Figure 4. View of the dams in 2011, Polo Regional Centro Norte, Pindorama, SP, Brazil.

Figure 5. Reforestation and agroforestry system in the edges of the ponds for vegetation cover restoration.

Figure 6. Examples of fauna visitation in the area after gully restoration, Polo Regional Centro Norte, Pindorama, SP, Brazil. A: Asa-branca or black-bellied whistling-duck (*Dendrocygna autumnalis*), B: Capybara (*Hydrochoerus hydrochaeris*). C: Garibaldi or chestnut-capped blackbird (*Chrysomus ruficapillus*), D. Frango-d'água-azul or American purple gallinule (*Porphyrio martinica*), E: Jaçanã or wattled jacana (*Jacana jacana*). Photo credit: Otaviano and Barros (2012).

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Vertebrate Fauna Evaluation After Habitat Restoration in a Reserve within Mexico City

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Little is known about how animals respond to restoration activities (Majer 2009). The presence of vertebrates has beneficial effects on restoration because they participate in processes that accelerate or influence the success of the restoration (Majer 1989, Tucker 2000). It is important to implement animal monitoring programs in order to effectively assess restoration outcomes.

The Pedregal de San Ángel ecological reserve (PSA), Mexico City, protects the xeric scrub community dominated by *Pittocaulon praecox* growing on a lava field. The PSA supports 32 protected species and 54 species endemic to Mexico (Lot and Cano-Santana 2009). However, the reserve is embedded within the city and suffers disturbances such as: fire, garbage, and introduced exotic species, both plants and animals (MacGregor-Fors et al. 2010). Since 2005, two sites located within buffer zones of the PSA have been subject to ecological restoration (A8 and A11). A8 (0.51 ha), is surrounded by buildings and soccer fields,

Table 1. Similarity indices (IS_j) between vertebrate communities from two sites under ecological restoration (A8 and A11) and one reference zone (RZ) in the Pedregal de San Ángel ecological reserve, Mexico City, Mexico. Data from February 2009 to May 2010.

Group	A8–A11	A8–RZ	A11–RZ
Birds	0.658	0.746	0.703
Mammals	0.636	0.417	0.500
Native mammals	0.857	0.500	0.625
Vertebrates	0.652	0.682	0.682
Native vertebrates	0.667	0.699	0.694

and since 1974 to 2005 it had a steady accumulation of yard waste and garbage. The vegetation was dominated by *Eucalyptus camaldulensis* and *Montanoa tomentosa*. In 2005, eucalyptus plants were removed and native plants were introduced. During 21 restoration working days, done every two to three months since April 2005, volunteers dug up the basalt substrate and other exotic plants were removed. Also, two areas with piles of rocks (diameter of 2–3 m and 1.2 m height) were created as shelter. During this study, the vegetation height was on average 2.5 m, with 12 trees of *E. camaldulensis* reaching 10 to 20 m in height. At the other site, A11 (0.31 ha), removal of original vegetation occurred in January 2005, and basaltic substrate was covered for a parking lot; but, eventually the construction was canceled (Antonio-Garcés et al. 2009). For restoration at this site, a considerable amount of foreign material was removed and the zone was covered again with basaltic rocks. Dominant exotic plants were then removed by hand during 13 restoration working days, done every one to four months since October 2006 (Antonio-Garcés et al. 2009). During this study, the vegetation height was on average 2.0 m, with trees of *Buddleia cordata* reaching 2 to 4 m in height, which was the dominant plant. The reference zone (RZ; 0.29 ha) was located 15 m north of the A11 plot. The area had a diverse topography, with large cracks and areas with exposed large flat slabs of basaltic rock. This area was dominated by *P. praecox*, *B. cordata*, and *E. camaldulensis* (Antonio-Garcés et al. 2009, Villeda-Hernández 2010). At RZ, *E. camaldulensis* trees were 7 to 19 m height.

