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Recent changes in plant and animal distribution in the southern extreme of the Paranaense biogeographical province (northeastern Buenos Aires province, Argentina): Ecological responses to climate change?

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Abstract: The Northern region of Buenos Aires province, in Argentina, suffered an uninterrupted increase in rainfall and temperature values during the last decades. The aim of the present contribution is to analyze the effects of such climatic change in the distribution of local flora and fauna. The analysis resulted in the recognition of distributional shifts in a total of 115 species. These changes represented the progressive southern expansion of species typically present in subtropical areas. Because all these changes have a similar orientation and direction, and included a large number of plant and animals with different ecological requirements, it is here postulated that those geographical changes are probably a response to climatic alteration.

Key words: Buenos Aires; climate change; riparian forest; species distribution.

Resumen: Cambios recientes en la distribución geográfica de plantas y animales en el extremo sur de la provincia biogeográfica Paranaense (noreste de la provincia de Buenos Aires, Argentina): ¿Respuestas ecológicas al cambio climático? La región norte de la provincia de Buenos Aires, en la Argentina, sufrió un incremento ininterrumpido de los valores de precipitación y temperatura durante las últimas décadas. El objetivo de esta contribución es analizar los efectos de dicho cambio climático en la distribución de la flora y fauna locales. El análisis resultó en el reconocimiento de corrimientos en la distribución de un total de 115 especies. Estos cambios representaron una expansión progresiva hacia el sur de especies presentes típicamente en áreas subtropicales. Como todos estos cambios tienen una orientación y dirección similares, e incluyen un gran número de plantas y animales con diferentes requerimientos ecológicos, se postula que estos cambios de distribución geográfica son probablemente una respuesta a la alteración climática.

Palabras clave: Buenos Aires; cambio climático; bosques en galería; distribución de especies.

INTRODUCTION

Buenos Aires province is located in East-Central Argentina. It is biogeographically integrated within the Pampean biogeographical province, of the Chacoan dominion in the Chacoan sub-region (Cabrera, 1971; Morrone, 2014; Figure 1). Most of Buenos Aires province is characterized by grasslands (locally named "pampas") and *Celtis ehrenbergiana* xerophytic woods (locally named "talares") both typical of the Pampas biogeographical province (Morrone, 2014). However, subtropical gallery rainforests and coastal forests from northeastern Argentina have their southernmost limit of distribution alongside large rivers to the La Plata River latitude (Cabrera, 1971; Figure 2). From an Ecoregional framework, Burkart *et al* (1999) named this complex "Delta and Paraná Islands Ecoregion". Riparian rainforest's plants belong to the Paranaense biogeographical province (Cabrera & Dawson, 1944; Cabrera, 1971) whereas coastal-forest plants and animals are widespread in Chaco and Paranaense provinces (Ringuelet, 1955). Then, in northeastern Buenos Aires province, Paranaense flora and Subtropical fauna intergrades with Pampean biota, forming an ecotone (the "subtropical-pampásico" ecotone *sensu* Ringuelet, 1961, 1981).

Climatic change is largely known to affect

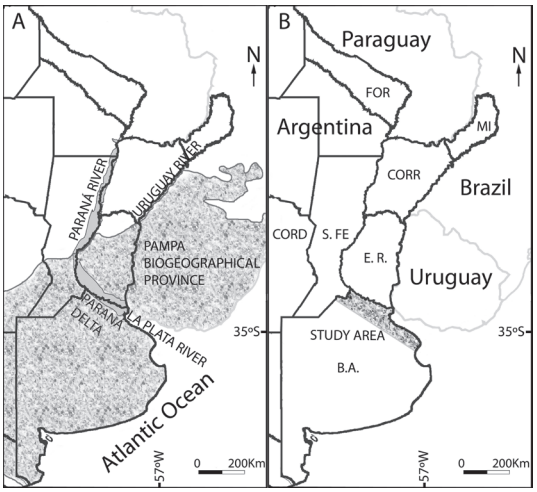

Fig. 1: Map of northeastern Argentina and bordering countries. A: Biogeographical units. In grey = Paraná River floodplain (Delta and Paraná Islands ecorregion of Burkart *et al.,* 1999); Dotted = Pampa Biogeographical province *sensu* Morrone (2014). B: Political division. Argentinean provinces mentioned in the main-text: MI = Misiones; FOR = Formosa; CORR = Corrientes; S. FE = Santa Fe; CORD = Córdoba; E.R. = Entre Ríos; B.A. = Buenos Aires.

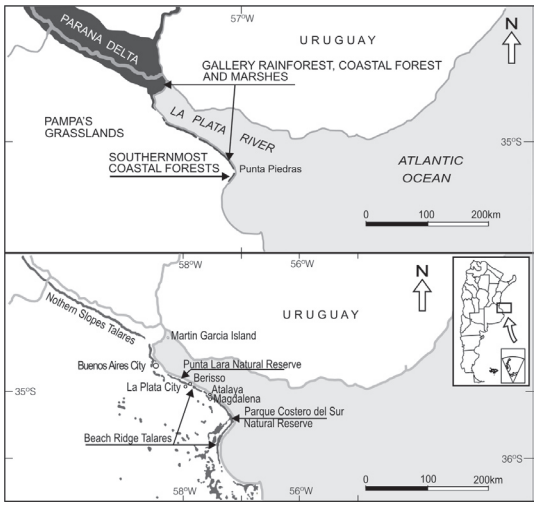

Fig. 2: Physical features of the study area and sites mentioned in the text.

plant and animal distribution, having diverse effects on biotic communities and ecosystems (McCarty, 2001; Walther *et al.,* 2002; Parmesan, 2006; Walther, 2010). Climatological studies in Argentina show that during the 20th century, Buenos Aires province suffered an uninterrupted increase in precipitation and temperature values (Berbery *et al.,* 2006; Menéndez, 2006; Servicio Meteorológico Nacional, 2015; Barros *et al.,* 2015). Having in mind such large-scale climatic change, a poleward shift in the geographical distribution of plant and animal communities is expected.

In spite of that, an integrative study about the impacts of recent climate change on Argentinean ecosystems is still lacking. Studies about changes in species geographical distribution related to climatic variation were mainly conducted in mammals (e.g. Udrizar Sauthier *et al.,* 2005; Fracassi *et al.,* 2010), medically important snakes (Nori *et al.,* 2013), insects (Farina, 2006; Medone *et al.,* 2015), and arachnids (Guerrero, 2014a). Furthermore, there is a single phenological study of changes in arriving times of a migratory swallow (Spescha *et al.,* 2004). Nevertheless, each one of these works focus on single species or on a small taxonomic group of animals. On the other hand, plant species range shifts deserved almost no attention. The aim of this paper is twofold: first, to show that geographical changes in species are not isolated and that there is a common tendency to extend the southern limit of subtropical plant and animal species; and second: to examine if the observed shifts on animal and plant species distribution could be attributed to climatic change.

MATERIALS AND METHODS

Geographical settings

We analyzed the northeastern sector of Buenos Aires province, where Paranaense riparian forests have their southernmost patches along the coast of the Lower Paraná and La Plata rivers (Figure 2). We restricted our research to this area because it was largely considered as the best known region in Argentina from a biological viewpoint, and because it was the focus of study of several researchers during the 19th and 20th centuries. Consequently, large biological collections are available from this area since historical times. This allows comparison between old and recent collections. We did not include central and southern Buenos Aires province, even though some recent cases of shifts on animal species distributions were probably caused by climate change (e.g. Zamorano & Scillato-Yané, 2008; Doumecq-Milieu *et al.,* 2012). This is because those areas were poorly sampled by researchers in historical times.

