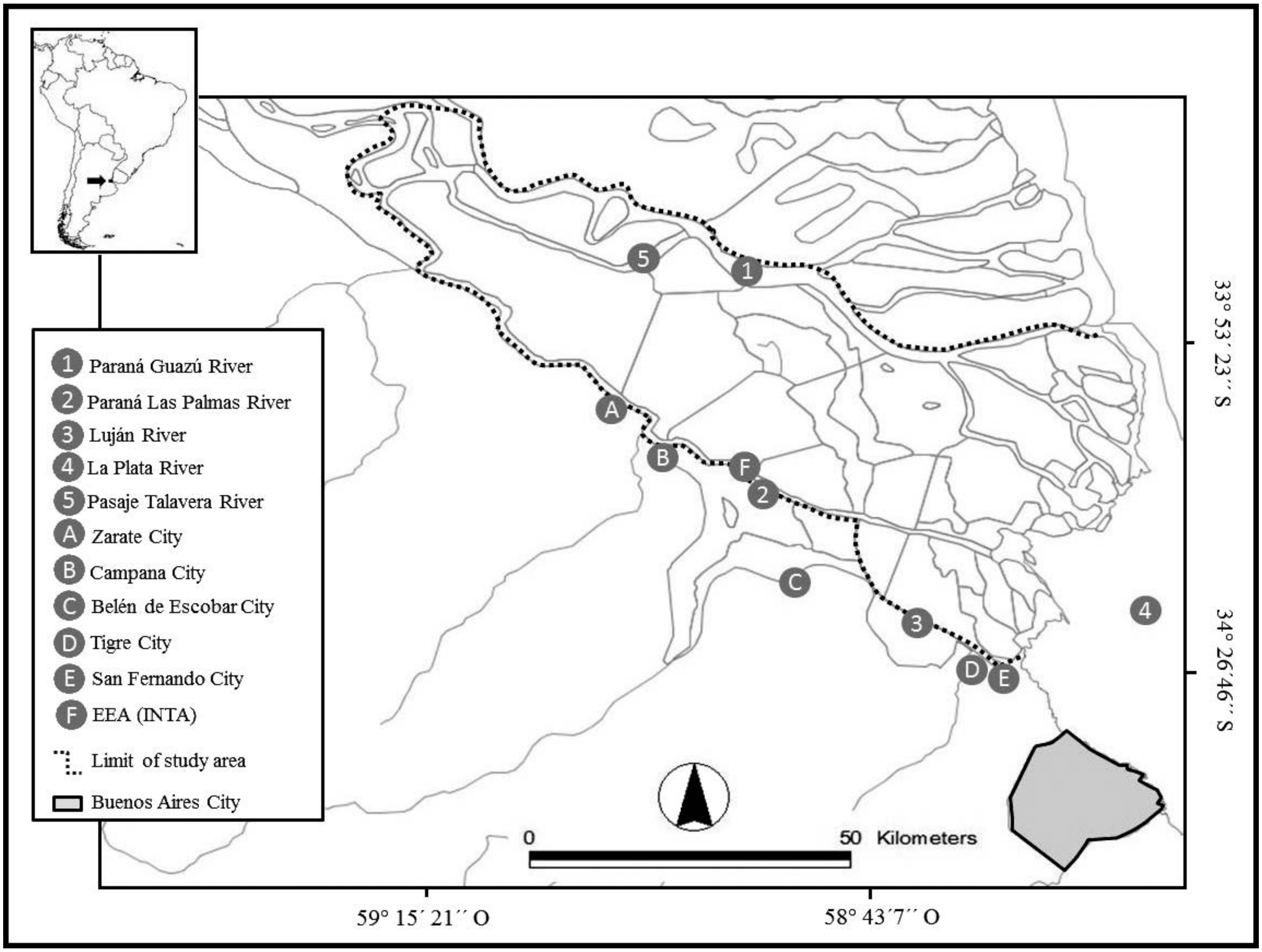

FIG. 1.—Study area, the Lower Delta of the Paraná River (Bonaerense Delta), and spatial reference points. Note: EEA, Estacion Experimental Agropecuaria (Agricultural Experiment Station); INTA, National Institute for Agricultural Technology.

