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BIRD DIVERSITY IN AN AGROFORESTRY SYSTEM IN VERACRUZ, MEXICO

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AUTHORS' CONTRIBUTIONS

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ABSTRACT

The present study investigated the variety and abundance of migratory and resident birds in the confined agroforestry system of an educational farm, from July-October 2019, identifying each specimen with a metal band. With the aid of Howell & Webb's specialized guide for birds of México and Northern Central America, a presence/absence analysis was carried out, along with first-order Chao 2, Chao 1, ICE and Jackknife species richness estimators; the difference between months observed was represented by a species accumulation curve, and data was evaluated with the Estimates (V.9.1) software. 540 specimens from 66 species, 44 genera, 19 familiae, and 6 orders were captured. The family Parulidae was the most abundant, as was the order Passeriformes; the greatest presence of species was recorded in September and October, with a predominance of 5 specific species. There were 15 recaptures of individuals from 11 species; one was recognized as endemic, 26 migratory species, 1 summer migratory species, 13 transient species, 24 resident species, and 2 species outside their normal distribution area. 3 species are listed in the NOM-059-SEMARNAT-2010 standard, two are classified as "Subject to special protection" (Pr): Limnothlypis swainsonii and Passerina ciris, and one is classified as "Endangered" (A): Geothlypis tolmiei. Two of the represented bird species, *Bubulcus ibis* and *Fulica americana*, have been reported as carriers of the West Nile virus, a pathogen that has been recognized as the origin of a zoonosis that affects house animals and humans.

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1. INTRODUCTION

Upon comparison of natural and semi-natural habitats, urban habitats show significant differences in the presence of abiotic factors, such as atmospheric pollution levels, noise and artificial light; the latter has had an important impact on avian species [1-4], compelling them to modify their behavior to adapt to urban spaces [5,6]. These factors force urban fauna to face new biotic factors, such as different food resources, an increased presence of pathogens, and competition for food and space with new species of the urban areas, among others [7-9].

Another element threatening bird biodiversity is the transformation of natural ecosystems for human use of the land, especially in the tropics [10,11]. On a worldwide scale, 27 ± 5.0% of the total environmental disruption between 2001 and 2015 was due to deforestation for the production of basic commodities; thus, the expansion of agriculture in tropical areas is the main factor behind the loss of forests [12]. These changes in the vegetation alter the structure of bird feeding sites [13-15], and noise pollution can alter the territorial behavior of bird species [16-18].

The implementation of environment-friendly practices, such as sylvo-pastoral systems, the introduction of tree species in grasslands, allow for alleviation of some of the negative impacts of agriculture on forests by reducing extraction pressure, fostering connectivity between forest patches, and providing habitat for tree species [19,20], with additional impact on some microclimatic characteristics [21,22] that provide thermal comfort and variation to the systems [23,24] and contribute, at the same time, to the reduction of greenhouse gases (GHG) [25].

The presence of birds is ecologically significant because they cover diverse and complex functions in the natural dynamics of ecosystems [26], and are considered an indicator of biodiversity, due to their biological and ecological characteristics [27,28] such as the presence of taxonomic groups which exhibit specific responses to environmental changes [29].

However, the change in land use may boost the appearance of zoonoses in humans, due to the incorporation of natural habitats as agricultural lands or urban spaces which creates interfaces between humans, cattle and wildlife, which are reservoirs for these diseases [30]; disease effects may vary with the type of zoonotic reservoirs present, with the most frequent being rodents, bats, and passerine birds. This is greatly significant for veterinary education farms, where farm animals and humans interact with wildlife, and where outbreaks of zoonotic diseases have been reported, transmitted by wild birds, which infect farm animals, and these, in turn, infect the student population upon contact with diseased animal tissue [31].

Of the 10,770 bird species extant in the world, between 1,123 and 1,150 live in Mexico; this ranks the country as the 11th richest in bird diversity among the megadiverse countries of the world [32]. Among the coastal regions of the Gulf of Mexico, the state of Veracruz shows great bird migratory activity, and gives shelter to birds in its conservation areas; this gives the state the 2nd national place in bird biodiversity, with nearly 30% of all migratory bird species of Mexico [33]. These conservation areas not only give protection to resident bird species, but they are also very important for migratory birds, such as passeriformes, which, in their transit through Mexican territory on their way to South America, stop temporarily in several types of them, among which sylvo-pastoral systems stick out, to spend winter or restore energy to continue with their journey.