To assess the status of vertebrate fauna, we recorded species richness, composition, abundance, and diversity of vertebrate fauna (amphibians, reptiles, diurnal birds, and non-flying mammals) at A8 and A11 after five years of restoration activities, and compared these variables with those from RZ. We looked for amphibian and reptile species during slow random walks through and around the sites from 10:00 AM to 12:00 PM (which corresponded to the peak hours of diurnal bird activity; Gill 2007), between May 2009 and May 2010. Sampling occurred throughout the year with eight days of observations per site. We recorded the frequency of sightings during each visit. To determine the composition of bird species, we sampled from June 2009 to May 2010, once every 15 days through

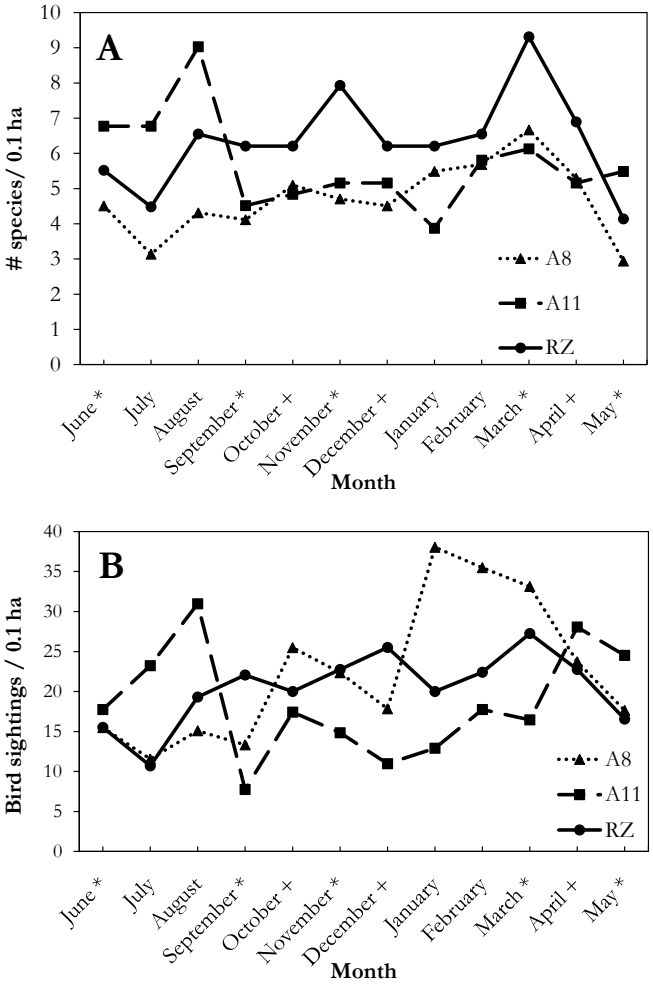

Figure 1. Birds recorded at three study sites in the Pedregal de San Ángel ecological reserve, Mexico City, Mexico from June 2009 to May 2010. (A) Bird species density and (B) bird sightings frequency. Dates of restoration working days at A11 and A8 are represented by (+) and (*), respectively. RZ: reference zone.

direct observations at each site. We recorded the frequency of sightings observed within each site. Small mammals were sampled every three months, from February 2009 to May 2010, to determine presence and abundance. We placed 16 Sherman traps on the ground at each site. We sampled during two consecutive nights each time near the new moon period. Captured mammals were temporarily ventral tagged with gentian violet to recognize them in case of recapture. To determine the presence of medium sized mammals, we recorded diurnal and nocturnal occurrence events during site visits, done every two weeks from May 2009 to May 2010. We also took samples from latrines and identified the species through analysis of food and hair.

We calculated the Jaccard similarity index (IS_j) between the vertebrate communities of the three sites. Additionally, we calculated the Shannon-Wiener (H'; $\log_{10}$) diversity index and the Pielou index (J') (Magurran 1988) for birds because they were the more abundant group. H' values were compared among the restored and reference sites with Student t tests (Zar 1999). The abundance of small

mammals on each sampling date was determined as the sum of individuals recorded on two consecutive nights.