From north to southeast, Pergamino, San Nicolás, Ramallo, San Pedro, Baradero, Zárate, Campana, Pilar, Zelaya, Tigre and San Isidro districts, together with Martín García Island

encompasse the northern boundary of Buenos Aires province, including Paraná's Delta and slope talares; from Buenos Aires City to the southeast are located the districts of Avellaneda, Quilmes, Berazategui, Ensenada, La Plata, Berisso, Magdalena and Punta Indio; Punta Lara Natural Reserve is placed between Berazategui and Ensenada districts, and Parque Costero del Sur Natural Reserve in Magdalena and Punta Indio districts.

Taxon selection

Analyzed taxa were chosen under two main criteria. Firstly, we selected relatively well-studied species from the biogeographical point of view. On the other hand, we analyzed if a comparison between old and recent researches was possible. Consequently, we analyzed selected vascular plants, harvestmen (Arachnida, Opiliones), spiders (Arachnida, Araneae), Rhopalocera butterflies (Insecta, Lepidoptera), and some vertebrates, including birds (Aves), chelonians (Testudines), and mammals (Mammalia). Present paper is based on an exhaustive review of published literature and our own research. Distributional areas in each case were determined from bibliographical data such as catalogues and reviews. Below is a brief review of the bibliography and collections we examined for each group:

Vascular plant distribution. The oldest well-referenced collections from La Plata River coast are those of John Tweedie (between 1825 and 1832) and Carlos L. Spegazzini (in 1880 decade). Nikolai M. Alboff, Carlos Berg, Lucien Hauman, Cristóbal Hicken, and many others collected a big amount of specimens in the area by the late 19th and early 20th centuries. Collections and works on the provincial flora increased quickly, and the monumental work "Flora de la provincia de Buenos Aires", directed by Ángel L. Cabrera (1963-1970) summarized the knowledge of plant species distribution in this province up to that date. Therefore this document became the basis for any further study, including the present contribution. Additional data was achieved from specialized works, especially about ferns (e.g. Capurro, 1961).

Arachnida distribution. We included in this item the clades Opiliones and Araneae. Opiliones in Argentina were studied in great detail by Raúl A. Ringuelet. Analyses of Ringuelet´s monograph about Argentinean species of the clade (1959) shows that northeastern Buenos Aires province is the area with most previous collection sites, probably due to its proximity to Buenos Aires and La Plata natural science museums (Acosta, 2014). Therefore, we infer that knowledge of haverstmen in this area is relatively good. Furthermore, in this part of the province several harvestmen that distribute along the Argentinean Mesopotamia (the geographical area encompassed between Paraná and Uruguay rivers) have their southern limit of geographical distribution (Ringuelet, 1959; Acosta, 2002). On the contrary, because the Araneae are not well studied on a zoogeographical point of view, only a brief analysis of two well-studied genera is added.

Lepidoptera distribution. Lepidoptera species were shown to be very useful in climatic change studies, with many responses to that phenomenon (Kocsis & Hufnagel, 2011). During the last decade, butterfly communities in northeastern Buenos Aires province were analyzed in detail in some sparse localities (Núñez Bustos, 2007, 2008, 2009; Núñez Bustos *et al.,* 2013). However, well-sampled old lepidopteran collections were made by researchers by late 19th and early 20th centuries (Breyer, 1939b; Hayward, 1973; Canals, 2000). In this way, it is possible to made useful comparisons between old collections and recent observations. When Hayward's comprehensive catalogue (1973) is compared with recent works (Canals, 2000; Núñez Bustos, 2007; 2008; 2009; Núñez Bustos *et al.,* 2013), a significant number of species were added recently to Buenos Aires fauna.

Bird distribution. The avifauna of Buenos Aires city and neighboring region was studied by the late 19th century by several authors (d'Orbigny, 1847; Burmeister, 1868; Lynch Arribálzaga, 1878; Holmberg, 1878, 1898; Sclater & Hudson, 1888; Narosky & Gallegos, 1992), and since then, this coastal zone has been considered as the best known area of Argentina from the ornithological point of view. Later works, like those of Olrog (1963, 1979) and Narosky & Di Giacomo (1993) allow good comparisons and recognition of main distributional patterns.

Chelonia distribution. Knowledge of the distribution of reptiles and amphibians in the northeastern sector of Buenos Aires province is still patchy and biased. Among them, it is possible that the best known group are the turtles, probably because they are easy to observe and identify. Furthermore, as indicated by Crick & Sparks (1999), the turtles are very sensitive and climate-affected taxa, mainly because their nestling is climate-driven. Information on geographic distribution of chelonians was taken from the exhaustive papers by Freiberg (1977), Gallardo (1977), and Cabrera (1998).

Fig. 3: Southernmost *Erythrina crista-galli* L. forests in Samborombón Bay. A-B: General view of the trees along the river coast (winter condition). C: *Teucrium vesicarium* Mill., a typical herb of the La Plata River hygrophilous forests.

Mammalia distribution. Small mammals, especially rodent, have been found as valuable sources indicative of climate regime (Cameron & Scheel, 2001). In Argentina, most studies regarding detailed distribution and taxonomy of small-mammals were carried out by the relatively recent efforts of Elio Massoia by the 1960 decade. An important contribution is that of Galliari *et al*. (1991), which stands as the main compilation of mammalian records of the province up to that date. Since then, the studies on micromammal assemblages in Buenos Aires have been greatly increased (e.g., Udrizar Sauthier *et al*., 2005; Teta *et al.,* 2010, 2014; Pardiñas *et al.,* 2010), but unfortunately species distribution in Buenos Aires province is still far from being well-understood. Therefore, we focus our work on middle mammals, which are well represented in public collections, they are usually well known by hunters, and are mentioned in 19th century explorers' books.

RESULTS

Changes in vascular plants distribution

A total of 44 distribution changes in vascular plant species was confirmed (Table 1).

Many novel species records are here made for the first time in the Punta Lara gallery rainforest. First explorations to this Natural Reserve were made by Nicolás M. Alboff, Carlos L. Spegazzini and Lucien Hauman by the late 19th and early 20th centuries. Later, Ángel L. Cabrera and collaborators studied extensively this rainforest between 1926 and 1944 (Cabrera & Dawson, 1944). Plant collections in that place did not stop after that, and late to Cabrera & Dawson's work, new information was available during the preparation of the "Flora de la provincial de Buenos Aires" (Cabrera, 1963-1970). More recently, the exhaustive efforts of Flavio Moschione (1987, 1992) and Moschione & Klimaitis (1988) resulted in the addition of 17 new records of native plant species to Punta Lara's flora. Finally, Giudice *et al*. (2011) collected other three fern species not previously found in that locality. The works commented here were conducted in the same 6.6 hectares of the Punta Lara Natural Reserve. It is surprising that after 100 years of botanical research in this relatively small area, the increase in species richness did not reach the asymptote.

The progressive enrichment of the flora in this region, as noted by the above mentioned authors, is due to the conquest of plants from more northern locations. The "bugre", *Lonchocarpus nitidus*, is a particular case. In Buenos Aires province it grows in the lower Paraná Delta, Martín García Island, Avellaneda and Quilmes districts, and has its southernmost populations in the Punta Lara Natural Reserve. This legume tree is one of the most important components of Punta Lara riparian rainforest (e.g. Cabrera & Dawson, 1944; Dascanio & Ricci, 1988) and Martín García Island forest (Arturi & Juárez, 1997). However, it is curious that there are no collected specimen from there or any another part of the province up to 1925 (Paraná Delta, 1925, collected by A. C. Scala, deposited in LP herbarium). Because the species grows in an area that was visited several times by botanists during the end of the 19th and early 20th centuries, it is unlikely that this big ornamental plant was overlooked in the Punta Lara forest. Its distributional shift may have occurred at the end of 19th century, and represents an example of early distributional expansion.