significance rather than using a large number of less important variables. Sources of information varied, with data obtained from satellite images, interviews, and web pages. We did not include any climatic variables in the analysis, because these showed minimal variation between cells in the study area. In each of the 114 cells, the following 15 environmental predictors were measured:

1. Topography (m above sea level): Obtained from the website of the National Geophysical Data Center ETOPO1 through a global 1-arc-min surface model.
2. River length (m): The shapes of permanent rivers were obtained from the Argentinean Geographic Institute (2011).This shape was provided by Grupo de Sensores Remotos de la Universidad Nacional de Luján (Argentina). ArcView v.3.2 software (ESRI 2008) was used to generate the buffer, from which meters of rivers and streams in each cell were estimated.
3. River width (m): Using a set of satellite imagery from Google Earth (Google 2010 and 2011, 500-m eye-height resolution) we drew a cross from the vertices of the square formed by each cell of the study area. The widths of rivers and streams were measured every time they were intersected by the cross. The mean width for each cell was incorporated to the analyses.
4. Settlement density (settlements/km^2): Georeferenced points of buildings and settlements in the study area were obtained from different sources: human settlement shapes were obtained from Argentinean Geographic Institute (2011), gazetteer data (DIVA-GIS 2011), satellite imagery from Google Earth (2010–2011 images), interviews with local people, and web pages about tourism and recreation in the study area. The number of settlements per cell was divided by cell surface area.
5. Polder cover (%): In each cell we calculated the area occupied by polders and expressed this as a percentage of the total area. Polder shape was obtained from Gaute et al. (2007).
6. Boat traffic: We counted the number of boats visible to the naked eye in each cell in 2 available sets of satellite

images (years 2010–2011) for the study area, obtained from Google Earth with a resolution of 500-m eye height (height from the surface). This method for measuring boat traffic has the advantages of being easy to complete and capable of covering a large area; however, it cannot capture temporal variability in boat traffic (for example, an increase in tourism during the summer and weekends).

7. Tree cover (%): Vegetation coverage data were obtained from DIVA-GIS (2011). Cover of perennial and deciduous trees were discriminated, so the type assigned to each cell was that with the highest percent cover in a 150-m buffer around permanent rivers.
8. Forestry (%): Data were obtained from a digital map of the Delta Forest Plantations produced by the GIS and Forest Inventory Area of the Ministry of Agriculture, Livestock and Fisheries of Argentina in 2010. We calculated the area occupied by forest plantations in each cell using a 150-m buffer. This area was transformed into a percentage of the total buffer area in each cell.
9. Floodplain area (%): Originally resampled to 30 s onto spatial country-level grid (DIVA-GIS 2011), these data were reclassified in 2 categories: floodplain area and free land (the remaining area).
10. Protected area (%): The protected areas that were partially or totally included in the study area were: a UNESCO Biosphere Reserve called "Delta del Paraná" designated in 2000 by UNESCO, Botija Island (Organismo Provincial para el Desarrollo Sustentable), and Otamendi National Reserve (Administración de Parques Nacionales). The percentage of surface occupied by protected areas in each cell was incorporated in the analysis. For the latter reserve, only two small portions of its area were included within the Paraná Delta ecoregion (Fig. 2b), although it is expected that its management affects the surrounding area.
11. Suspended solids (mg/l).
12. Nitrates (mg/l).
13. Phosphates (μg/l).
14. Coliforms (most probable number/100 ml).
15. Dissolved oxygen (mg/l) in waters from rivers and streams.

Estimates of 5 water-quality measurements (11–15) were obtained from Gomez and Cassini (pers. comm.), who extrapolated to the entire Lower Delta data of previous studies collected in several points of the region. Extrapolation was done using multiple regressions and a database of these parameters. Reflectance was obtained from Landsat Thematic Mapper(TM) and Enhanced Thematic Mapper Plus (ETM+) images.

To reduce the effects of multicollinearity between environmental variables we applied the criterion used by Dormann et al. (2012), Syfert et al. (2013), and Kramer-Schadt (2013), that variables should be eliminated from the final analysis when Pearson's $|r| > 0.75$.

