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ARTÍCULO

The observation of birds from a citizen science leisure project to systematic research: Contributions of a 10-year record in the state of Chihuahua, Mexico

[es] La observación de aves desde un proyecto de ocio de ciencia ciudadana a la investigación sistemática: Aportes de un registro de 10 años en el estado de Chihuahua, México

Fidel González-Quiñones[1a]; Luis Roberto Granados-Campos[2]; José Manuel Jurado-Ruiz[3]; Javier Tarango[1b]; Juan D. Machin-Mastromatteo[1c]; José Refugio Romo-González[1d]; Katherine Howard[4]

[1 a, b, c, d] Universidad Autónoma Chihuahua (México); [2]Universidad Veracruzana; [3]Secretaría de Turismo de Chihuahua; [4]University of South Australia (Australia) y Digital Research Analyst, Intersect Australia

1a| 2| 3| 1b| 1c| 1d| 3| 4

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ABSTRACT

This article analyses historical data from observations made of birds in breeding season, throughout two routes with urban characteristics. The data were collected during a consecutive period of 10 years (2009-2018), following a precise methodology designed by the North American Breeding Bird Survey. The analyzed routes are officially registered in the Mexican Commission for Biodiversity's Knowledge and Use, the United States Geological Survey Patuxent Wildlife Research Center, and the Canadian Wildlife Service Research Centre. The observations were made by citizens without formal professional education; hence the results may be considered within the framework of citizen science. Their contributions provided important data for decision-making regarding environmental issues, since the presence of birds is considered one of the main indicators of the health conditions of an ecosystem. Data analysis identified two basic conditions: (1) a reduction of the 23% in the number of species found, many of which disappeared during counting; and (2) the significant increase in population of other species, including three species of pigeons. Apart from the study of variations in the numbers of bird species present in the routes with urban characteristics, the article acknowledges the lack of connection and use of this citizen science for decision-making and education regarding environmental issues. Therefore, we consider it crucial to create scientific observations that are available to both experts in the field and to the general population, which is the essence of citizen science.

KEYWORDS

Birdwatching, citizen science, environmental impact, urban areas, ecosystems, Chihuahua (Mexico).

RESUMEN

El presente artículo analiza los datos históricos de las observaciones realizadas de aves en reproducción provenientes de dos rutas con características urbanas, registradas oficialmente en la Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), la United States Geological Survey Patuxent Wildlife Research Center y Canadian Wildlife Service Research Centre durante un periodo consecutivo de 10 años (2009-2018) siguiendo una estricta metodología diseñada por North American Breeding Bird Survey. Las observaciones fueron realizadas por ciudadanos sin una preparación académica profesional por lo que los resultados pueden considerarse dentro del marco de la ciencia ciudadana, quienes aportaron datos importantes para la toma de decisiones en cuestiones ambientales, esto debido a que la presencia de aves se identifica como uno de los principales indicadores sobre el estado de salud de un ecosistema. El análisis de datos identifica dos condiciones fundamentales: (1) la presencia de una disminución del 23% en el número de especies encontradas, habiendo desaparecido en los conteos varias de ellas; y (2) el notable incremento en el alza de población de otras especies, entre ellas tres de palomas. Además del estudio del comportamiento de aves en rutas con características urbanas, en el artículo se reconoce la falta de vinculación y uso de la información generada por el monitoreo para la toma de decisiones y educación en materia medioambiental, por lo que se considera estratégico la generación de observatorios científicos, accesibles tanto a expertos en el tema como a la población en general, teniendo como punto culminante la generación de ciencia ciudadana.

PALABRAS CLAVE

Obseración de aves, ciencia ciudadana, impacto ambiental, áreas urbanas, ecosistemas, Chihuahua (México).

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Introduction

Birdwatching is an activity where a person or a group of people meet to identify wild or feral birds that live in a specific environment. The main characteristics of birdwatching are: (1) it can be performed by amateurs or experts; (2) it is not mandatory to have specialized or scientific training; and (3) it can be initiated with a relatively small financial investment. When the birdwatching activity is performed by amateurs who systematically document and record what they see and the relevant environmental conditions, it can be considered to be 'citizen science' – that is, scientific research that is conducted either partially or fully by non-professional scientists (Manzano, 2019). Many citizen scientists are retirees, children, or professionals not connected with this field, such as doctors, architects, chemists, engineers, entrepreneurs and geographers (Gómez & Alvarado, 2011). However, some birdwatchers do have enough technical training and knowledge to perform activities that are based on scientific methodology, for example, monitoring regular routes to report the influence of birds in a specific location (Ramírez, 2016).

To ensure minimal interaction with the fauna and the bird watching sites, birdwatchers restrict themselves to record their observations with photographs, notes, and videos and audio recordings. They may also use simple manuals and guides that encourage members of the public who intend to conduct birdwatching as citizen scientists to conduct such tasks in a certain manner (Ehrlich, Dobkin & Wheye, 1988).

Despite being a relatively new term, the public participation in scientific research is not a new activity. Amateur contribution to scientific discovery can arguably be traced back to Galileo (Cornell Lab of Ornithology, 2019) and the so-called 'Cabinets of Curiosity', popular with gentlemen scholars and the leisure class throughout the 16th, 17th and 18th centuries (Impey and MacGregor, 1985; Waibel and Erway, 2009). However, there are documented cases of what could realistically be considered citizen science dating back to 1804 with American John Audabon's discovery that the Eastern Phoebes bird returns to the same nesting place each year (Planetary Science Institute, 2019); Mary Annings' discoveries of dinosaur skeletons and excrement in 1815 (Planetary Science Institute, 2019); and Wells Cooke ornithological work from the late 1800s (National Geographic, 2019).

Citizen science can take one of several approaches (Roy et al., 2012). 'Contributory citizen science' is perhaps the most popular approach and is used by professional scientists who engage volunteers to collect - or contribute - data for a specific project. Another approach, and the type undertaken to create the dataset reported on in this paper, is when a non-professional scientist documents and records observations for personal enjoyment.