Changes in plant communities distribution

Leaving aside individual species range extensions, an expansion of the entire Paranaense coastal woods is documented. When comparing the southern limit of this plant community as observed by Vervoorst (1967) with today limit, we realize this wood advanced more than 25 kilometers to the south, from Salvador Grande Point to the northern limit of Samborombón Bay (both sites in Parque Costero del Sur Natural Reserve, Punta Indio district). In this regard, lineal patches of a coastal forests are present in a beach ridge between 35º 30,219' S – 57º 9,795' W and 35º 30,447' S – 57º 10,019' W (Figures 2 and 3). There, the characteristic tree *Erythrina crista-galli* is associated with *Acacia caven*, *Sesbania punicea*, *S. virgata*, *Senna corymbo-*

Fig. 4: Some sedimentary features of Punta Indio ridges (Parque Costero del Sur). Redrawn from Guerrero (2014a). A: General view of a stratigraphic cut in *Erythrina crista-galli* forests at Punta Indio. B: Detail of the same stratigraphic cut. Note the plastic buoy taken from the lower part of the strata. C: Recently formed ridge. Arrows indicate plastic waste embedded in the geoform.

sa, *Celtis ehrenbergiana*, *Elymus scabrifolius*, *Cynodon dactylon*, *Hibiscus striatus*, *Hydrocotyle bonariensis*, *Teucrium vesicarium*, *Eclipta prostrata*, *Tillandsia aëranthos*, *Passiflora caerulea*, *Ipomoea cairica* and *Araujia sericifera*. This association conforms a Paranaense woodland of very recent origin, showing that the forest is actually extending its distribution to southern latitudes.

It is also worth mentioning that several humid forests within the Parque Costero del Sur Natural Reserve may have appeared within the area during the 20th century, as inferred from sedimentary evidence (Guerrero, 2014a). In fact, there is a fine sand stratum of about one meter thick carrying human solid waste under the soil where the forest grow up, and in some places a thin mud stratum with plastic fragments underlies the previous one (Figure 4). On this basis, it was concluded that the forests obviously grew up after these strata have settled down, and the presence of plastics within the sediment indicates they were deposited during the 20th century (Guerrero, 2014a).

Changes in Arachnida distribution

Table 2 summarizes taxa with recent extensions on their geographical distributional area.

A total of 6 harvestmen (Opiliones) species have increased their distributional range from north to south along the La Plata River fluvial system: *Discocyrtus prospicuus, Discocyrtus testudineus, Gryne orensis, Hernandaria scabricula, Metalibitia argentina* and *Varinodulia insularis*. The southward expansion of Mesopotamian harvestmen species is strikingly coincident with the increase of rainfall and temperature in Buenos Aires province (Guerrero, 2014a). This distributional change was proposed as a climate-driven phenomenon that produced first geomorphological modifications, then physiognomic changes in the flora, and finaly harvestmen colonization (Guerrero, 2014a).

Among spiders, we recognize distributional changes in *Nephila clavipes* and *Neotrops pombero*. The first one is a good example of a recent southward expansion. This subtropical spider reached Corrientes province as its southern limit up to the 2000s, but to present time occurs on almost every humid coastal wood from Paraná Delta to Punta Indio district (Guerrero *et al*., 2012). Dispersion of *Nephila clavipes* was related to a flood event that swept some spiders downstream to north Buenos Aires. *Neotrops pombero* is a common species in northeastern Argentina and Paraguay (Grismado & Ramírez, 2013). Its sudden appearance in Costanera Sur Ecological Reserve in 2011 was attributed to a recent dispersal (Grismado & Ramírez, 2013; Zapata & Grismado, 2015). Many other spider species may have reached the study area in the last decades, but unfortunately lot of research is needed (Zapata & Grismado, 2015). For example, *Micrathena furva* (Keyserling 1892) was recorded by Levi (1985) up to Punta Lara Natural Reserve, but nowadays it extends southwards to Parque Costero del Sur Natural Reserve (Arachnological collection of La Plata Museum, La Plata, Buenos Aires, Argentina: MLP_Ar 19407).

Changes in lepidopteran distribution

Southward expansions were detected in butterfly species from different localities at Buenos Aires province. 33 taxa were found as having important distributional changes (Table 3).

Morpho epistropheus argentinus, considered the national butterfly due to its beauty, is a big and conspicuous species on its adult and larval stages. Farina (2006) followed the increase of its range extension across the eastern part of the province between 1985 and 2003. Up to 1939 the species was known from a few localities of northern Buenos Aires province, its southern limit being at Punta Lara (Breyer, 1939a). To early 2000s it expanded its range to Punta Piedras (Punta Indio district) and General Madariaga district (Klimaitis, 2000). Finally, a few years later it was detected in the southern General Pueyrredón district (Farina, 2006). As its favorite host plant, *Scutia buxifolia* (*Rhamnaceae*), exists in the xerophitic woods or "talares" almost since the beginnings of the 20th century (Parodi, 1940), Farina (2006) concluded that the range expansion of this butterfly could be connected with the climatic change. Also, *Hypanartia bella*, *Doxocopa laurentia laurentia*, *Phoebis neocypris*, and *P. sennae marcelina* showed the same pattern of southward extension through the "talares" (Farina, 2006).

Another remarkable case is *Adelpha syma*, of which the original distribution encompasses southeastern Brazil, Uruguay, Paraguay and northeastern Argentina, was not reported in Buenos Aires province prior to the 2000s (Hayward, 1973; Willmott, 2003). Klimaitis (2000) argued the species arrived to the area due to passive raft dispersal downstream the Paraná or Uruguay rivers or by active dispersal along the Atlantic coast. Nowadays it is a common butterfly in several sites of northeastern Buenos Aires province (Núñez Bustos *et al.*, 2013).

Finally, some species increased their abundance during the last decades. For example, Núñez Bustos *et al.* (2013) mention that *Badecla argentinensis*, which had scarce past records in Buenos Aires, became much more frequent in recent decades.

Changes in chelonian distribution

As a result of comparing old works with recent papers and observations, we found that three turtle species changed their geographical distribution and expanded its geonemy (Table 4).

The case of the Red eared slider *Trachemys dorbignyi* merits some explanatory comments. This species is frequent in northeastern Argentina, north to Entre Ríos province (Barco & Larriera, 1991; Richard & De La Fuente, 1992; Cabrera, 1998). Freiberg (1977; probably based on Marelli, 1924) mentioned its presence in Buenos Aires, but this report was not based on actual specimens and was considered as dubious (Richard & De La Fuente, 1992; Cei, 1993; Alcalde *et al.,* 2012). Consequently, Williams (1991) did not include the species within Buenos Aires herpetofauna, a criterion followed by many authors. In the last decade this turtle was found in several localities of northern Buenos Aires province: San Isidro and Campana districts, and Buenos Aires city (Pereira & Haene, 2003; Chebez, 2009; Agnolin *et al.,* 2014), possibly Punta Lara (Saibene *et al.,* 2012), and in Magdalena, which constitutes its current southernmost locality (Alcalde *et al.,* 2012). Thus, we consider these records corroborate the hypothesis of a geographical expansion in this species.

Hydromedusa tectifera was recently found in Sierra de La Ventana, 495 kilometers south of its previously known geographic distribution (Di Pietro *et al.,* 2012). We did not include this record here because it is unclear if it is due to a recent natural expansion or human introduction. However, the new record here reported at Punta Indio district (Arroyo Salvador Grande, near the bridge of Route 11, 7 January 2009) may be an evidence of a natural southward expansion of the species following La Plata River coast.