Species distribution models.—We applied 3 SDMs: maximum entropy (MaxEnt), ecological niche factor analysis (ENFA), and a generalized linear model based on a logistic regression (Logit). The first 2 models only use the presence of otters as the dependent variable, whereas the 3rd uses a dichotomous dependent variable of 1s and 0s (presences and absences, respectively). First, these models were used to associate data on presence/absence of otters with the 15 independent variables in the sampled cells, and then used to obtain the probabilities of occurrence for the 114 cells into which the whole study area was divided. The independent variables were transformed into ASCII format for ESRI, for more fluid management of information, and ASCII files were manipulated by the software ArcView 3.2 (ESRI 2008), DIVA-GIS 7.3.0 (DIVA-GIS 2010), and GLOBAL MAPPER 11 (Blue Marble Geographics 2011).

For MaxEnt analysis we used a Java environment, generating a comma separated values (CVS) file for presence data and a package of dependent variables in ASCII format. The following settings were used in MaxEnt v.3.3.2 (Phillips et al. 2010) to produce the model: automatic feature selection, regularization multiplier at unity, and maximum 500 iterations. BIOMAPPER software 4.0 (Hirzel et al. 2002) was used for ENFA. A set of independent variables in the denomination of IDRISI Raster Format (RST), as well as the dependent variable in a Boolean format (required by the model), were generated by DIVA-GIS. The variables were standardized and the model was developed with the mean as a measure of distance. A distance geometric-mean algorithm was used for habitat suitability computations (Hirzel and Arlettaz 2003). This algorithm makes no assumption about the shape of the species distribution, but the density of observations must be representative of the species niche. The logistic regression was performed using STATISTICA 8 (StataCorp 2003). To evaluate the role of each environmental variable after the regression analyses we used the Wald statistic for all effects in the model, including types I and III of the likelihood ratio test; and Spearman correlations between the environmental variables and the 0–1 data on otter distribution.

Modules were applied after algebraic manipulation of DIVA-GIS grids to obtain a habitat suitability map. For MaxEnt, ENFA, and Logit, we used a random tests percentage of 25%. Model fit was evaluated using the area under the curve (AUC) from the receiver operating characteristic curve (ROC), which is the relationship between the sensitivity and the false-positive fraction (Woodward 1999).

Results

The values of $|r|$ were less than 0.75 for any pair of comparisons, so we used all variables in the models (Table 1). Forty one (63%) cells were positive for the presence of this species. We found a significant overlap between the presences determined by interviews and the presences determined by camera-trap data (60.42%). When applied to otter training data, the logit regression model had a better fit to the data according to the ROC curve (AUC = 0.89, $SD = 0.01$) than ENFA (AUC = 0.44, $SD = 0.05$) and MaxEnt (AUC = 0.37, $SD = 0.08$). Due to the low AUC values obtained for ENFA and MaxEnt