As with any scientific method, there are advantages and disadvantages to using data collected by citizen scientists. The major advantages are the sheer amount of data able to be collected in a cost-effective manner, particularly in the case of contributory citizen science referred to above; the potential for long-term monitoring by committed citizen scientists; it can enhance the well-being of the participants; and increase the awareness of environmental issues in the participants' local area. Indeed, it has been pointed out that collecting data from species' presence, particularly birds, are important to assess biodiversity changes (Boakes, 2010) and the impact of human populations and settlements on species and their habitats (Snäll, 2010). Issues of data quality have been raised, however if data are collected within acceptable guidelines and protocols, and with appropriate quality assurance, "it is eminently suitable for regulatory purposes" (Pocock et al., 2014, p. 5).

Much of the literature covering the disadvantages associated with citizen science is often based on the contributory citizen science approach (Pocock et al., 2014; Freitag et al., 2016), although some disadvantages are also applicable to those citizen scientists who collect data for personal enjoyment. The most frequently cited objections concern data quality and biases (Geoghegan et al., 2016).

Biases in citizen science can take many forms. It can include bias in the participants, for example, those who are older and more highly educated (Trumbull et al., 2000); white males with high incomes

(West et al., 2015; Wright et al., 2015); or white females with high incomes (Crall et al., 2013). Biases can also take the form of the quality of the equipment used, the inference being that low-quality equipment leads to the collection of low-quality data (Geoghegan et al., 2016). Related to this is the requirement for specialized data to be collected using specialized equipment, which may be beyond the abilities of the citizen scientist. If this specialized equipment incorporates aspects of technology, this can introduce a further bias, as not all citizen scientists are tech-savvy.

This is by no means an exhaustive list of the potential biases in data collected by citizen scientists, but it is crucial to note that *any* form of science, whether conducted by citizen scientists or professional scientists is subject to some form of bias (Haklay, 2015). Even in data collected by professional scientists there can be a failure to recognize errors, biases and uncertainty (Bird et al., 2014).

The research being reported on in this paper used an established protocol from the United States Geological Survey Patuxent Wildlife Research Center (USGSPWRC) and the Canadian Wildlife Service Research Centre (CWSRC) (USGSPWRC, 1998). The protocol is discussed in more detail in the Materials and Methods section. The data were collected over a period of ten years by the third named author on this paper, who enjoys birdwatching as a hobby. The remaining Mexican authors came together to systematize and perform this first analysis of the dataset. By making this dataset available, it is anticipated that the results from this analysis may be used in cross-examination and correlation with other datasets, such as population, economic, and climate data. It may also serve to promote birdwatching in this region, raise awareness of its importance and perhaps even entice people or organizations to provide financial support to increase birdwatchers and hence gather more detailed or extensive data. This may enable birdwatchers to conduct monitoring after sunset; to gather data about what species are active at night; and to monitor birds during the non-breeding season. Interestingly, from the end of 2018, there has been a renewed interest from the authorities at the Mexican National Council of Science and Technology (CONACYT) to develop meaningful citizen science initiatives through collaboration with national researchers. They are also establishing a scientific agenda more centered on national issues, the environment and sustainable development, reflecting the Millennium Development Goal 7 of the World Health Organization (WHO, 2019).

Urban infrastructure and bird observation

In the context of a primarily urban modern society, 74.2% of the Mexican population lives in cities of more than fifteen thousand inhabitants (Secretaría de Desarrollo Agrario, 2018). Under such conditions, it becomes necessary to raise awareness and to educate people regarding sustainable development, by carrying out activities such as the systematic and participative observation of the ecological dynamics in populations such as birds. As people learn about the coexistence of avian life in their cities, they begin to promote the need to improve the environment, such as encouraging the conservation of species and ensuring cities are suitable habitats for other living beings, not just humans (Tejeda & Medrano, 2018).

Although there are limited, supported options for developing activities related to environmental issues in Mexico, it is important to point out that the activities that do emerge are from voluntary initiatives. This includes the case of those participating in the observation of birds: the activities are mainly conducted because of the aesthetic satisfaction and personal interest, along with the enjoyment of interacting with the birds, the environment and other participants. Before the 2000s, some strategies existed for the conservation of the species observed, as well as for developing and disseminating knowledge about the environmental impact of the anthropogenic activities in the local, regional and global level (Villaseñor & Santana, 2002). As we mentioned before, there is now a renewed will for promoting citizen science by having researchers collaborate with the non-professional scientists.

The study and tracking of birds in urban and semi urban environments has become more popular for different reasons, including the closeness of the observation sites to the watchers' homes (Orbe, Quispe, Pezo & Acosta, 2016); the opportunity to become familiar with the species of the area and identifying their main characteristics (Sanabria & Sosa, 2018); and learning about the urban features and their influence in bird species' presence, for instance in desert environments (Johnston, Macías & Castillo, 2015).

In our review of the literature, we identified several birdwatching projects in urban and semi-urban areas. One such example is in the town of Sitio Ramsar Vado de Meoqui, located within an urban area within the state of Chihuahua. The town has a record of serious damage in its ecology, due to inappropriate urban planning and human activities that produce waste and contamination (Moreno, 2018). After monitoring regular routes both annually and periodically in order to report the movement of birds, the town was declared a protected area under an international environmental agreement that enforces the conservation and rational use of the wetlands through local, regional and national actions (Institute for Environmental Diplomacy, 2015).

Similarly, the city of Guayaquil in Ecuador identified 130 species of birds in a study that lasted 20 months. With this data, the city's authorities were able to plan and build appropriate infrastructure, such as pathways, tourist facilities, viewpoints, piers and accessible infrastructure that took into account what was required for the birds to co-exist in an urban area, which plays an important role in the environmental education of Guayaquil's residents (López, Ruiz & Arellano, 2017).

Another example where data on the observation of birds has led to a proposal for environmental education is in the protected natural areas of the Parque Natural Municipal de Saltos Küpper and the Reserva Privada de Vida Silvestre Virgen de Paticuá in the town Eldorado, Colombia. The data collection in this case was supported by citizen scientists (Palavecino et al., 2016).