Changes in bird distribution

Several authors considered that some bird species inhabiting the La Plata River coast expanded their southern distribution in recent times (Haene, 2006; Chimento *et al.,* 2011; Godoy *et al.,* 2012; Agnolin & Rivero, 2014). Based on available data, at least 24 different species of birds can be considered as being more widely distributed than previously known (Table 5).

All the species included in the table were scarce or absent from Buenos Aires province but they are frequent nowadays and were reported from many localities. Among them, most taxa are related to woodland habitats, both aquatic (*Anhinga anhinga, Tigrisoma lineatum, Aramides cajanea*) and terrestrial (*Penelope obscura, Columba picazuro, Columbina talpacoti, Tapera naevia, Crotophaga ani, Leucochloris albicollis, Picumnus cirratus, Melanerpes candidus, M. cactorum, Phacellodomus ruber, Thamnophilus caerulescens, Hemitriccus margaritaceiventer, Euscarthmus meloryphus, Basileuterus leucoblepharus, Saltatricula multicolor, Saltator aurantiirostris, Cyanocompsa brisonii*), whereas a minor component includes taxa of more opened areas and generalist habits (*Elaenia spectabilis, Phylloscartes ventralis, Sporophila hypochroma, Sporophila cinnamomea*) (Nores *et al.,* 2005).

We include below a brief account of some remarkable species that, according to current records, habits, and visibility, are known to have expanded its geographical distribution southwards.

The Darter *Anhinga anhinga* inhabits freshwater environments surrounded by wooded areas of northeastern Argentina (Olrog, 1963; Narosky & Di Giacomo, 1993). Narosky (1969) was the first author reporting its presence in Buenos Aires; its nestling was later corroborated by López Lanús & Roda (1987). Since then, it was reported from several localities of the province and Buenos Aires city. Its southernmost record is from the Punta Lara Natural Reserve (Narosky & Di Giacomo, 1993; Babarskas *et al.,* 2003; Pugnali & Chamorro, 2006; Pagano *et al.,* 2012).

The Guan *Penelope obscura* is common in wood areas and forests from northeastern Argentina (Olrog, 1963; Narosky & Di Giacomo, 1993). César i & Alonso (1975) cited the species for the first time in the northern tip of Buenos Aires province, and since then it was found in several localities, including the Paraná Delta (Narosky & Di Giacomo, 1993), Otamendi (Babarskas *et al.,* 2003), Punta Indio (F.L. Agnolin pers. obs.), Buenos Aires city (Eguía, 2012), and more recently, maped in Punta Rasa (Narosky & Yzurieta, 2010).

The Woodpecker *Melanerpes cactorum* was first reported for the province in the locality of Ramallo (Maugeri & Montenegro, 2002). Recently, Chimento *et al.* (2009) reported for the first time that this species nests in La Plata city, 250 kilometers to the south of its previously known distribution. More recently, the species was repeteadly reported for Buenos Aires and La Plata cities (Chimento *et al.,* 2011; Borsellino, 2012), and Vuelta de Obligado, San Pedro district (Chimento *et al.,* 2011). The presence and nestling of the species on its southern geographical limit was considered by Chimento *et al.* (2011) as probably driven by climatic changes in the region.

The Green-backed Becard *Pachyramphus viridis* was observed for the first time in Buenos Aires province in 1989 (Narosky & Di Giacomo, 1993). Since then, the species expanded its distribution to several localities of the area (Krapovickas *et al.,* 1992; Narosky & Di Giacomo, 1993; Grilli & Areta, 2002; Bodrati, 2001; Bodrati *et al.,* 2006; Areta in Pagano & Mérida, 2009). Similarly, the Cardinal *Paroaria capitata* was not observed by ancient authors in the province (e.g., Holmberg, 1898; Burmeister, 1868; Pereyra, 1938). Klimaitis & Moschione (1987) stated the species was present though very scarce in Punta Lara. Narosky & Di Giacomo (1993) reported a large amount of localities at northern and eastern Buenos Aires province, and Pugnali and Chamorro (2008) and Zelaya & Pérez (2008) indicated that this species currently is common in Buenos Aires city. Also Chimento *et al.* (2012) reported new records for the Cardinal and said that it probably expanded its geographical range to the south of the province in recent times. Likewise, the Saltator *Saltator similis* was first found in the northern extreme of Buenos Aires province by Fernández (1991). Since then, it was found in other localities of the province, including Punta Lara and Atalaya (Bodrati *et al.,* 2001b; Mérida & Bodrati, 2006; Bodrati & Sierra, 2009), and Buenos Aires city (Pugnali & Chamorro, 2008).

Previous to the 1980s, *Phacellodomus rube*r presence in Buenos Aires province was inferred from a single skin coming from Avellaneda district (Narosky &Di Giacomo, 1993). This species is related to wooded areas and forests from northern Argentina north to Santa Fe province (Olrog, 1963, 1979). However, since 1989 the species has become more frequent in different localities at northeastern Buenos Aires province (Chebez & Haene, 1991; Narosky & Di Giacomo, 1993; Bodrati *et al.,* 2001a). Bodrati *et al.* (2001a) considerably expanded the knowledge of the species in the province, and indicated that it is relatively frequent in Vuelta de Obligado (San Pedro district), where it nests. Similarly, in the early 20th century *Thamnophilus caerulescens* had only two records in northeastern Buenos Aires province (Sclater, 1890; Holmberg, 1898), and was considered a rare species in the province by Narosky & Di Giacomo (1993). More recently, it was frequently reported in the studied area, with records from Zárate, San Isidro, Campana, San Pedro, Baradero and Llavallol districts, and Buenos Aires city (Narosky, 1983; Barbetti *et al.,* 1985; Babarskas *et al.,* 2003; Bodrati *et al.,* 2001a; Pugnali & Chamorro, 2008; Lucero *et al.,* 2011). Furthermore, in Baradero and Llavallol districts the species is relatively frequent (Bodrati *et al.,* 2001a).

Several other species that were considered rare, scarce or hypothetical for Buenos Aires have been increasing its occurrence in the region. For example, up to late 1980s the Woodcreeper *Lepidocolaptes angustirostris* was considered a very rare species at Punta Lara Natural Reserve (Klimaitis & Moschione, 1987), whereas more recently it is considered "very common" and frequent in all environments (Pagano *et al.,* 2012). The species is also very common in Buenos

Aires city (F. L. Agnolin pers. obs.), and has expanded its southern and western distribution in several counties of the province (Haene, 2006; Chimento *et al.,* 2012). The same may be said for *Myiodynastes maculatus*, which was a rare resident on the northern tip of the province, with only a few records (Narosky & Di Giacomo, 1993). Recent overviews indicate that the species is common at several localities, including La Plata city (F. L. Agnolin pers. obs.), Llavallol (Lucero *et al.,* 2011), Avellaneda and Quilmes districts (Godoy *et al.,* 2012), and Punta Lara Natural Reserve (Pagano *et al.,* 2012). A similar pattern may be recognized for the Trushes *Turdus rufiventris* and *T. amaurochalinus*. The fomer was considered scarce by d'Orbigny (1847) and Withington (1888) in Buenos Aires neighborhood. However, since the 1960s the species has been increasing its abundance in the province (Narosky, 2012). Nowadays, this Thrush is probably one of the most frequent birds in several localities, including Buenos Aires city (Narosky, 2012; Narosky *et al.,* 1996; Haene, 2006) and expanded its distribution towards the south in Buenos Aires province. Similarly, *T. amaurochalinus* was an uncommon species in the province, where it was frequent only in some streams of the Paraná Delta (Pereyra, 1938). Daguerre (1922) indicated it was a very rare species at Rosas (Las Flores district). It is today distributed along a large area in the province, including its southernmost limit, and it is very frequent along the coastal line, where this species increased its abundance at least since the 1990s (Narosky & Di Giacomo, 1993; Roesler, 2001; Maugeri, 2002; Haene, 2006).