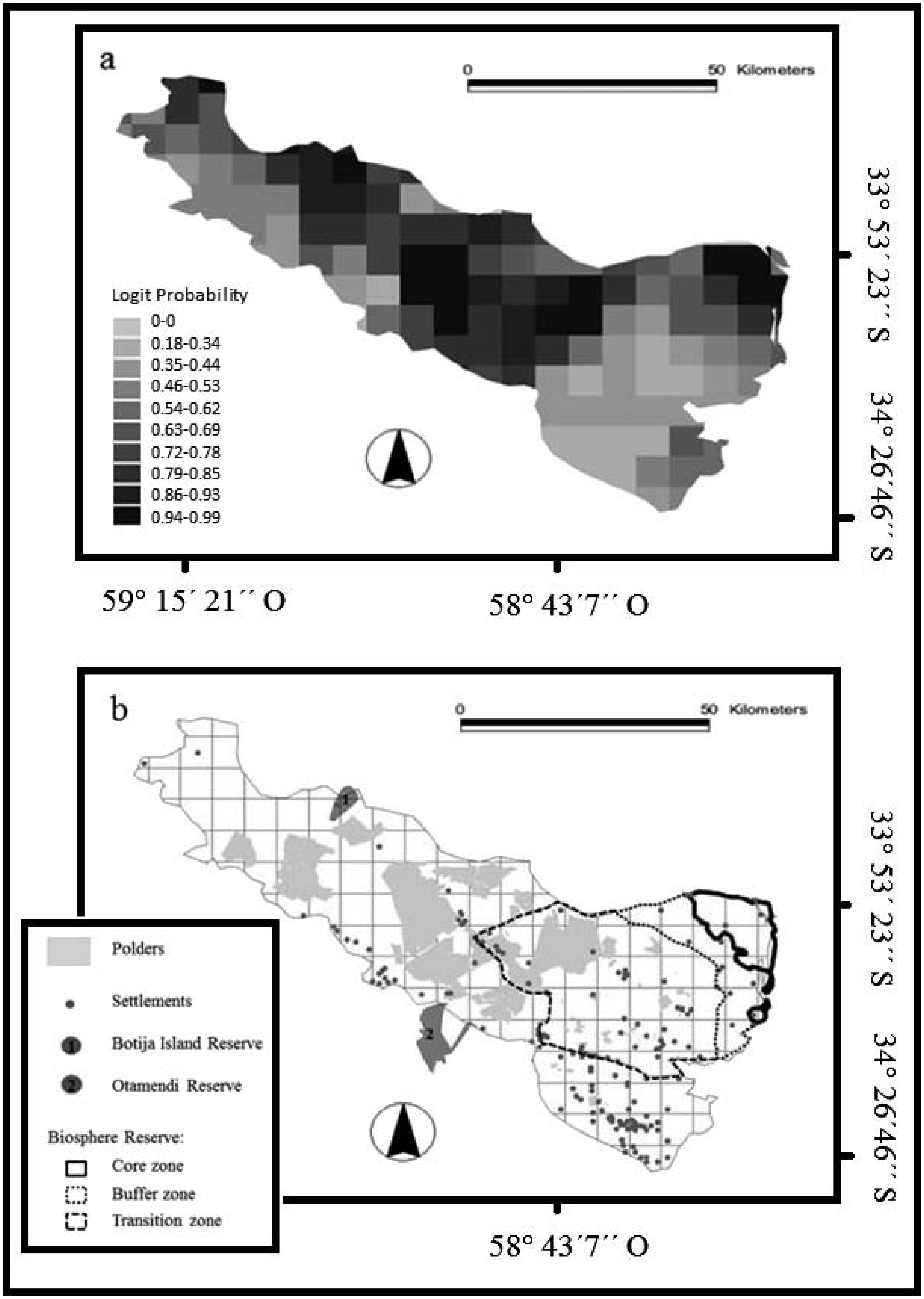

Fig. 2.—a) Distribution of the probability of occurrence of otters obtained from logistic regression; b) distribution of the environmental variables most related to *L. longicaudis* occurrence in the Lower Delta of the Paraná River. We can also see the Biosphere Reserve and the grid (0.05° × 0.05°) that divided the study area.

TABLE 1.—Pearson's correlations | *r* | between environmental variables. All paired comparisons | *r* | << 0.75. Var = variable; the numbering corresponds to the methodology.

Var	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	−0.24	−0.14	0.09	−0.39	−0.19	−0.17	−0.18	0.24	0.01	−0.22	−0.19	0.02	−0.12	0.00
2		1	0.32	−0.33	0.08	−0.13	0.38	0.08	0.00	−0.17	0.07	−0.14	−0.05	0.01	−0.04
3			1	−0.26	0.28	0.17	−0.15	−0.09	0.05	0.17	−0.09	0.28	0.13	0.03	−0.35
4				1	0.20	0.28	−0.33	0.34	−0.06	−0.14	0.06	−0.23	0.11	0.10	−0.07
5					1	0.50	−0.35	0.13	−0.20	−0.14	0.52	0.19	0.13	0.15	−0.30
6						1	−0.29	0.07	−0.03	−0.04	0.08	0.18	0.15	−0.01	−0.30
7							1	0.08	−0.14	−0.16	−0.09	−0.08	−0.06	−0.11	0.18
8								1	−0.21	−0.17	0.01	−0.03	−0.06	−0.01	−0.04
9									1	−0.28	−0.25	−0.08	−0.08	−0.16	−0.05
10										1	−0.23	0.24	−0.14	−0.01	0.03
11											1	0.02	0.22	0.22	−0.19
12												1	0.06	0.07	−0.21
13													1	0.35	−0.08
14														1	−0.30
15															1

models, we only used results provided by the logit regression analysis.

The map of habitat suitabilities for the Lower Delta of the Paraná River showed 2 trends: the central zone and those areas closest to the northern border showed the highest probabilities of occurrence (Fig. 2a).