In Mexico, government institutions work methodically with bird observation. For example, the Commission for Biodiversity's Knowledge and Use (CONABIO) fosters birdwatching by funding the people who are involved in it. The data gathered in these supported monitoring activities identify the density of birds' population and health indicators of the ecosystems, such as the rise or fall on the number of individuals for a specific species. The data also assists in detecting environmental alteration elements, such as droughts or groundwater depletion, harmful fertilizers, and the commerce or illegal trade of species (Sánchez-Aizcorbe, 2017). Birdwatching data was recently included in a legal environmental study related to the construction of the new airport in Mexico City. One hundred and thirty-one different species of birds were reported to exist within the construction area. This is extremely valuable data, not only from the perspective of conserving the habitat of these birds, but also from the safety perspective of airline passengers and crew, given the damage that can be caused by a flock of birds flying into an aircraft's engine (Pérez, 2019).

In the particular case of the state of Chihuahua, the scenario of the present study, we identified the following studies: (1) in the Ramsar zone known as 'Vado de Meoqui' in the riverbed of Río San Pedro, where the authors studied species' richness, taxonomic distinctness and conservation (Mondaca-Fernández, 2017); (2) the identification of 30 species of birds through a study of variability about the frequency of sighting of seabirds, in relation to the months of year (Ramírez, 2016); and (3) the observation of species of little frequency through 36 points of observation (Moreno-Contreras, 2016); and (iv) the observation of birds through the presence of nests and hatchings of the American avocet (Recurvirostra americana), which was considered a species present in the area as a result of migration (Venegas, 2015).

Materials and Methods

The current study was conducted in the city of Chihuahua, capital of the state of Chihuahua to the north of Mexico, neighboring with the United States. The two monitoring routes where the observations were made were previously vast desert regions that have suffered many changes during the last 90 years. In 1935, the area was created as the Delicias municipality. The area gained rapid agricultural importance, and in 1932 it was established as the main irrigation point to harness the water of the Conchos river. In

1949, the Francisco Madero Dam was built, which enabled the development of large agricultural and livestock activities. This led to the establishment of urban and semi-urban settlements, and an increase of the population and human infrastructures. Between 2011 and 2012 there was a light drought (Ortega-Gaucin, 2013), and interestingly, our data indicates that the sightings of many of species diminished after this weather event.

The count of bird species' presence is conducted yearly at the exact same 50 observation points that have been marked by GPS. This is something strongly recommended in the specialized literature (Boakes, 2010), and by the observation protocol used, which is intended for conducting North American breeding bird surveys, designed by the USGSPWRC and the CWSRC (USGSPWRC & CWSRC), which details observation requirements and the methods used to collect data, including which birds to count and the variables that should be measured, as well as how to observe birds and how to establish observation rotes (USGSPWRC, 1998). These two institutions have provided training to the personnel from CONABIO, the same organization that trained our bird watcher (Author 3). Apart from receiving such training, he keeps up to date by frequently studying documents and tutorials from the USGSPWRC. Moreover, as bird observation cannot rely exclusively on eyesight, observers have access to diverse multimedia resources such as those offered by the Mexican Birds Sound Library (Instituto Nacional de Ecología, 2019).

This research was based on birdwatching data gathered during 10 continuous years (2009-2018) in two semi urban routes of observation located in the state of Chihuahua. These routes are registered by CONABIO, the USGSPWRC, and the CWSRC: La Regina (code 058) and Santa Mónica (code 059).

The routes were established by following the cited USGSPWRC-CWSRC protocol, which recommends dividing routes at 0.8 km intervals, which gives a total of 50 observation points (or stops). Hence, each of the studied routes are 40 kilometers long and each consists of 50 monitoring stops every 800 meters. Each stop was officially established by setting their GPS coordinates, a physical description of it and each site presents visible marks for ensuring that they are easily identifiable every year. Both routes pass through one urban area and another semi urban area, thus they are habitats that are directly influenced by human activities, such as dwellings, agricultural and familiar vehicles, parks, gardens, croplands, and irrigation ditches. La Regina is the most affected by land use change. La Regina is completely within an urban area, while a quarter of Santa Mónica passes through such area.

Record monitoring starts at 5:30 am and ends at 12:30 pm, which enables all 50 monitoring stops from one route to be covered in one day. Therefore, yearly observations take two days to conduct for the two routes and so each stop was visited and monitored once per year. The time spent at each stop is exactly 3 minutes, which is counted with a stopwatch. This time is used to detect and record the presence of birds by their sight and sound (by hearing their characteristic sounds) of the species present in a perimeter of 400 meters from the stop. Apart from the presence of species, records made by the birdwatcher contain temperature (°F), wind speed (mph), and sky conditions (clear, partially cloudy, mostly cloudy, cloudy, cloudy with rain). This protocol was repeated annually, starting at the same point and at the same time, to maintain uniformity in sampling conditions. Also, monitoring was made every year within the period of May-July, when the breeding season starts and migratory species have already travelled to their nesting places, thus decreasing the possibility of sighting species that are not from the area.

After yearly records are ready, the birdwatcher uploads the data to CONABIO, the USGSPWRC and the CWSRC. These three organizations share this data due to the migration of bird species among the three countries of Mexico, Canada, and the United States of America. However, there have not been efforts to analyze the data of these two routes until this research.