Changes in mammals distribution

Three mammals species are known to have changed their distributional limits in the last decades (Table 6).

The occurrence in the last decades of some mid- to large mammals, including *Dasypus novemcinctus, Cerdocyon thous*, and *Procyon cancrivorus*, in the north of Buenos Aires province was interpreted by some authors as a result of more humid and temperate conditions in the area (Zamorano & Scillato-Yané, 2008; Fracassi *et al.,* 2010). The latter species was reported by Fracassi *et al.,* (2010) from several localities of the province, including the Reserva Natural Otamendi. This protected area was prospected in high detail during decades in search of mammals (Heinonen de Fortabat & Chebez, 1997; Pereira *et al.,* 2003). Since these researches were unable to find *P. cancrivorus*, the arrival of the species in the area was probably recent (Fracassi *et al.,* 2010).

In the same line, the new records of the micromammals *Cryptonanus chacoensis*, *Deltamys kempi* and *Oligoryzomys nigripes* in more southern localities than previously known (Udrizar Sauthier *et al.*, 2005) may be due to an expansion in their range. Likewise, *Holochilus chacarius* was first recorded in Buenos Aires in 2004, where it was never found previously (Voglino *et al*., 2004; Courtalon *et al*., 2013). Nevertheless these four species were not considered in our study because the extension of their southern distributional limits could also be attributed to lack of historical collections.

DISCUSSION

This contribution indicates important changes on the geographical distribution of 115 species belonging to seven major groups of plants and animals. Plants, butterflies and birds were the groups with the larger number of southward expansions, with 44, 33, and 24 species respectively, whereas arachnids, mammals and turtles were represented by 8, 3 and 3 respectively. In addition, an increase in abundance was detected in a butterfly and some bird taxa. It is worth noting that several of these species have divergent ecological habits. The plants that have expanded their distribution encompass all known kinds of growth represented in riparian forests and marshes from northeastern Argentina and surrounding countries, with the single exception of parasitic plants (Table 7). This fact suggests there is no ecological bias in recently geographically-expanded species. The same may be said for birds, in which insectivorous, frugivorous and piscivorous species have been expanded southward (De La Peña, 2010).

Almost all taxa expanding their southern limits of distribution are inhabitants of South-American subtropical forests and surrounding wetlands, and show biogeographical affinities with Chaco and Paranaense biogeographical provinces. There are no reports of species from the Pampa or Patagonia biogeographical provinces that had increased their distributional area from south to north in the last decades. On the contrary, some Pampean taxa of Patagonian or Central Argentinean affinities disappeared from several localities and reduced their geographic distribution in the last centuries, mainly due to human disturbance, but also probably due to climatic change (Agnolin & Lucero, 2014; Teta *et al.,* 2014; Agnolin & Rivero, 2014). In this regard, some taxa, like the rodent *Ctenomys talarum* and the birds *Sturnella loyca* and *Geositta*

cunicularia, among others, moved towards more arid and cold regions (Agnolin & Lucero, 2014; Agnolin & Rivero, 2014).

With the aim to correlate these changes with the increase in some climatic values during the lasts centuries, it is necessary to rule out other factors that may produce distributional shifts in some species. A main change that occurred in the area of study during late 19th and the 20th centuries is the raise of intensive agriculture, which is clearly not a positive factor for native species (Rapoport, 1996). As stated by Hickling *et al*. (2006), the use of landscape negatively affects species lacking dispersal abilities to spread over these strongly modified and fragmented habitats.

Human introduction of several exotic tree species in the Pampa grasslands may enable some bird taxa increase their southern limits of geographic distributions (Chimento *et al.,* 2012). Nevertheless, the area here studied had native woods, like the "talares" (Fig. 2), long before the first European explorations (Delucchi & Charra, 2012).

Probably, colonization of the La Plata River coast by the riparian subtropical rainforest is a climate-driven event (Schnack, 2000). In fact, it was hypothesized that it occurred when the Little Ice Age ended by the mid 19th century (Deschamps *et al*., 2002; Deschamps & Tonni, 2007; Guerrero, 2014b). Whenever the time of appearance of riparian forest in the studied area, it is probable that this habitat richness steady increased since the end of 19th century, as noticed early by William H. Hudson (Narosky & Gallegos, 1992) and Carlos L. Spegazzini (1905). Paraphrasing the last author, northeastern Buenos Aires province flora changed from xerophyte to hygrophyte between 1881 and 1905. Although more evidence is wanting, many species of plants and animals probably arrived from northern locations in that period (Guerrero, 2014b). Among the evidence listed in this paper, the tree *Lonchocarpus nitidus* could be a good example of those shifts. Most geographical changes listed in the present contribution may have taken place since 1970 to the date, when an important increase in temperature and rainfall has been registered in northern Buenos Aires province (Berbery *et al*., 2006; Servicio Meteorológico Nacional, 2015). Furthermore, Menéndez (2006) recognized a raise in the discharge of the La Plata Fluvial System over the last four decades. It is well-documented that in almost every raise in this fluvial system level, large masses of floating vegetation (locally called "camalotales") are dragged down and carry lot of individuals and propagules of diverse animal and plant species (Achaval *et al*., 1979; Guerrero *et al*., 2012; Katinas *et al*., 2013). This phenomenon has taken place at least since the colonial period (see *e.g*. Robertson, 1916), but in most cases, when tropical species arrived to Buenos Aires, they failed to colonize new environments and died due to severe winter temperatures (Spegazzini, 1905; see Hudson commentaries from Narosky & Gallegos, 1992). Otherwise, the local increase in temperature and humidity, and changes on hydrological parameters since the 1970s, may have enhanced and allowed the possibilities of raft dispersal and effective colonization for many taxa.

CONCLUSIONS

First, we summarized, analyzed, and discussed the distributional changes of plants and animals detected in recent times in northeastern part of Buenos Aires province, a well-known transitional area between forested galleries of the La Plata Fluvial System and Pampas grasslands. One hundred and fifteen species belonging to different major groups extended their geographical ranges towards southerly locations in northeastern Buenos Aires province by late 20th and early 21th centuries. Geographical extension was detected in species of each reviewed taxonomical group. The changes of geographical distribution limits observed in a large diversity of plant and animal taxa of ecologically divergent groups appear to be coeval with some well-known climatic changes. Buenos Aires riparian forests as a whole show an incessant increment in species richness and a southward geographical expansion that probably represent ecological responses to climatic changes. Although we summarized distributional changes in well-sampled groups, it is highly probable that a greater part of the flora and fauna is being also affected by the same pattern.

This paper is the first comprehensive analysis demonstrating the possibility of an ecological response of a large number of animals and plants to recent climatic change in Argentina. It is clear that more studies are urgently needed, since most other aspects of the ecological and evolutionary responses to climate change remain largely unknown.

Table 1: Selected plant species showing distributional changes. LP: La Plata Museum Herbarium, La Plata, Buenos Aires, Argentina; SI: Darwinion Herbarium, San Isidro, Buenos Aires, Argentina. PCSNR: Parque Costero del Sur Natural Reserve. PLNR: Punta Lara Natural Reserve.