The School of Veterinary Medicine and Animal Husbandry of the Universidad Veracruzana (FMVZ - UV) maintains an area destined for agroforestry activities, called Rancho "Torreón del Molino", within the urban sprawl of the city of Veracruz, which provides shelter and food for different groups of birds. This place is especially relevant due to its abundance of bird species, and the possibility, estimated by veterinarians, of the increase in the propagation of pathogens affecting animal and human health, and which foster the appearance and dissemination of epizootics, zoonoses and epidemics, raising the risk of a pandemic [34].

The objective of this study was to record the abundance and diversity of bird species in two seasons of the year (summer and fall) in a sylvo-pastoral system of the central coastal region of Veracruz state, and to underscore the importance of studying bird populations in urban habitats, and the risk of zoonoses that they entail, to improve the conservation strategy in these agricultural areas.

2. METHODS

Rancho Torreón del Molino, property of the FMVZ-UV in Veracruz municipality, state of Veracruz, and located in latitude 19°10' 22.63" N and longitude 96°12' 13.75" O (Fig. 1), was established as the

sampling site. It is a sylvo-pastoral system which show favorable ecological conditions, such as the diversity of its vegetation, and a wide variety and abundance of birds [35,36] these conditions permitted a sizeable and varied capture, which fulfilled the expectations of the study. Fieldwork was carried out during the months of July-October 2019 with the recording of the arrival of winter migratory birds. Before this, a field trip was organized to locate the most suitable areas for monitoring, implementing the Ralph transect method [37]; aditionally, the participants identified those migratory bird species which have been demonstrated to be the carriers of pathogen viruses in the studied area, and which may pose a risk of zoonosis. Emphasis was placed on the West Nile Virus (VON), because that its vector, hematophagous mosquitoes of the Culex genus (DIPTERA: Culicidae), was recognized as an endemic species of the site [38,39].

The captures were made in a second-growth forest area of Rancho "Torreón del Molino" (RTM); the capture and handling procedure was determined according to section 7, chapter 3 of the Guidelines of the School of Veterinary Medicine and Animal Husbandry, regarding the handling of animal specimens used for research, and regulated by the Bioethics and Animal Welfare commission of the School (26/08/2019 article 91-94). Permits were obtained from the Secretariat of Natural Resources and the Environment (SEMARNAT, 09/K5-1602/10/18), under the Mexican official standard NOM-059-SEMARNAT-2010.

The captures were made through 39 x 8 ft. mist nets, with four 38-mm. mesh bags, located in strategic points of the area of the sylvo-pastoral system. Clear days, with moderate wind and light cloud cover were considered the ideal conditions for the capture and record of species, specifically during the first four hours after dawn, using mist nets due to their widespread use for the capture and record of bird species [40]. This method permitted the capture of resident and migratory species, and the sorting by order, family, genus and species was done following the criteria from specialized guides (Howell and Webb [41-43]. Once sorted, the specimens were tagged with identification bands.

Every bird captured, except hummingbirds, was fitted with an identification band on the lower right leg, made of aluminum, or a different metal, depending on the species. These bands contain a special code that records data without producing duplicates due to recaptures. This banding process is done following the method and code of ethics established by the North American Banding Council [44].