Taking into account the contribution of each variable separately, the regression analysis indicated that polder cover was the only significant variable, according to a test of all effects (Table 2), whereas river width and settlement density were the other significant variables according to a likelihood type I test. The effect of river width appeared to be an artifact of an unavoidable skew in the amount of data for small and large rivers. There were 2 very wide rivers that were positive for presence of the species. When these 2 points were removed the statistical significance disappeared.

A simple additional statistical analysis was conducted by applying Spearman rank correlation analyses, which showed that polders, settlements, and boat traffic were significantly correlated with presence/absence of otters (Table 2). Habitat suitability for *L. longicaudis* increased with polder cover and decreased with human settlements (Fig. 3). These trends can be established visually by comparing the distribution of habitat suitabilities (Fig. 2a) with the distribution of environmental variables (Fig. 2b).

There were no significant relationships between biodiversity reserve distribution and the presence of otters. However, visual

TABLE 2.—Multiple regressions and Spearman correlations between environmental variables and the distribution of *Lontra longicaudis* in the Lower Paraná River delta. Significant statistics ($P < 0.05$) appear in italics.

Environmental variable	All effects Wald[a]	Type I test: Log-likelihood	Type I test: Chi-square test[a]	Type III test: Log-likelihood	Type III test: Chi-square test[a]	Spearman rank
Intercept	0.10	−38.01				
1. Topography	1.71	−29.03	0.34	−26.43	2.10	−0.08
2. River length	0.83	−30.21	0.04	−25.82	0.87	0.00
3. River width	0.31	−35.65	*4.73*	−25.60	0.43	0.13
4. Settlement density	1.57	−33.24	*4.82*	−26.38	2.00	*−0.30*
5. Polder cover	*3.90*	−30.68	*4.41*	−27.91	*5.06*	*0.30*
6. Boat traffic	0.15	−29.97	0.49	−25.45	0.15	*−0.37*
7. Tree cover	0.85	−32.88	0.71	−25.82	0.88	−0.211
8. Forestry	1.61	−30.23	0.88	−26.29	1.82	−0.14
9. Floodplain area	0.11	−29.51	0.32	−25.44	0.12	−0.13
10. Protected area	0.53	−29.20	0.63	−25.74	0.73	0.08
11. Suspended solids	0.39	−29.67	0.59	−25.58	0.40	−0.10
12. Nitrates	1.91	−28.00	2.05	−26.39	2.03	−0.25
13. Phosphates	2.76	−26.77	2.46	−26.92	3.08	−0.14
14. Coliforms	2.14	−25.38	2.39	−26.58	2.39	0.19
15. Dissolved oxygen	0.00	−26.58	0.40	−25.38	0.00	−0.03

[a] For all variables, $d.f. = 1$

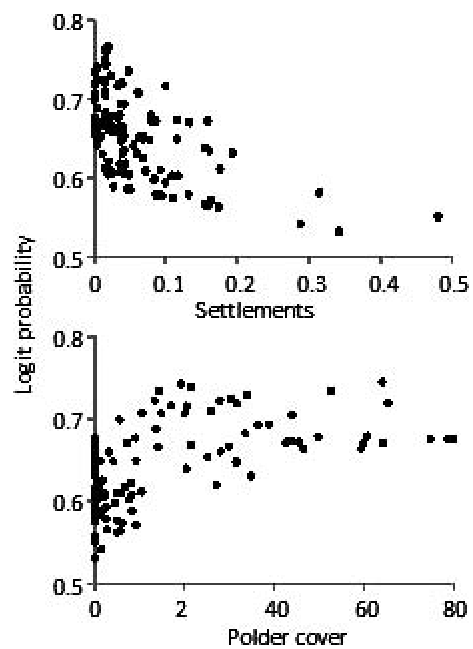

FIG. 3.—Response curve of the probability distribution of *L. longicaudis* as a function of each of the most significant independent variables.

inspection of Fig. 2 suggests that habitat suitability tended to increase in some protected areas. In the largest, the UNESCO Biosphere reserve, the buffer zone and a transition area showed low probability of use by otters (Fig. 2b).