Name	Southern limit known in the 20th century	Source	Present southern limit	Source
Abutilon pauciflorum A. St.-Hil.	Northern Buenos Aires slopes	Cabrera (1963-1970)	Quilmes and PLNR	Guerrero 186 (LP); Moschione & Klimaitis (1988)
Adiantopsis chlorophylla (Sw.) Fée	Paraná Delta	Capurro (1961)	PLNR	Moschione (1987)
Aloysia gratissima (Gillies & Hook.) Tronc.	Northern Buenos Aires slopes	Cabrera (1963-1970)	PLNR	Moschione & Klimaitis (1988)
Araujia angustifolia (Hook. & Arn.) Steud.	Paraná Delta	Cabrera (1963-1970)	PLNR and Berisso district	Moschione & Klimaitis (1988); Guerrero 471 (LP)
Blepharocalyx salicifolius (Kunth) O. Berg	Berisso district	Cabrera (1963-1970)	PCSNR	Guerrero 19 (LP)
Canavalia bonariensis Lindl.	Berisso district	Cabrera (1963-1970)	PCSNR	Galup (2009)
Clytostoma callistegioides (Cham.) Baill.	Punta Lara Natural Reserve	Cabrera (1963-1970)	PCSNR	Galup (2009)
Combretum fruticosum (Loefl.) Stuntz	Entre Ríos province	Burkart (1969-1987)	Martín García Island	Lahitte & Hurrell (1994)
Dioscorea sinuata Vell.	Punta Lara Natural Reserve	Cabrera (1963-1970)	Magdalena district	Guerrero 381 (LP)
Dolichandra cynanchoides Cham.	Entre Ríos province	Burkart (1969-1987)	Costanera Sur Ecological Reserve	Cabanillas *et al.* s.n. (LP)
Doryopteris concolor (Langsd. & Fisch.) Kuhn	Northern Buenos Aires slopes and Martín García Island	Capurro (1961); Cabrera (1963-1970)	PLNR	Moschione (1987)
Doryopteris pedata (L.) Fèe	Corrientes province	De la Sota (1977)	Martín García Island	Ramos Giacosa *et al.* (2004)
Doryopteris pentagona Pic. Serm.	Corrientes province	Zuloaga *et al.* (2008)	PLNR	Giudice *et al.* (2011)
Enterolobium contortisiliquum (Vell.) Morong	Paraná Delta	Cabrera (1963-1970)	Avellaneda and Quilmes districts	Guerrero *et al.* (2012)
Gomesa bifolia (Sims) M.W. Chase & N.H. Williams	Paraná Delta and Buenos Aires City	Cabrera (1963-1970); Correa *et al.* (2009)	PLNR and PCSNR	Tonni s.n. (LP); Cellini *et al.* (2009)
Heteropterys glabra Hook. & Arn.	Paraná Delta and Buenos Aires City	Cabrera (1963-1970)	PLNR	Moschione & Klimaitis (1988)
Lonchocarpus nitidus (Vogel.) Benth.	Entre Ríos province	Lorentz (1878)	PLNR	Cabrera & Dawson (1944)
Mimosa pigra L. var. *pigra*	Paraná Delta	Cabrera (1963-1970)	Avellaneda and Quilmes districts	Guerrero *et al.* (2012)
Mutisia coccinea A. St.-Hil.	Paraná Delta	Cabrera (1963-1970)	PLNR and Magdalena district	Moschione & Klimaitis (1988); Galup (2009)
Myrceugenia glaucescens (Cambess.) D. Legrand & Kausel	Berisso district	Cabrera (1963-1970)	PCSNR	Galup (2009)
Osmunda regalis L.	Paraná Delta	Capurro (1961)	PLNR	Moschione (1987)

Name	Southern limit known in the 20th century	Source	Present southern limit	Source
Oxalis hispidula Zucc.	Paraná Delta	Cabrera (1963-1970)	PLNR	Moschione & Klimaitis (1988)
Passiflora morifolia Mast. in Mart.	Córdoba, Chaco and Corrientes provinces	Deginani (2001)	Berazategui district	Cellini 78 (SI)
Philodendron tweedieanum Schott	Entre Ríos province	Hurrell & Delucchi (2008)	PCSNR	Hurrell & Delucchi (2008)
Phyllanthus sellowianus (Klotzsch.) Müll. Arg.	Punta Lara Natural Reserve	Cabrera (1963-1970)	PCSNR	Galup (2009)
Pleopeltis minima (Bory) J. Prado & R.Y. Hirai	Paraná Delta	Capurro (1961); Cabrera (1963-1970)	PLNR and La plata district	Giudice *et al.* (2011); Guerrero 173 ,519 (LP)
Pleopeltis pleopeltifolia (Raddi) Alston	Corrientes province	Zuloaga *et al.* (2008)	La Plata and Magdalena district	Guerrero 172 (LP); Cellini 22 (SI)
Pouteria salicifolia (Spreng.) Radlk.	Berisso district	Cabrera (1963-1970)	PCSNR	Galup (2009)
Psilotum nudum (L.) P. Beauv.	Corrientes province	De la Sota (1977)	PLNR	Moschione (1992)
Rumohra adiantiformis (G. Forst.) Ching	Martín García Island	Capurro (1961)	PLNR	Moschione (1987)
Sicyos polyacathos Cogn.	Entre Ríos province	Burkart (1969-1987)	Avellaneda and Quilmes districts	Guerrero *et al.* (2012)
Solanum sarrachoides Sendtn.	Paraná Delta	Cabrera (1963-1970)	PLNR	Moschione & Klimaitis (1988)
Spartina spartinae (Trin.) Merr.	Santa Fe province	Lewis & Collantes (1975)	Pergamino district	Lewis & Pire (2006)
Tarenaya hassleriana (Chodat) Iltis	Paraná Delta	Cabrera (1963-1970)	PLNR	Moschione & Klimaitis (1988)
Terminalia australis Cambess.	Berisso district	Cabrera (1963-1970)	Magdalena district and PCSNR	Guerrero 30, 518 (LP)
Tessaria integrifolia Ruiz & Pav.	Paraná Delta and Buenos Aires City	Hicken (1910); Cabrera (1963-1970)	Berisso district	Guerrero 83 (LP)
Thelypteris abbiatti C.F. Reed	Ensenada district	Ponce (1987)	Magdalena district	Guerrero 382 (LP)
Thelypteris decurtata subsp. *platense* (Weath.) de la Sota	Ensenada district	Capurro (1961); Ponce (1987)	PCSNR	Galup (2009)
Thelypteris hispidula (Decne.) Reed	Entre Ríos province	Ponce (1987)	Ramallo district and PLNR	Ramos Giacosa *et al.* (2004); Giudice *et al.* (2011)
Thelypteris rivularioides (Fee) Abbiatti	Entre Ríos province	Ponce (1987)	PLNR	Moschione (1987)
Thelypteris totta (Thunb.) Schelpe	Paraná Delta	Capurro (1961); Cabrera (1963-1970)	PLNR	Ponce (1987); Moschione (1987)
Tillandsia myosura Griseb. ex Baker	Colonia Department, Uruguay	Zuloaga *et al.* (2008)	PLNR	Cellini *et al.* (2012)
Vicia macrograminea Burkart	Escobar district	Cabrera (1963-1970)	PLNR	Moschione & Klimaitis (1988)
Vigna adenantha (G. Mey.) Maréchal, Mascherpa & Stainier	Paraná Delta and Buenos Aires City	Cabrera (1963-1970)	PLNR and Berisso district	Moschione & Klimaitis (1988); Buet 233 (LP)

Table 2: Selected arachnid species showing distributional changes. PCSNR: Parque Costero del Sur Natural Reserve. PLNR: Punta Lara Natural Reserve.