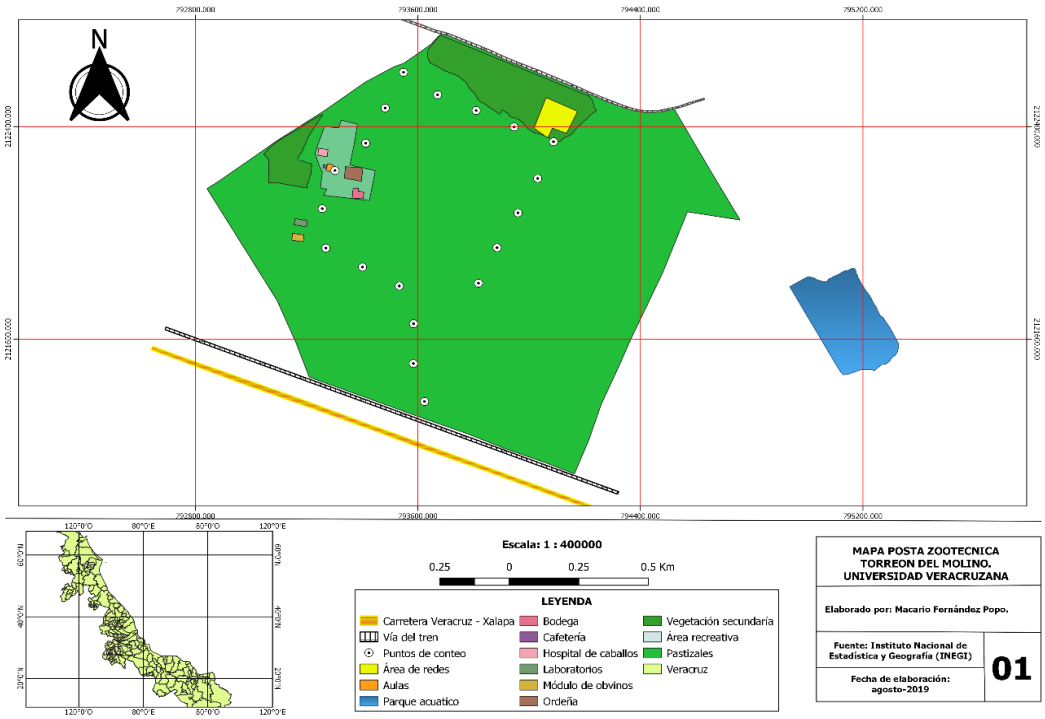

Fig. 1. Map of the study area

To estimate the representativeness of the inventory of captures, the percentage represented by the richness of species in each sampling site is calculated about the average values of the Chao 2, Chao 1, ICE and Jackknife first-order richness estimators, which are based on presence/absence data [45]. A species accumulation curve was drawn up to determine the difference in species richness between the summer and fall months, only considering differentiated sites as those whose confidence intervals do not overlap (95%). Both the richness estimates and the accumulation curve are calculated with version 9.1 of the Estimate S software Colwell [46] randomizing the samples 1,000 times to avoid any possible effect on their order.

The degree of risk of each species was evaluated according to the NOM-059-SEMARNAT-2010 standard [47] and the IUCN 2020 red list.

3. RESULTS

In the only field trip, using the transect method, 144 specimens were recorded from 35 species (Table 1). 540 specimens were captured with the mist nets, spread among 44 genera, 19 families, 6 orders, and 66 species.

The most numerous one was the family Parulidae, with 18 species. 28 winter migratory species, 26 resident and 12 transient species were recorded (Table 2).

Within the research period, the highest registers were made during September and October; in total, 15 recaptures were made during the research period, from the following species: Cardellina pusilla (1), Empidonax minimus (1), Mniotilta varia (1), Pachyramphus aglaiae (1), Pitangus sulphuratus (1), Polioptila caerulea (1), Setophaga americana (1), Setophaga citrina (1), Setophaga ruticilla (1), Setophaga petechia (3) and Vireo griseus (3).

According to the records obtained in six months of the banding season, the 5 species that were best represented were: Empidonax traillii (10%), Icterus spurius (8.5%), Dumetella carolinensis (7.7%), Myiarchus crinitus (5.3%) and Setophaga citrina (5.3%), (Fig. 2). One endemic species was recorded (Campylorhynchus rufinucha rufinuca), 26 migratory species, 1 migratory summer species, 13 transient species, and 2 out-of-range species: Geothlypis tolmiei y Piranga olivacea. 4 species are listed in the NOM-059-SEMARNAT-2010 standard, 2 are catalogued as "subject to special protection" (Pr): Limnothlypis swainsonni and Passerina ciris; two are catalogued as "Vulnerable" (VU): Geothlypis tolmiei and Campylorhynchus rufinucha rufinucha; and 9 species appear in the IUCN List as Near Threatened (NT) (Table 1).