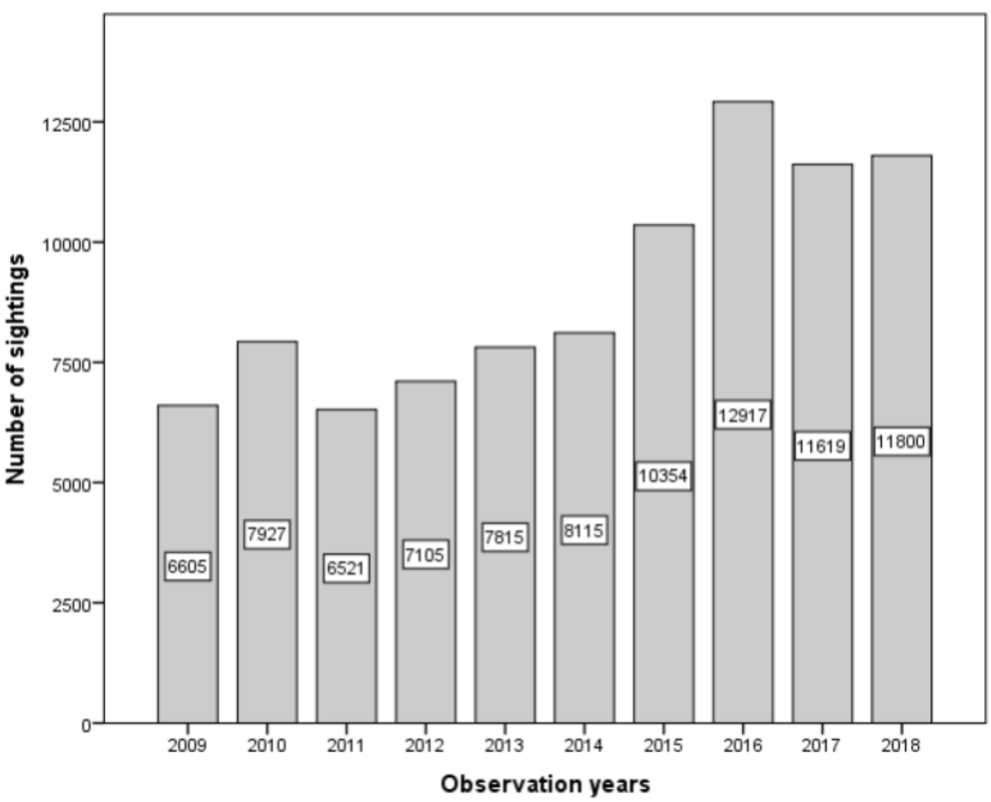
Although experts claim that it is an advantage to use long-term monitoring data for assessing species' presence (Szabo et al., 2010) and this is one of the strengths of the data we collected, there are some limitations of our data that must be acknowledged. Given that each stop and route are visited only once per year, data from this kind of survey that centers in recording species' presence becomes much more accurate if repeated visits to the sites are made per year, as they improve confidence intervals and detecting weak trends (Snäll, 2010). Hence, the importance of drawing attention to the study of this region, so more than one birdwatcher can monitor these routes increasing the yearly visits, and then develop further research with more data that can allow estimating population numbers and other complex trends that are hard to estimate with the current data. Other limitations pointed out in the literature deal with the tendency of changing the interest in monitoring only certain species over time (Snäll, 2010) or the bias of just recording data from endangered or popular species (Boakes, 2010). However, the only bias present in this research, was the issue of a single yearly measurement per site.

Analysis of the results

Data were transcribed into a Microsoft Excel spreadsheet from the field annotations of the trained observer (Author 3). Once the data were reviewed and normalized, they were exported to IBM SPSS Ver. 24, which allowed to conduct the statistical analyses presented in this article. We carefully checked the correlations and significance levels, to prevent the risk of reproducing data transcription errors.

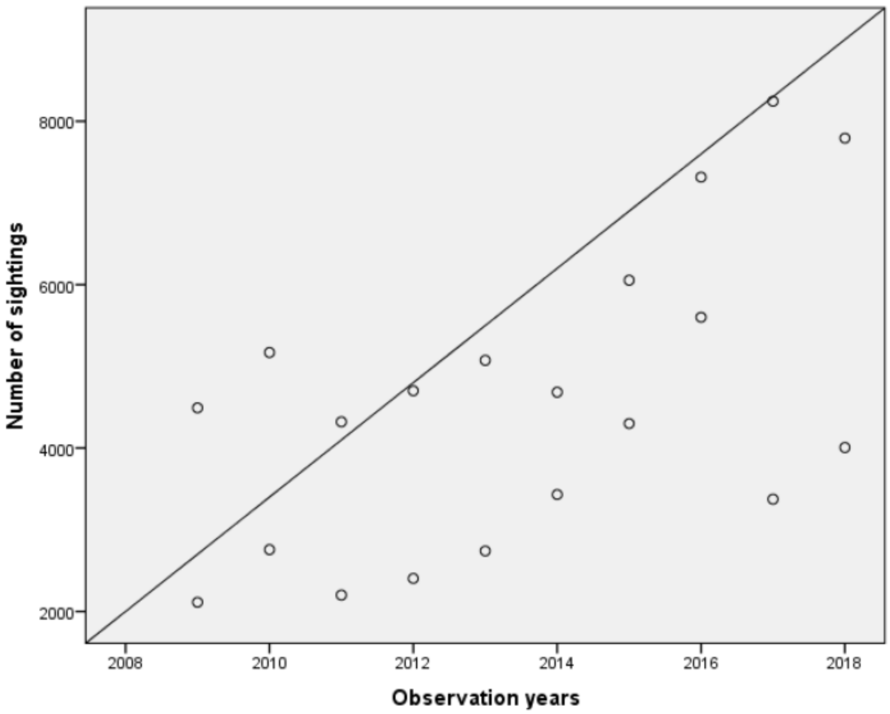
The descriptive analysis of the species found was made from the global data of both routes observed, with its corresponding correlations; using tables and graphics by route, which show the increase and decrease of species, as well as an analysis by number of species. During the 10-year period, a total of 139 species were identified and observed in both routes. Supplementary material submitted with this article compiles species common names in English, their scientific names, and the number of sightings per species from 2009 to 2018; this work allowed determining each species' presence in both routes. There was a continuous increase in the total observations, except for the years 2010 and 2016, a period in which the results were more representative in terms of growth (Fig 1).

Figure 1. Longitudinal changes in species' sightings within both routes from 2009 to 2018.



Data exhibit a rising tendency regarding data dispersion as the years pass by (Fig 2).

Figure 2. Dispersion of data.



The Pearson correlation, taking into account both routes and between the variables 'year' and 'total sightings', was of r=.569. This indicates a low correlation level. However, the significance was of .009, which corresponds to a high significance (Table 1).