Discussion

We applied 3 species distribution models to the distribution of the Neotropical river otter (*L. longicaudis*) in the Buenos Aires Lower Delta of the Paraná River. These models have 4 advantages compared with just mapping existing results, as they allow association of the dependent variables with many environmental factors simultaneously, identify the most relevant environmental factors affecting the distribution, permit extrapolation of the probabilities of occurrences to nonsampled areas, and provide maps that can be used in the design of action plans for wildlife conservation. The distribution of otters in the Paraná Delta was related mainly to 2 types of anthropogenic influences on the environment, polders built mainly for forestry, and human presence/settlements. Habitat suitability increased with surface cover by polders. In the Lower Delta of the Paraná River, D'Alessio et al. (2002) and Fracassi and Somma (2010) found that marsh deer, *Blastocerus dichotomus*, were frequently found in polders; they attributed this finding to the protection provided by this anthropogenic habitat against flood and poaching. Similarly, maximal bird diversity was found in abandoned forestations partially reinvaded by native vegetation of natural or artificial polders (Quintana 1999; Quintana et al. 2002). These authors suggested that landscapes with polders are composed of a diverse mosaic of habitats (different shapes, species, and plantation ages; different production systems and forestry channels), which permit a large quantity of species to use the islands. Malzoff et al. (2012) found that abundance of guans, *Penelope obscura*, is mainly related to the available area of secondary woodland, but to a lesser extent also to the presence of mature *Salix* forestations, where this emblematic species of the Delta region would find more food and shelter than in other types of landscapes.

There are at least 3 possible explanations for a positive association between otter presence and polders: areas with polders might provide more stable environments due to protection against flooding than some natural areas of the delta; they are better protected from poaching; or they increase landscape connectivity. The functioning and structure of the lower Paraná River delta are influenced by periodic flooding originating from the northwest through the high discharge rates of the Paraná River, and rising tides and winds from the southeast ("sudestadas"—Kandus et al. 2011). These inputs of water, sediments, and organisms create flood pulses (Junk et al. 1989), which vary according to climate processes defined by the general circulation of the atmosphere and anomalies, such as the El Niño–Southern Oscillation. The effect of these pulses on the biology of wildlife varies among taxonomic groups, and many of the organisms that colonize river floodplains, deltas, and estuaries are adapted to a hydrological regime characterized by cyclical or unpredictable floods (Junk et al. 1989). However, more generalist species that are capable of using a diverse range of ecosystems are expected to prefer more stable aquatic habitats. Like most freshwater otters, *L. longicaudis* is a semiaquatic carnivore that constructs burrows and has a social organization based on territorial defense, whose territories are scent marked (Kruuk 2006). Floods are likely to modify otter behavior by eliminating marks, flooding burrows, and causing major disturbance in the environment. For example, on the river banks of the Atlantic forest of southeastern Brazil, Pardini and Trajano (1999) found that these otters more frequently used shelters in higher locations, probably because they were less vulnerable to flooding. It is likely that protection provided by polders minimizes these effects.

The 2nd potential benefit of polders may be reduced poaching. This illegal activity is by far the most important threat to marsh deer (D'Alessio et al. 2002). Control of hunting appears to be effective only in the nucleus of protected areas. Local people hunt regularly and other hunters enter the Paraná Delta from the large cities located on the southern border of the reserve. In our interviews, 95 local people informed us that there was hunting in the neighborhood (81% positive response for poaching), whereas only 22 indicated the contrary. In this context, access control exerted by the owners of private land used for forestry probably acts as an effective limitation for poaching in the Paraná Delta. Hunting probably also explains why *L. longicaudis* habitat suitability decreases closer to human settlements, considering that most otter species are tolerant of human presence and to a considerable degree of degradation of habitat structure (Kruuk 2006).

The 3rd hypothesis postulates that forestry increases habitat connectivity because of the many channels built for water management (Taylor et al. 1993). In the only previous study conducted on *L. longicaudis* in the Paraná Delta, Cabrera (2006) found that these otters can make extensive use of channels, especially in autumn and winter. The importance of connectivity for otter population structure has been highlighted in previous studies using genetic techniques. For example, Latch et al. (2008) found genetic discontinuities in North American river otters *L. canadensis* in a region of Louisiana that were interpreted as a result of limited dispersal (Latch et al. 2008). The opposite was found with *L. longicaudis* in the Lacantun River system of Chiapas, Mexico, where high levels of landscape connectivity were estimated using similar genetic techniques (Ortega et al. 2012).