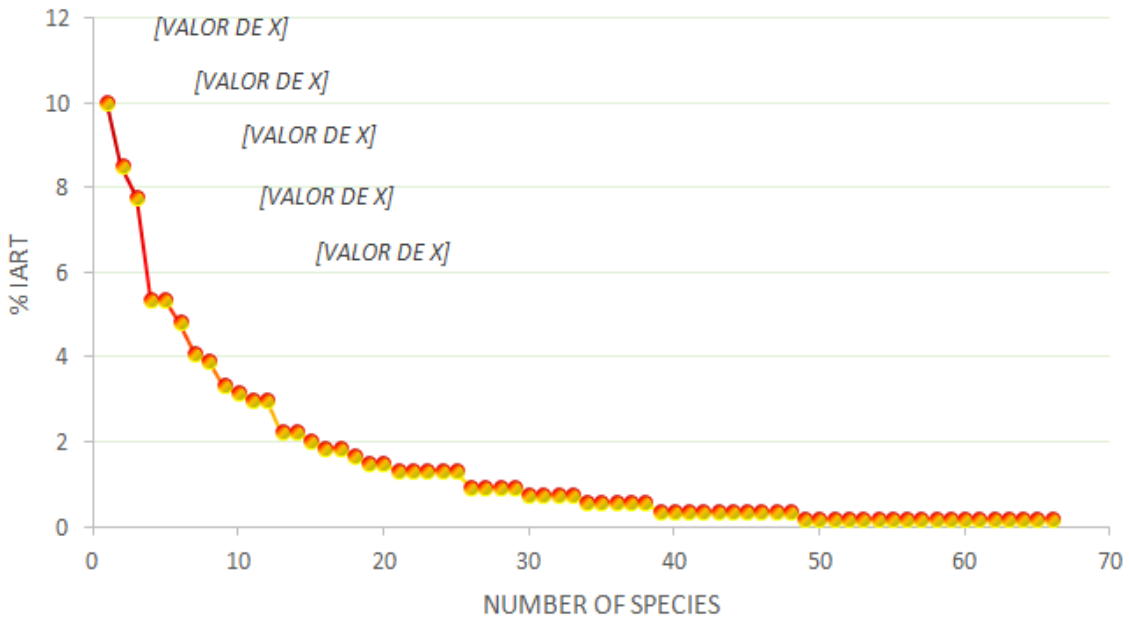

Fig. 2. Abundance curve for the species recorded in the monitoring of Rancho Torreón del Molino. The 5 most abundant species are shown

Table 1. List of birds recorded with the transect method in Rancho Torreón del Molino, state of Veracruz, from the American Ornithologists' Union (aou 1998), using the latest supplement (Chesser et al., 2017)

Order	Family	Genus	Species	Nom-059	Iucn	Resident?	Individuals
Anseriformes	Anatidae	Dendrocygna	*Dendrocygna autumnalis*	SC	LC	R	4
Galliformes	Odontophoridae	Colinus	*Colinus virginianus*	SC	NT	R	2
Columbiformes	Columbidae	Patagioenas	*Patagioenas flavirostris*	SC	LC	R	1
	Columbidae	Streptopelia	*Streptopelia decaocto*	SC	LC	R	1
	Columbidae	Columbina	*Columbina inca*	SC	LC	R	4
	Columbidae	Columbina	*Columbina passerina*	SC	LC	R	2
	Columbidae	Columbina	*Columbina talpacoti*	SC	LC	R	5
Cuculiformes	Cuculidae	Crotophaga	*Crotophaga sulcirostris*	SC	LC	R	9
Charadriiformes	Jacanidae	Jacana	*Jacana spinosa*	SC	LC	R	2
Pelecaniformes	Ardeidae	Bubulcus	*Bubulcus ibis*	SC	LC	R	4
	Ardeidae	Butorides	*Butorides virescens*	SC	LC	R	1
Cathartiformes	Cathartidae	Coragyps	*Coragyps atratus*	SC	LC	R	5
	Cathartidae	Cathartes	*Cathartes aura*	SC	LC	R	1
Accipitriformes	Accipitridae	Rupornis	*Rupornis magnirostris*	SC	LC	R	1
Piciformes	Picidae	Melanerpes	*Melanerpes aurifrons*	SC	LC	R	5
	Picidae	Dryobates	*Dryobates scalaris*	SC	LC	R	1
Falconiformes	Falconidae	Caracara	*Caracara cheriway*	SC	LC	R	1
	Tyrannidae	Pitangus	*Pitangus sulphuratus*	SC	LC	R	6
	Tyrannidae	Myiozetetes	*Myiozetetes similis*	SC	LC	R	5
	Tyrannidae	Myiodynastes	*Myiodynastes luteiventris*	SC	LC	MV	2
	Tyrannidae	Tyrannus	*Tyrannus melancholicus*	SC	LC	R	3
	Tyrannidae	Pyrocephalus	*Pyrocephalus rubinus*	SC	LC	R	1
	Hirundinidae	Stelgidopteryx	*Stelgidopteryx serripennis*	SC	LC	R	24
	Troglodytidae	Campylorhynchus	*Campylorhynchus zonatus*	SC	LC	R	4
	Turdidae	Turdus	*Turdus grayi*	SC	LC	R	2
	Icteridae	Sturnella	*Sturnella magna*	SC	LC	R	2
	Icteridae	Icterus	*Icterus spurius*	SC	LC	MI	2
	Icteridae	Icterus	*Icterus gularis*	SC	LC	R	1
	Icteridae	Agelaius	*Agelaius phoeniceus*	SC	LC	R	1
	Icteridae	Molothrus	*Molothrus aeneus*	SC	LC	R	6
	Icteridae	Dives	*Dives dives*	SC	LC	R	2
	Icteridae	Quiscalus	*Quiscalus mexicanus*	SC	LC	R	24
	Thraupidae	Thraupis	*Thraupis episcopus*	SC	LC	R	1
	Thraupidae	Volatinia	*Volatinia jacarina*	SC	LC	R	1
	Thraupidae	Sporophila	*Sporophila morelleti*	SC	LC	R	8