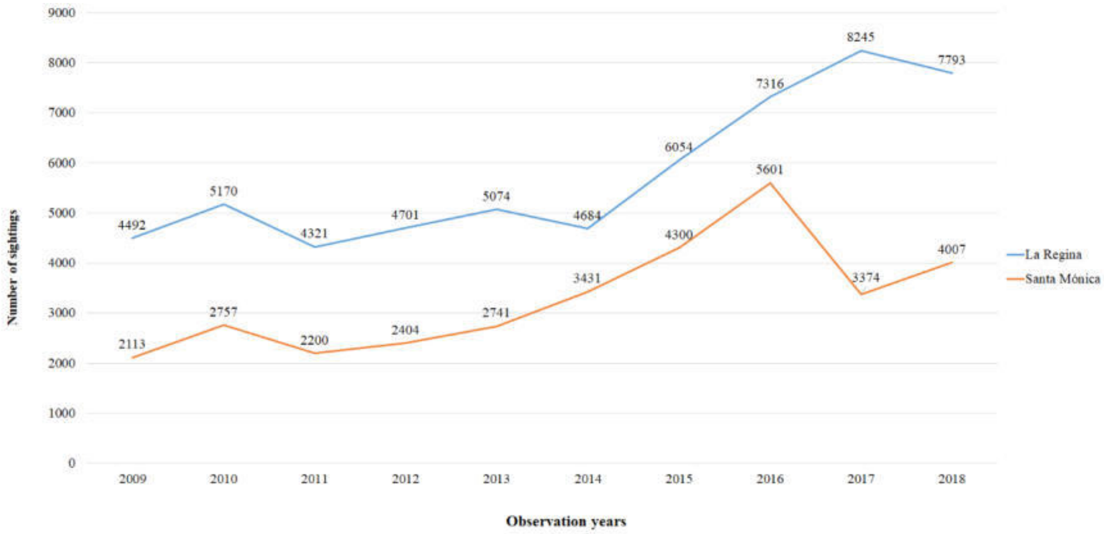
Table 1. *Correlation between the variables 'year' and 'total sightings'*

		Year	Total sightings
Year	Pearson Correlation	1	.569**
	Sig. (2-tailed)		.009
Total sightings	Pearson Correlation	.569**	1
	Sig. (2-tailed)	.009	

** Correlation is significant at the 0.01 level (2-tailed).

When analyzing the data by route, we observed a similar tendency regarding the increase of the total number of sightings per year (Fig 3).

Figure 3. Number of sightings per route



When correlating the variables of total sightings against year, La Regina route shows a Sig. of .001, with a correlation coefficient r=.869 (very high) and for Santa Mónica, Sig. is .013 and its correlation coefficient is of r=.748 (high). These data are shown in Table 2.

Table 2. *Correlations between both observation routes*

Route			Year	Total sightings
La Regina	Year	Pearson Correlation	1	.869**
		Sig. (2-tailed)		.001
	Total sightings	Pearson Correlation	.869**	1
		Sig. (2-tailed)	.001	
Santa Mónica	Year	Pearson Correlation	1	.748*
		Sig. (2-tailed)		.013
	Total sightings	Pearson Correlation	.748*	1
		Sig. (2-tailed)	.013	

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Increase and decrease of species during the evaluated period

We calculated correlations between sightings and both observation routes, and we found significant relations with 30 species. In the cases where the correlation value is negative, it means that sightings decreased, and vice versa. Although there are species that underwent relevant changes in only one of the routes, in most of the cases such changes happened in both routes. The species whose common names in English show a '*' at the beginning indicate that they were identified in the monitoring, but they were not included in the initial observation lists. Such treatment is maintained throughout this paper. Data presented in Table 3, identifies the main species to analyze for each route. In the case of La Regina, six species had a decrease in sightings per year and 15 species showed an increase. In Santa Mónica, eight species decreased and 16 increased.

Table 3. *Increase and decrease of sightings per species by route*

La Regina route: Species with a decrease in sightings		
Species	**Pearson Correlation**	**Sig. (2-tailed)**
Common ground dove (Columbina passerina)	-.915**	0
Cassins sparrow (Peucaea cassinii)	-.909**	0
Ruddy ground dove (Columbina talpacoti)	-.847**	0.002
Common pauraque (Nyctidromus albicollis)	-.710*	0.021
*Virginiarail (Rallus limicola)	-.699*	0.025
Ruf crowned sparrow (Aimophila ruficeps)	-.654*	0.04
La Regina route: Species with an increase in sightings		
Species	**Pearson Correlation**	**Sig. (2-tailed)**
Painted bunting (Passerina ciris)	.942**	0
Blue grosbeak (Passerina caerulea)	.926**	0
Red winged blackbird (Agelaius phoeniceus)	.906**	0
White winged dove (Zenaida asiatica)	.887**	0.001
Mourning dove (Zenaida macroura)	.845**	0.002
*Verdin (Auriparus flaviceps)	.831**	0.003
Inca dove (Columbina inca)	.793**	0.006
Gold front woodpecker (Melanerpes aurifrons)	.786**	0.007
*Eurasian collared dove (Streptopelia decaocto)	.768**	0.01
*Blue-gray gnatcatcher (Polioptila caerulea)	.765*	0.01
Yellow breasted chat (Icteria virens)	.749*	0.013
Lark sparrow (Chondestes grammacus)	.708*	0.022
Vermilion flycatcher (Pyrocephalus rubinus)	.688*	0.028
Lesser goldfinch (Spinus psaltria)	.672*	0.033
Yellow billed cuckoo (Coccyzus americanus)	.642*	0.045
Santa Mónica route: Species with a decrease in sightings		
Species	**Pearson Correlation**	**Sig. (2-tailed)**
Common ground dove (Columbina passerine)	-.887**	0.001
Ruf-crowned sparrow (Aimophila ruficeps)	-.863**	0.001
Blk chinned sparrow (Spizella atrogularis)	-.817**	0.004
Northern cardinal (Cardinalis cardinalis)	-.765**	0.01
Indigo bunting (Passerina cyanea)	-.712*	0.021
Ruddy ground dove (Columbina talpacoti)	-.710*	0.021
Chihuahuan raven (Corvus cryptoleucus)	-.663*	0.037
Red shafted flicker (Colaptes auratus)	-.639*	0.047
Santa Mónica route: Species with an increase in sightings		
Species	**Pearson Correlation**	**Sig. (2-tailed)**
Mourning dove (Zenaida macroura)	.940**	0
Red winged blackbird (Agelaius phoeniceus)	.910**	0
White winged dove (Zenaida asiatica)	.861**	0.001
Inca dove (Columbina inca)	.845**	0.002
Curve billed thrasher (Toxostoma curvirostre)	.814**	0.004
Blk throated sparrow (Amphispiza bilineata)	.774**	0.009