It is critical to realize that the benefits obtained in altered habitats, such as those associated with an increase in stability, habitat diversity, or protection against poaching, are short-term benefits. Forestry activity causes significant habitat alterations not only because it changes the composition of the plant community, but also the geomorphology of the islands and the dynamics of flooding (Kandus et al. 2011). In the long run, changes in the dynamics of these wetlands damage the entire native biota. Recently Fracassi et al. (2013) have proposed biodiversity conservation strategies for Delta forest plantations that will allow sustainable management of forestry without any significant impact on water quality and biodiversity.

The results for protected areas deserve attention, even though no statistically significant association with habitat suitability for otters was found. There were areas with legal protection that matched high suitability zones, such as the Botija. Similarly, those cells with maximal habitat suitability along the southern border of the Lower Delta were those within or close to the Otamendi Reserve, suggesting that this protected area has a positive influence on biodiversity conservation in the nearby portions of the Delta. As most UNESCO Biosphere reserves, it consists of 3 zones with different levels of protection. There was only 1 guard for 88,625 ha, who concentrated his vigilance on the core sector (pers. comm.), which in turn is the only 1 of the 3 zones with high suitability for otters. These examples demonstrate the importance for the future of the Paraná Delta to have an effective management of legally established protected areas.

We incorporated potential pollutants as environmental variables because the study area is close to highly contaminated areas (such as the city of Buenos Aires), and otters are known to be affected by pollution (Kruuk 2006). However, we did not find a correlation between chemical composition of water and otter distribution. Because we conducted a gross analysis using occurrence data and at relatively large scale, we cannot rule out the possibility that the effect of pollution occurs at a finer scale or affects other aspects of otter biology, such as diseases or population density. Unfortunately, there were no data on fish distribution in the study area; thus we were unable to test for the effect of food availability on *L. longicaudis*.

Our study demonstrates that SDMs can be used as an effective method for rapidly evaluating potential threats to wildlife: habitat suitability for otters was higher in areas with polders built for forestry and lower in areas with human settlements. Typical conservation biology models such as population viability analyses (PVA) are robust tools but require large amounts of data that are normally difficult or costly to collect, particularly in countries where financial and institutional resources are limited. Additionally, PVA are normally applicable to small scales, but conservation strategies must be applied frequently to large scales. SDMs are correlative models that are rarely used to test hypotheses or explain causations, and are normally used with limited data collected unsystematically. However, they can be especially useful as exploratory techniques, to generate scenarios and objective hypotheses that can guide regulatory agencies to identify main sources of threats to wildlife.

Resumen

El lobito de río *Lontra longicaudis* es un depredador acuático de muchos sistemas de agua dulce de América Central y del Sur. Su categoría actual en la Unión Internacional para la Conservación de la Naturaleza es “datos insuficientes”, lo que hace imprescindible determinar el estado de conservación adecuado. Se aplicaron modelos de distribución de especies para construir un mapa de idoneidades de hábitat, y para identificar posibles factores antrópicos que influyen en la presencia de *L. longicaudis* en el Bajo Delta del Río Paraná en el Cono Sur de América del Sur. Se obtuvo la presencia / ausencia de *L. longicaudis* utilizando tres métodos (se midieron las encuestas signos, trampas de cámaras y entrevistas), y 15 predictores ambientales. La idoneidad del hábitat fue mayor en las zonas con diques construidos para la silvicultura y baja en las zonas con asentamientos humanos y tráfico de embarcaciones. En la actualidad, el aislamiento geográfico y el control en terrenos privados y las reservas parecen ser eficaces en la protección de la fauna en el delta del Paraná. Este estudio muestra que los modelos de distribución de especies se pueden utilizar para evaluar rápidamente las posibles amenazas a la vida silvestre.

Acknowledgments

This work was supported by grants from Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET, Argentina, and PIP 0367 Res. 845 /1), the University of Luján (Fondos Finalidad 3.5), and the National Institute of Agricultural Technology. MHC and JIT are researchers of the CONICET. B. Lartigau kindly provided data on 5 locations of otters. M. Gauté provided the information on the polders.

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Submitted 18 October 2013. Accepted 10 March 2014.

Associate Editor was Marcus V. Vieira.