Table 2. List of birds of the Rancho Torreón del Molino, state of Veracruz, from the American Ornithologists' Union (aou 1998), using the latest supplement (Chesser et al., 2017)

Order	Family	Genus	Species	Nom-059	IUCN	Resident?
Columbiformes	Columbidae	Columbina	Columbina inca	SC	LC	R
	Columbidae	Columbina	Columbina passerina	SC	LC	R
	Columbidae	Columbina	Columbina talpacoti	SC	LC	R
	Columbidae	Leptotila	Leptotila verreauxi	SC	NT	R
Cuculiformes	Cuculidae	Crotophaga	Crotophaga sulcirostris	SC	LC	R
Apodiformes	Trochilidae	Anthracothorax	Anthracothorax prevostii	SC	LC	R
	Trochilidae	Archilochus	Archilochus colubris	SC	LC	R
	Trochilidae	Amazilia	Amazilia yucatanensis	SC	LC	R
Strigiformes	Strigidae	Glaucidium	Glaucidium brasilianum	SC	LC	R
Piciformes	Picidae	Melanerpes	Melanerpes aurifrons	SC	LC	R
Passeriformes	Tityridae	Pachyramphus	Pachyramphus aglaiae	SC	LC	R
	Tyrannidae	Camptostoma	Camptostoma imberbe	SC	LC	R
	Tyrannidae	Myiarchus	Myiarchus crinitus	SC	LC	T
	Tyrannidae	Pitangus	Pitangus sulphuratus	SC	LC	R
	Tyrannidae	Myiozetetes	Myiozetetes similis	SC	LC	R
	Tyrannidae	Empidonax	Empidonax flaviventris	SC	LC	MI
	Tyrannidae	Empidonax	Empidonax alnorum	SC	LC	T
	Tyrannidae	Empidonax	Empidonax trailli	SC	LC	T
	Tyrannidae	Empidonax	Empidonax minimus	SC	LC	MI
	Tyrannidae	Sayornis	sayornis phoebe	SC	LC	MI
	Vireonidae	Vireo	Vireo griseus	SC	LC	MI
	Vireonidae	Vireo	Vireo flavifrons	SC	LC	T
	Vireonidae	Vireo	Vireo solitarius	SC	LC	MI
	Vireonidae	Vireo	Vireo olivaceus	SC	LC	T
	Hirundinidae	Stelgidopteryx	Stelgidopteryx serripennis	SC	LC	R
	Troglodytidae	Troglodytes	Troglodytes aedon	SC	LC	MI
	Troglodytidae	Campylorhynchus	Campylorhynchus zonatus	SC	LC	R
	Troglodytidae	Campylorhynchus	Campylorhynchus rufinucha	A	LC	R
	Polioptilidae	Polioptila	Polioptila caerulea	SC	LC	R
	Turdidae	Catharus	Catharus ustulatus	SC	LC	MI
	Turdidae	Hylocichla	Hylocichla mustelina	SC	NT	T
	Turdidae	Turdus	Turdus grayi	SC	LC	R
	Mimidae	Dumetella	Dumetella carolinensis	SC	LC	MI
	Fringillidae	Euphonia	Euphonia affinis	SC	LC	R
	Fringillidae	Euphonia	Euphonia hirundinacea	SC	LC	R
	Icteriidae	Icteria	Icteria virens	SC	NT	MI
	Icteridae	Icterus	Icterus spurius	SC	NT	MI
	Icteridae	Icterus	Icterus gularis	SC	NT	R
	Icteridae	Icterus	Icterus galbula	SC	NT	MI
	Icteridae	Molothrus	Molothrus aeneus	SC	LC	R
	Parulidae	Seiurus	Seiurus aurocapilla	SC	LC	MI