Name	Southern limit known in the 20th century	Source	Present southern limit	Source
Discocyrtus prospicuus (Holmberg, 1876)	Berisso district	Ringuelet (1959)	PCSNR and the Atlantic seacoast of the province	Acosta & Guerrero (2011)
Discocyrtus testudineus (Holmberg, 1876)	Paraná Delta	Ringuelet (1959)	Quilmes and Berazategui districts	Guerrero *et al.* (2012); Guerrero (2014a)
Gryne orensis (Sørensen, 1879)	Santa Fe province	Ringuelet (1959)	San Pedro and San Nicolás districts	Guerrero (2012); Acosta & Vergara (2013)
Hernandaria scabricula Sørensen, 1884	Berisso district	Ringuelet (1959)	PCSNR	Guerrero (2014a)
Metalibitia argentina (Sørensen, 1884)	San Nicolás district	Ringuelet (1959)	PLNR	Guerrero (2011)
Varinodulia insularis Canals, 1935	Punta Lara Natural Reserve	Ringuelet (1959)	Berisso district	Guerrero (2014a)
Nephila clavipes (Linnaeus, 1767)	Corrientes province	Levi (1980)	PCSNR	Guerrero *et al.* (2012)
Neotrops pombero Grismado & Ramírez, 2013	Corrientes province	Grismado & Ramírez (2013)	Costanera Sur Ecological Reserve	Grismado & Ramírez (2013)

Table 3: Selected butterfly species showing distributional changes. PCSNR: Parque Costero del Sur Natural Reserve. PLNR: Punta Lara Natural Reserve.

Name	Southern limit known in the 20th century	Source	Present southern limit	Source
Adelpha syma (Godart,1884)	Misiones province	Hayward (1973)	PLNR	Núñez Bustos *et al.* (2013)
Adelpha zea (Hewitson, 1850)	Misiones province	Hayward (1973)	Paraná Delta and Costanera Sur Ecological Reserve	Canals (2000); Núñez Bustos (2008)
Anarthria jatrophae jatrophae (Linnaeus, 1763)	Entre Ríos and Santa Fe provinces	Hayward (1973)	PLNR	Núñez Bustos *et al.* (2013)
Antigonus liborius areta Evans, 1953	Misiones province	Hayward (1973)	PLNR	Núñez Bustos *et al.* (2013)
Cymaenes gisca Evans, 1955	Northeaster Argentina	Hayward (1973)	PLNR	Núñez Bustos *et al.* (2013)
Cymaenes tripunctata (Latreille, 1823)	Entre Ríos province	Hayward (1973)	Berisso district	Canals (2000)
Diaethria candrena candrena (Godart, 1824)	Berisso district	Klimaitis (2000)	PCSNR	Núñez Bustos (2009)
Doxocopa kallina (Godart, 1824)	Corrientes province	Hayward (1973)	PLNR	Núñez Bustos *et al.* (2013)
Eantis thraso (Hübner, 1807)	Corrientes and Santa Fe provinces	Hayward (1973)	PLNR	Núñez Bustos *et al.* (2013)
Emesis lupina melancholica Stichel, 1910	South Brasil and Uruguay	Núñez Bustos (2007)	PLNR	Núñez Bustos *et al.* (2013)

Name	Southern limit known in the 20th century	Source	Present southern limit	Source
Enantia lina psamathe (Fabricius, 1793)	Paraná Delta and Martín García Island	Hayward (1973); Canals (2000)	PLNR	Núñez Bustos *et al.* (2013)
Hamadryas februa februa (Linnaeus, 1823)	Martín García Island	Canals (2000)	PLNR	Núñez Bustos *et al.* (2013)
Heraclides astyalus (Godart, 1819)	Entre Ríos and Santa Fe provinces	Hayward (1973)	PLNR	Núñez Bustos *et al.* (2013)
Hermeuptychia hermes (Fabricius, 1775)	Entre Ríos province	Hayward (1973)	PLNR	Núñez Bustos *et al.* (2013)
Hypanartia bella (Fabricius, 1793)	Córdoba and Corrientes provinces	Hayward (1973)	PCSNR and Atlantic seacoast	Núñez Bustos (2009); Farina (2006)
Lycorea ilione ilione (Cramer, 1775)	Corrientes province	Hayward (1973)	PLNR	Núñez Bustos *et al.* (2013)
Marpesia chiron marius (Cramer, 1779)	Corrientes province	Hayward (1973)	Costanera Sur Ecological Reserve	Núñez Bustos (2008)
Mechanitis lysimnia lysimnia (Fabricius, 1793)	Corrientes province	Hayward (1973)	PCSNR	Núñez Bustos (2009)
Ministrymon una (Hewitson, 1873)	Misiones and Formosa provinces	Hayward (1973)	Paraná Delta and Martín García Island	Núñez Bustos (2007)
Monca telata penda (Evans, 1955)	Santa Fe province	Hayward (1973)	Martín García Island	Núñez Bustos (2007)
Morpho epistrophus argentinus Frühstorfer, 1907	PLNR	Breyer (1939a)	PCSNR and Atlantic seacoast	Núñez Bustos (2009); Farina (2006)
Ortilia ithra (Kirby, 1900)	Entre Ríos and Santa Fe provinces	Hayward (1973)	PCSNR	Núñez Bustos (2009)
Paryphtimoides poltys (Prittwitz, 1865)	Santa Fe province	Hayward (1973)	PLNR	Núñez Bustos *et al.* (2013)
Paryphtimoides zeredatha (Butler, 1869)	Corrientes and Santa Fe provinces	Hayward (1973)	Martín García Island	Núñez Bustos (2007)
Phoebis neocypris neocypris (Hübner, 1823)	Campana district and Martín García Island	Canals (2000)	PCSNR and Atlantic seacoast	Núñez Bustos (2009); Farina (2006)
Phoebis sennae marcelina (Cramer, 1777)	PLNR	Canals (2000)	PCSNR and Atlantic seacoast	Núñez Bustos (2009); Farina (2006)
Polites vivex catalina (Plötz, 1886)	Entre Ríos province	Hayward (1973)	PLNR	Núñez Bustos *et al.* (2013)
Priamides anchisiades capys (Hübner, 1809)	Entre Ríos and Santa Fe provinces	Hayward (1973)	Berisso district	Canals (2000)
Pyristia nise tenella (Boisduval, 1836)	Córdoba province	Hayward (1973)	PLNR	Núñez bustos *et al.*, (2013)
Rekoa malina (Hewitson, 1869)	Misiones province	Hayward (1973)	Magdalena district	Canals (2000)
Siproeta epaphus trayja (Hübner, 1823)	Entre Ríos and Santa Fe provinces	Hayward (1973)	PLNR	Núñez Bustos *et al.* (2013)
Strymon canitus (H.H.Druce, 1907)	Corrientes province	Hayward (1973)	PLNR	Canals (2000)
Urbanus zagorus (Plötz, 1880)	Corrientes and Córdoba provinces	Hayward (1973)	Costanera Sur Ecological Reserve	Núñez Bustos (2008)

Table 4: Selected turtle species showing distributional changes. PCSNR: Parque Costero del Sur Natural Reserve.

Name	Southern limit known in the 20th century	Source	Present southern limit	Source
Hydromedusa tectifera Cope, 1869	Magdalena district	Cabrera (1998)	PCSNR	E. L. Guerrero, pers. obs.
Phrynops hilarii (Duméril & Bibron, 1835)	Zelaya and Zárate districts	Williams (1991); Cabrera (1998)	Magdalena district	Derocco *et al.* (2005)
Trachemys dorbignyi (Duméril & Bibron, 1835)	Entre Ríos province	Barco & Larriera (1991); Richard & De La Fuente (1992); Cabrera (1998)	Magdalena district	Alcalde *et al.* (2012)

Table 5: Selected bird species showing distributional changes. PCSNR: Parque Costero del Sur Natural Reserve. PLNR: Punta Lara Natural Reserve.