Brn headed cowbird (Molothrus ater)	.763*	0.01
Santa Mónica route: Species with an increase in sightings		
Species	**Species**	**Species**
Lark sparrow (Chondestes grammacus)	.747*	0.013
Blue grosbeak (Passerina caerulea)	.740*	0.014
*Eurasian collared dove (Streptopelia decaocto)	.724*	0.018
*Verdin (Auriparus flaviceps)	.714*	0.02
Yellow billed cuckoo (Coccyzus americanus)	.706*	0.022
House sparrow (Passer domesticus)	.685*	0.029
Barn swallow (Hirundo rustica)	.671*	0.034
*Blue-gray gnatcatcher (Polioptila caerulea)	.650*	0.042
Vermilion flycatcher (Pyrocephalus rubinus)	.640*	0.046

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Species with a decrease in sightings

In this section, we present the analysis of the changes in the sightings of species, starting with the ones that shown a dramatic decrease in their numbers, according to the Pearson correlation coefficient and significance. Further information about the species studied can be found in online databases (see www.naturalista.mx/taxa and https://ebird.org). Table 4 shows the number of sightings during each year of the 10-year period for each of the species with a decrease in sightings, together with the sum of sightings per specie and the total of sightings per year for all these species; then, we offer comments about these species' tendencies.

Table 4. *Species with a decrease in sightings*

Species	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Sum
Common ground dove (Columbina passerina)	51	45	35	34	46	12	2	0	0	0	225
Ruddy ground dove (Columbina talpacoti)	24	14	17	18	24	0	2	0	0	0	99
Cassin's sparrow (Peucaea cassinii)	51	113	42	52	52	62	21	21	2	0	416
Rufous crowned sparrow (Aimophila ruficeps)	83	47	41	25	58	0	2	0	0	0	256
Black-chinned sparrow (Spizella atrogularis)	26	25	20	12	42	0	2	0	0	8	135
Indigo bunting (Passerina cyanea)	10	34	17	12	23	0	3	0	2	0	101
Common pauraque (Nyctidromus albicollis)	6	0	4	3	2	0	0	0	0	0	15
*Aztec rail (Rallus tenuirostris)	9	3	1	0	1	0	0	0	0	0	14
Northern cardinal (Cardinalis cardinalis)	88	132	55	25	46	8	6	32	31	11	434
Chihuahua raven (Corvus cryptoleucus)	80	61	45	52	81	62	36	55	4	0	476
Red-shafted Flicker (Colaptes cafer)	6	7	4	2	0	19	11	0	0	0	49
All species	434	481	281	235	375	163	85	108	39	19	2,220

The Common ground dove (Columbina passerina) might have moved some years from the Big Bend National Park to the observation routes, but from 2015 onwards it was not observed at all. The Ruddy ground dove (Columbina talpacoti) is not a common species in Chihuahua and it only showed up from 2009 to 2013, as it is a bird that permanently resides in coastal areas. The Cassin's sparrow (Peucaea cassinii) has not been seen since 2017, we hypothesize that because of climate change it might be emigrating to their summer locations earlier than in previous years, which could account for why it was not spotted during the months of May to July (the months in which the observations were made during the 10-year period). Explanations for the variations of migratory timing has been previously studied and supported for some species (Hurlbert & Liang, 2012). The Rufous crowned sparrow (Aimophila ruficeps) prevails in the mountains and part of the routes are adjacent to the 'Sierra de Orinda' mountain range, which may have provided shelter for it, although it has not been sighted since 2013.

In the case of the Black-chinned sparrow (Spizella atrogularis), the monitoring routes studied correspond to their breeding areas and they are attracted to the presence of cattle in the routes. In the monitored routes, there has been an increase of livestock farming, which attracts insects (particularly flies) because of these animals' feces; this is why birds feeding on insects may be drawn to these areas. The Indigo bunting (Passerina cyanea) used to have a notable presence at the beginning of the 10-year period studied, but observations suddenly dropped. The Common pauraque (Nyctidromus albicollis) is typical from coastal areas, so it is not common to the studied areas, but some individuals were observed, possibly because they were moving between coasts, but they have not been spotted after 2013.

Sadly, the *Aztec rail (Rallus tenuirostris) was not observed at all after 2012 and it is in danger of extinction in Mexico (Naturalista, 2019). The count of the Northern cardinal (Cardinalis cardinalis) have significantly dropped, possibly because they have changed their nesting areas or because it is a highly-desired bird by illegal traffickers. Finally, sightings of the Chihuahua raven (Corvus cryptoleucus) and the Red-shafted flicker (Colaptes cafer) have decreased and this may be because they have changed their nesting locations.

Species with an increase in sightings

This section includes the analysis of three groups of species: pigeons, sparrows, hawfinch, and three isolated species, which had an increase in their numbers. Table 5 shows the number of sightings during each year of the 10-year period for each of the species with an increase in sightings, together with the sum of sightings per specie and the total of sightings per year for all these species; then, we offer comments about these species' tendencies.