Order	Family	Genus	Species	Nom-059	IUCN	Resident?
	Parulidae	Helmitheros	Helmitheros vermivorum	SC	LC	MI
	Parulidae	Parkesia	Parkesia noveboracensis	SC	LC	MI
	Parulidae	Vermivora	Vermivora cyanoptera	SC	LC	T
	Parulidae	Mniotilta	Mniotilta varia	SC	LC	MI
	Parulidae	Limnothlypis	Limnothlypis swainsonii	Pr	LC	T
	Parulidae	Leiothlypis	Leiothlypis celata	SC	NT	MI
	Parulidae	Leiothlypis	Leiothlypis ruficapilla	SC	NT	MI
	Parulidae	Geothlypis	Geothlypis tolmiei	SC	LC	MI
	Parulidae	Geothlypis	Geothlypis philadelphia	SC	LC	T
	Parulidae	Geothlypis	Geothlypis trichas	SC	LC	MI
	Parulidae	Setophaga	Setophaga citrina	SC	LC	T
	Parulidae	Setophaga	Setophaga ruticilla	SC	LC	MI
	Parulidae	Setophaga	Setophaga americana	SC	LC	MI
	Parulidae	Setophaga	Setophaga magnolia	SC	LC	MI
	Parulidae	Setophaga	Setophaga petechia	SC	LC	MI
	Parulidae	Cardellina	Cardellina canadensis	SC	LC	T
	Parulidae	Cardellina	Cardellina pusilla	SC	LC	MI
	Cardinalidae	Piranga	Piranga rubra	SC	LC	MI
	Cardinalidae	Piranga	Piranga olivacea	SC	LC	T
	Cardinalidae	Pheucticus	Pheucticus ludovicianus	SC	LC	MI
	Cardinalidae	Passerina	Passerina cyanea	SC	LC	MI
	Cardinalidae	Passerina	Passerina ciris	Pr	NT	MI
	Thraupidae	Volatinia	Volatinia jacarina	SC	LC	R
	Thraupidae	Sporophila	Sporophila morelleti	SC	LC	R
	Thraupidae	Saltator	Saltator coerulescens	SC	LC	R

The resident species Bulbulcus ibis and Fulica americana have been identified as carriers of the West Nile pathogen [38] in a site located 54 miles from the research area, the Alvarado lagoon, located at 30 m.a.s.l, 18.8089° N and 95.8330° W; thus, it is possible to have a potential health risk for the animal and human population. Chao 1, which is based on abundance data, was used in the estimation of species richness; this estimator counts with a database of 80 species, which indicates that, according to the results of the recordings (n = 66), 14 species were not found in the sampling site (Fig. 3).