Name	Southern limit known in the 20th century	Source	Present southern limit	Source
Anhinga anhinga (Linnaeus, 1766)	Entre Ríos and Santa Fe provinces	Olrog (1963)	Berisso district	Narosky (1969); López Lanús & Roda (1987)
Aramides cajanea Statius-Muller, 1776	Martín García Island	Dabbene (1917); Pereyra (1938)	PCSNR	Pagano & Merida (2009)
Basileuterus leucoblepharus (Vieillot, 1817)	Entre Ríos and Santa Fe provinces	Olrog (1963, 1979)	Quilmes district and PLNR	Montaldo *et al.* (1987); Godoy *et al.* (2012)
Columbina talpacoti Temminck, 1810	North Buenos Aires, i.e. San Pedro and Ramallo districts	Hartert & Venturi (1909); Pereyra (1938); Narosky (1983); Moschione *et al.* (1992); Narosky & Di Giacomo (1993); De La Peña (2013)	PLNR	Bodrati *et al.* (2006); Pagano *et al.* (2012)
Crotophaga ani (Linnaeus, 1758)	Avellaneda districts	Hartert & Venturi (1909); Olrog (1979)	PCSNR	Pagano & Merida (2009)
Cyanocompsa brissonii (Lichtenstein, 1823)	Santa Fe province and Paraná Delta	Holmberg (1898); Olrog (1963, 1979)	PCSNR	Pagano & Mérida, (2009)
Elaenia spectabilis Pelzeln, 1868	Northern Santa Fe province	Olrog (1963, 1979)	PCSNR	Pagano & Merida (2009)
Euscarthmus meloryphus Wied, 1831	Entre Ríos province	Olrog (1979)	PLNR	Povedano & Moschione (1989); Pagano *et al.* (2012)
Hemitriccus margaritaceiventer (d'Orbigny & Lafresnaye, 1837)	Northern Entre Ríos and Santa Fe provinces	Olrog (1979)	PCSNR	Pagano & Merida (2009)
Leucochloris albicollis (Vieillot, 1818)	Pilar districts	Pereyra (1965)	PCSNR and Atlantic seacoast	Narosky (1983); Montaldo (1984); Narosky & Di Giacomo (1993); Pagano & Merida (2009)
Melanerpes cactorum (d'Orbigny, 1840)	Santa Fe and Entre Ríos provinces	De La Peña (2006, 2013)	La Plata district	Chimento *et al.* (2009, 2011); Borsellino (2012)

Name	Southern limit known in the 20th century	Source	Present southern limit	Source
Melanerpes candidus (Otto, 1796)	North Buenos Aires province	Hudson (1870); Lynch Arribálzaga (1878)	PCSNR	Pagano & Merida (2009)
Pachyramphus viridis (Vieillot, 1816)	Santa Fe and Corrientes provinces	Olrog (1979)	Magdalena district	Pagano & Merida (2009)
Paroaria capitata (d'Orbigny & Lafresnaye, 1837)	Scarce or absent in Buenos Aires province at the beginnings of the 20th century	Holmberg (1898); Burmeister (1868); Hudson (1870); Pereyra (1938)	PCSNR and Atlantic seacoast	Narosky & Di Giacomo (1993); Pagano & Merida (2009); Chimento *et al.* (2012
Penelope obscura Temminck, 1815	Corrientes and Santa Fe provinces	Olrog (1963)	PCSNR and La Costa district	F.L. Agnolin pers. obs.; Narosky & Yzurieta (2010)
Phacellodomus ruber (Vieillot, 1817)	Santa Fe province. Accidental in Avellaneda district (see text)	Olrog (1963, 1979)	La Plata district	Chebez & Haene (1991); Narosky & Di Giacomo (1993); Bodrati *et al.* (2005); Pagano *et al.* (2012)
Phylloscartes ventralis (Temminck, 1824)	Entre Ríos province	Olrog (1979)	PLNR	Klimaitis & Moschione (1987); Pagano *et al.* (2012)
Picumnus cirratus Temminck, 1825	Entre Ríos province	Olrog (1963)	Buenos Aires city	Narosky & Di Giacomo (1993)
Saltator similis d'Orbigny & Lafresnaye, 1837	Entre Ríos and Santa Fe provinces	Olrog (1979)	Magdalena district	Bodrati *et al.* (2001b)
Sporophila cinnamomea (Lafresnaye, 1839)	Entre Ríos province	Narosky (1973); Olrog (1979)	Buenos Aires City	Bodrati *et al.* (1997a); Pugnali & Chamorro (2006)
Sporophila hypochroma Todd, 1915	Entre Ríos province	Olrog (1979); Wege & Long (1995)	Buenos Aires City	Bodrati *et al.* (1997b); Pugnali & Chamorro (2006)
Tapera naevia (Linnaeus, 1766)	Paraná Delta	Holmberg (1898)	PCSNR	Pagano & Merida (2009)
Thamnophilus caerulescens (Vieillot, 1816)	North Buenos Aires province	Sclater (1890); Holmberg 1898	Llavallol district	Lucero *et al.* (2011)
Tigrisoma lineatum (Boddaert, 1783)	Avellaneda, Campana and Escobar districts	Zotta & Da Fonseca (1936); Pereyra (1938); Eisenmann (1965)	PCSNR	Pagano & Merida (2009)

Table 6: Selected mammal species showing distributional changes.

Name	Southern limit known in the 20th century	Source	Present southern limit	Source
Cerdocyon thous (Linnaeus, 1766)	Entre Ríos province	Díaz & Lucherini (2006)	Paraná Delta (Buenos Aires province part)	Fracassi *et al.* (2010)
Dasypus novemcinctus Linnaeus, 1758	Entre Ríos province	Abba & Vizcaíno (2008)	Campana and Zárate districts	Fracassi *et al.* (2010)
Procyon cancrivorus (Cuvier, 1798)	Entre Ríos province	Díaz & Lucherini (2006)	Campana and Escobar districts	Fracassi *et al.* (2010)

Table 7: Plant species that expanded their distribution to northern Buenos Aires province and their growth habits.

Name	Growth habit	Name	Growth habit
Abutilon pauciflorum	Bush	*Passiflora morifolia*	Climber
Adiantopsis chlorophylla	Herb	*Philodendron tweedieanum*	Herb
Aloysia gratissima	Bush	*Phyllanthus sellowianus*	Bush
Araujia angustifolia	Climber	*Pleopeltis minima*	Epiphyte
Blepharocalyx salicifolius	Tree	*Pleopeltis pleopeltifolia*	Epiphyte
Canavalia bonariensis	Climber	*Pouteria salicifolia*	Tree
Clytostoma callistegioides	Climber	*Psilotum nudum*	Herb
Combretum fruticosum	Climber	*Rumohra adiantiformis*	Herb
Dioscorea sinuata	Climber	*Sicyos poliacanthos*	Climber
Dolichandra cynanchoides	Climber	*Solanum sarrachoides*	Herb
Doryopteris concolor	Herb	*Spartina spartinae*	Herb
Doryopteris pedata	Herb	*Tarenaya hassleriana*	Bush
Doryopteris pentagona	Herb	*Terminalia australis*	Tree
Enterolobium contortisiliquum	Tree	*Tessaria integrifolia*	Tree
Gomesa bifolia	Epiphyte	*Thelypteris abbiatti*	Herb
Heteropterys glabra	Bush	*Thelypteris decurtata* subsp. *platense*	Herb
Lonchocarpus nitidus	Tree	*Thelypteris hispidula*	Herb
Mimosa pigra var. *pigra*	Bush or small tree	*Thelypteris rivularioides*	Herb
Mutisia coccinea	Climber	*Thelypteris totta*	Herb
Myrceugenia glaucescens	Bush or small tree	*Tillandsia myosura*	Epiphyte
Osmunda regalis	Herb	*Vicia macrograminea*	Climber
Oxalis hispidula	Herb	*Vigna adenantha*	Climber

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