Overall, we found a total of 91 native vertebrate species at the three sites: 78 birds, eight mammals, four reptiles, and one amphibian. We also found five exotic species: four mammals and one bird. At A8 and A11, we recorded 76 species at each site, while at RZ, we recorded 72 species. The *ISJ* ranged from 0.417 to 0.857. A8 and RZ were similar in bird (0.740) and native vertebrates (0.699) composition (Table 1). We observed greater reptile and amphibian species richness (S = 4) at A8 and A11 than at RZ (S = 3). The lizards, *Sceloporus grammicus* and *S. torquatus*, were the most abundant species: *S. torquatus* was the most frequent at A11 (N = 27) while *S. grammicus* was the most abundant at A8 (N = 17). There were fewer lizards (N = 12) at RZ. The frequency of these organisms increased at A11 from June 2009 to May 2010. At A8, we found the snake, *Pituophis deppei*, while at A11 and RZ, we observed the rattlesnake, *Crotalus molossus*.

The site with the greatest bird species richness was A11 (64 species) followed by A8 (62) and RZ (62). All three sites were similar in their species density and their frequency of sightings (Figure 1). There were no significant differences in the Shannon-Wiener diversity indices among sites (A8 vs. A11: t = 0.26, d.f. = 835, p > 0.5; A8 vs. ZR: t = 0.89, d.f. = 893, p > 0.5; A11 vs. ZR: t = 0.58, d.f. = 696, p > 0.5) and the J' values ranged from 0.75 to 0.79.

We recorded a total of 12 mammal species. A8 had the highest species richness (10 species), followed by A11 (eight), and RZ (seven). In addition, A8 had the highest exotic species richness (four species), followed by A11 and RZ (both with one species). *Peromyscus gratus* was the small rodent dominant at A11 (56 specimens) and RZ (39 specimens) (Figure 2). At A8, we also registered the presence of *P. gratus*; however, this was not the dominant species (N = 4; Figure 2A). For the first time, we recorded *P. difficilis* at the restoration sites (Figures 2A and 2B. We only registered *Rattus norvegicus* and *Mus musculus* at A8. We captured the latter more frequently (N = 6) than other rodents. We recorded four medium sized mammal species at A8, four at A11, and five at RZ. We observed *Spermophilus variegatus* as the most abundant species at A8 (N = 6) and *Sciurus aureogaster* at A11 (N = 2) and RZ (N = 13). We found five individuals of the two transient feral species at A8 (domestic dogs and cats). Meanwhile, we observed the domestic cat only once at A11. We recorded the highest abundance of transient feral domestic dogs at RZ (N = 11). We found two latrines of *Didelphis marsupialis* at A8, six at A11 of *D. marsupialis* and *Bassariscus astutus*, and one at RZ of *B. astutus*.

Some vertebrate community properties that suggest recovery of these restoration sites are: 1) similar native vertebrate richness in restored sites and RZ; 2) low relative abundance of small mammal exotic species; 3) high similarity between communities at sites undergoing restoration