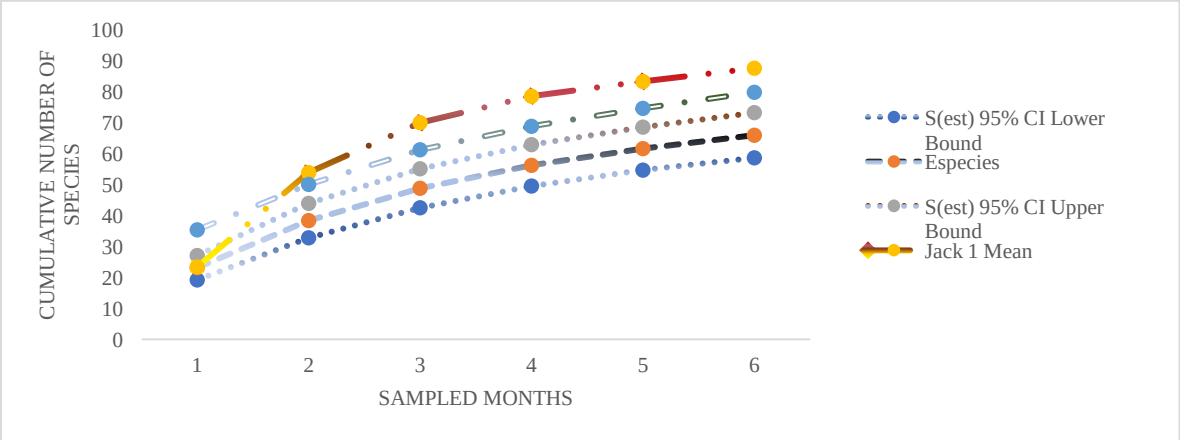

Fig. 3. Species accumulation curve of the sampling at Rancho Torreón del Molino

4. DISCUSSION

There have been major changes in the abundance and richness of bird species due to the disturbance of forest habitats [48-51], nonetheless, and even when Rancho Torreón del Molino only houses a small conservation area thanks to its agroforestry system, the diversity of its avian fauna represents 9.17% of the total diversity found in Veracruz state [33], which shows its major importance for bird conservation. Proof of this is the fact that the study recorded Campylorhynchus rufinucha rufinucha, a threatened subspecies of wren which is considered to inhabit the central coast region of Veracruz state, on the Atlantic watershed of Mexico [41], and Geothlypis tolmiei, plus 2 species subjected to special protection by the NOM-059-SEMARNAT-2010 standard, 9 species included in the Near Threatened IUCN category, 28 winter migratory species, and 12 transient species.

This study reported similar diversity findings in an anthropic environment in the central region of the state, where the bird population of urban gardens was compared with that of rural land plots, and it was found that the family Parulidae was the most abundant as well. Upon performance of a rarefaction analysis, the population of rural land plots showed greater species richness than in urban gardens, and it also indicated that, in general, the studied anthropic environment gives safe shelter to 7 endangered species. Regarding site character, a greater number of species has been reported in regenerating forest areas than in pasture land and mature forest areas [52]. When various migratory patterns of S. Platycercos, studying, in Veracruz, Hernández – Hernández et al. [53], found evidence that suggests that the movements of the populations of said species would be influenced in a differentiated way by climatic variations, according to seasonality and distribution. The presence of resident and migratory birds cohabitating with farm animals and humans, due to the educational and research activity on the site, requires observation of the standard precautions for the prevention of the transmission of zoonotic diseases among the research staff, recommended by competent collegiate organizations [54]. Mancuso et al. [55], determined for Yellow-breasted Chat (*Icteria virens, chat*), an endangered specie in British Columbia, its precise migration routes, breeding and non-breeding sites, as well as types of vegetation cover habitat and the route carried out after reproducing in various latitudes, through Veracruz and Chiapas.

The presence of endemic species is considered as low, because they represent only 1.5% of the total records of the study, while migratory species represent 39.4%, summer migratory birds represent 1.5%, resident species represent 36.4%, transient species represent 19.7% and 3% for out-of-range species.

The important role of forest transition zones in the conservation of birds in the northern Neotropical zone, with gradients of plant disturbance, has been considered, for which it has been recommended to improve management in Neotropical landscape zones. These areas were modified by man, as in the case of the area where this research was carried out, which leads us to recommend that in these remaining forest fragments, generally located in the vicinity of residential areas and large masses of primary forest, prevail a habitat quality enhancement approach. This approach will prevent the loss of species and ecosystem services from these sites; Likewise, it will allow to maintain preserved areas and away from the composition of local communities [56].

Notwithstanding the proximity of populated areas, the species diversity of the studied area demonstrates the importance of sylvo-pastoral systems for the development of sites for the sheltering, feeding and repose of migratory and resident bird species, which guarantee the preservation of the abundance of these communities [57-61].

5. CONCLUSION

This study shows that the site, a school farm with a silvopastoral system, located within the urban sprawl of the city and seaport of Veracruz, is extremely important for migratory birds, thanks to the fact that it provides shelter, food, and protection, such as this is the case of the species like *Dumetella carolinensis*, which travels more than 3 thousand km to its hibernation places, which allows the site to be a key resting point for migratory birds.

ETHICAL APPROVAL

This study was carried out according to the guidelines of National Research Council Guide and in accordance with the principles of Good Laboratory procedure (GLP) following approval of the Institutional Ethical Committee on the Use and Care of Animals.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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