Table 5. *Species with an increase in sightings*

Species	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Sum
White winged dove (Zenaida asiática)	606	994	1,075	1,222	1,321	1,471	2,258	2,214	2,040	2,080	15,281
Mourning dove (Zenaida macroura)	899	1,165	1,250	1,365	1,529	1,337	1,743	2,174	2,300	2,340	16,102
Inca dove (Columbina inca)	185	152	144	164	110	220	405	534	1,056	851	3,821
*Eurasian Collared Dove (Streptopelia decaocto)	0	29	14	16	49	14	17	84	118	174	515
Black-throated sparrow (Amphispiza bilineata)	201	264	210	250	188	237	422	362	319	284	2,737
Lark sparrow (Chondestes grammacus)	21	124	37	55	29	53	57	138	224	251	989
House sparrow (Passer domesticus)	300	513	300	262	258	348	576	633	560	561	4,311
Blue grosbeak (Passerina caerulea)	43	50	67	78	96	130	132	197	124	179	1,096
Painted bunting (Passerina ciris)	0	6	6	10	12	36	27	33	37	48	215
Red Winged Blackbird (Agelaius phoeniceus)	335	475	472	510	570	533	768	743	756	839	6,001

Vermilion flycatcher (Pyrocephalus rubinus)	0	1	0	4	0	2	16	1	11	18	53
Species	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Sum
*Verdin (Auriparus flaviceps)	0	3	8	10	5	26	34	124	47	106	363
All species	2,590	3,776	3,583	3,946	4,167	4,407	6,455	7,237	7,592	7,731	51,484

In the case of the pigeons, four types of species were identified [White winged dove (Zenaida asiática), Mourning dove (Zenaida macroura), Inca dove (Columbina inca), *Eurasian Collared Dove (Streptopelia decaocto)] According to the results in Table 5, it is not possible to clearly appreciate the increase of the *Eurasian Collared Dove species, as it is an invasive species. Therefore, it requires special attention, because the increase in their numbers produces a displacement of native species. According to the data gathered of the four pigeon species, a correlation analysis was carried out to identify significance and correlation values in all the cases, as Table 6 shows, where the correlations of these species indicate mutual protection, which means that their numbers increase together.

Table 6. *Correlations of the four pigeon species that increased*

		White winged dove (Zenaida asiatica)	Mourning dove (Zenaida macroura)	Inca dove (Columbina inca)	*Eurasian collared dove (Streptopelia decaocto)
White winged dove (Zenaida asiatica)	Pearson Correlation	1	.911**	.685**	.647**
	Sig. (2-tailed)		.000	.001	.002
Mourning dove (Zenaida macroura)	Pearson Correlation	.911**	1	.815**	.749**
	Sig. (2-tailed)	.000		.000	.000
Inca dove (Columbina inca)	Pearson Correlation	.685**	.815**	1	.845**
	Sig. (2-tailed)	.001	.000		.000
*Eurasian collared dove (Streptopelia decaocto)	Pearson Correlation	.647**	.749**	.845**	1
	Sig. (2-tailed)	.002	.000	.000	

** Correlation is significant at the 0.01 level (2-tailed).

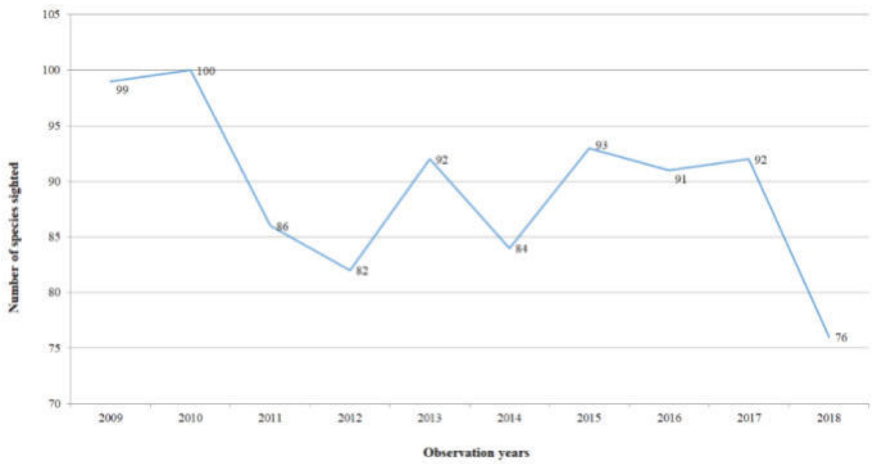
The sparrow species [Black throated sparrow (Amphispiza bilineata), Lark sparrow (Chondestes grammacus), and House sparrow (Passer domesticus)], were coming closer to and were identified more frequently in the urban and semi-urban areas studied within the two observation routes. One possible explanation is that they might be escaping from their natural predators, and they are feeding from the waste produced in the human settlements, parks and gardens.

The two species of hawfinch [Blue grosbeak (Passerina caerulea) and Painted bunting (Passerina ciris)] that increased their presence were characterized by similar foraging habits and distributions. They were spotted in areas with urban trees, such as the mulberry tree. The other species that saw an increase in sightings during the 10-year period, the Red Winged Blackbird (Agelaius phoeniceus) and the Vermilion flycatcher (Pyrocephalus rubinus) both feed on insects, which may account for the increased sightings of these species, as explained before. The *Verdin (Auriparus flaviceps) seems to have been regaining their numbers, possibly thanks to the reforestation of native plant species in the monitoring areas.

Analysis by number of species

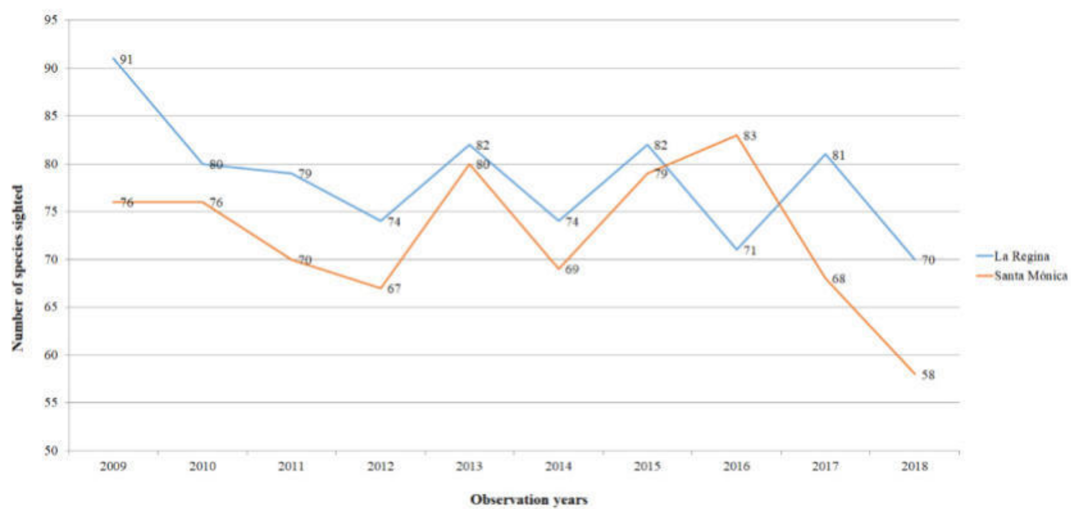
In this study, the total number of species observed during the evaluated period of 2009-2018 and in both routes, showed a global decrease from 99 to 76 species (23.33%) (Fig 4).