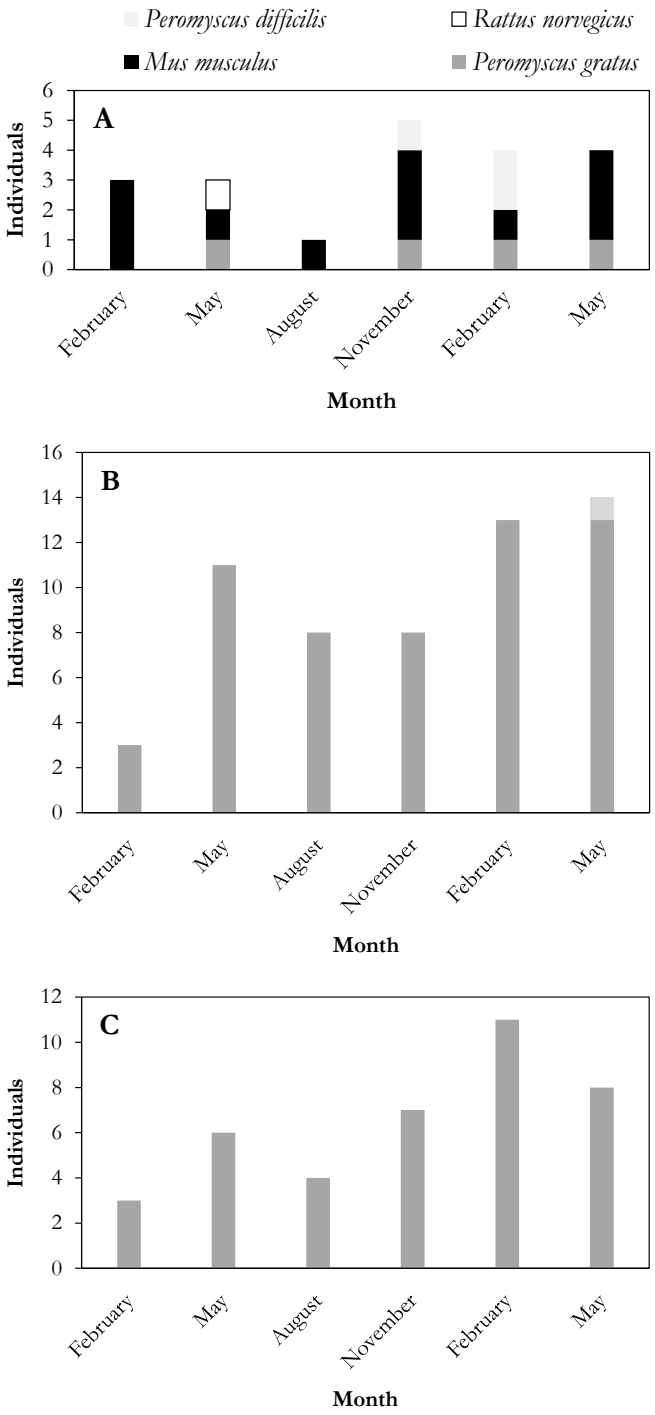

Figure 2. Temporal pattern of small mammal abundances at two sites under ecological restoration (A8 and A11) and one reference zone (RZ) in the Pedregal de San Ángel ecological reserve. A) A8, B) A11, and C) RZ. Data from February 2009 to May 2010.

with those present in RZ; 5) presence of keystone species and those of importance in terms of the trophic chain, such as *P. gratus*, *C. molossus*, and *Pituophis deppei* (Granados 2008, Balderas-Valdivia et al. 2009); and 6) similar IS_j values in the bird assemblages. According to the Society of Ecological Restoration (SER 2009), a restored ecosystem must contain a characteristic complement of species similar to those in the reference ecosystem. Our results suggest

that the sites have the conditions favorable for native fauna. Likewise, proximity to colonization sources favors similarity between disturbed and preserved sites.

The considerable similarity between A8 and RZ may be related to the similarity in their bird communities, which were the most conspicuous vertebrates. The arboreal stratum found at A8 and RZ (i.e., high trees of *E. camaldulensis*) facilitates the arrival of birds and provides roosting sites and feeding and nesting resources. We noticed a reduction in bird richness at A11 in August 2009 as a consequence of eucalypt removal. At this site, the abundance of lizards and mice was highest. This may be due to the large number of microhabitats provided by the rocks added at the site (Uribe-Peña et al. 1999).

Based on the plant community overview, the restoration process has not been completed (Cano-Santana et al. 2010). Nevertheless, the vertebrate community in general seems to be nearly restored. The comparison of the fauna among restoration and reference sites contributes to knowledge of the state of recovery and advances our understanding of ecological restoration.

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