Figure 4. Decrease in the total number of species in both routes



During 2009, the first year of monitoring, 76 different species were observed in Santa Monica route, and there was a progressive reduction until 58 species were observed during 2018 (23.6% decrease). In La Regina route, the observations during the same period of time resulted in a reduction from 91 to 70 species, which represented an almost identical reduction in percentage: 23.07% (Fig 5).

Figure 5. Comparison of species' decrease by route



Other findings from observations

The results included in this section are relevant for monitoring, because they may be useful for birdwatchers, in the sense that they communicate the ideal conditions in which the studied species can be found in the region. Such conditions were drawn from correlations between species and climatological conditions (Table 7).

Table 7. *Correlations between species and climatological conditions*

		Initial temperature (°F)	End temperature (°F)	Initial wind speed (mph)	End wind speed (mph)	Initial sky conditions (clear, partially cloudy, mostly cloudy, cloudy, cloudy with rain)	End sky conditions
Say's phoebe (Sayornis saya)	Pearson Correlation	-0.388	-.630**	0.321	0.313	.559*	.826**
	Sig. (2-tailed)	0.091	0.003	0.167	0.179	0.010	0.000
Ash-throated flycatcher (Myiarchus cinerascens)	Pearson Correlation	.654**	0.182	-.485*	-.500*	-0.293	-0.213
	Sig. (2-tailed)	0.002	0.444	0.030	0.025	0.210	0.366
Couch's kingbird (Tyrannus couchii)	Pearson Correlation	-0.086	-0.316	0.382	0.245	0.396	.515*
	Sig. (2-tailed)	0.720	0.174	0.096	0.297	0.084	0.020
Blue grosbeak (Passerina caerulea)	Pearson Correlation	.490*	.448*	-0.167	-0.410	-0.142	-0.412
	Sig. (2-tailed)	0.028	0.048	0.482	0.073	0.550	0.071
Western meadowlark (Sturnella neglecta)	Pearson Correlation	0.033	-.450*	0.104	-0.101	0.420	.717**
	Sig. (2-tailed)	0.890	0.046	0.662	0.673	0.065	0.000
*White-tailed kite (Elanus leucurus)	Pearson Correlation	0.299	-0.124	-.530*	-.603**	-0.389	-0.281
	Sig. (2-tailed)	0.200	0.602	0.016	0.005	0.090	0.230
*Elf owl (Micrathene whitneyi)	Pearson Correlation	-0.200	-.454*	0.292	0.315	.583**	.968**
	Sig. (2-tailed)	0.397	0.045	0.212	0.175	0.007	0.000
*Blue-winged teal (Spatula discors)	Pearson Correlation	-0.266	-0.440	.558*	0.312	.688**	.774**
	Sig. (2-tailed)	0.258	0.052	0.011	0.180	0.001	0.000
*Yellow-rumped warbler (Setophaga coronata)	Pearson Correlation	-0.266	-0.440	.558*	0.312	.688**	.774**
	Sig. (2-tailed)	0.258	0.052	0.011	0.180	0.001	0.000

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

The correlations presented above mean that, in the case of the Say's phoebe (Sayornis saya) was mostly observed under low temperatures and cloudy skies, while the Ash-throat flycatcher (Myiarchus cinerascens) was sighted mainly during the morning, and with a higher frequency when the temperature was high and the wind was low. The Blue grosbeak (Passerina caerulea) was sighted when the temperature was high, while the Western meadowlark (Sturnella neglecta) was observed under low temperatures and fast winds. The White-tailed kite (Elanus leucurus) was present when wind speed was low, but the Couch's kingbird (Tyrannus couchii), the Elf owl (Micrathene whitneyi), the Blue-winged teal (Spatula discors) and the Yellow-rumped warbler (Setophaga coronate) were sighted under high wind speeds.

Discussion and conclusions

According to the results, new species in the area were identified in the monitoring (Rufous-crowned sparrow, Ruddy-ground dove and Common-ground dove), which are out of their migratory routes; a condition that is attributed to changes in their usual routes and of the climatological conditions, which may see them seeking alternative routes. Different species observed were only present during some years and their presence was not registered again. Changes in their migration routes puts some species at risk, both at rural and in urban environments, mainly due to the presence of different predators.

The Aztec rail species, of which some sightings were reported since 2009, drew the attention of national and international ornithologists, because they were previously observed at the center of Mexico, 1,000 kilometers or more from the routes studied. Sadly, this Mexican species is in danger of extinction (Naturalista, 2019).

The frequency of sightings has increased for some species thanks to the insects linked with increased agricultural activities within the area. Invasive species like the Eurasian collared-dove and the European starling have notoriously increased their populations, which cause the displacement of native species.

Some positive activities have been accomplished in the monitoring routes, such as the reintegration of native species. This has turned out to be beneficial to some species, such as the Verdin, which is regaining its population. In fact, a change in the counting of different species between the years 2013-2014 was observed. The species whose numbers dropped or that disappeared during the monitoring period have similar habits related with meadows or lower lands. Conversely, the species that have increased their numbers seem to have the tendency to fly or remain in higher areas.

We can pose the following hypotheses regarding the decrease in numbers: the indiscriminate use of agrochemicals without performing environmental evaluations may negatively affect bird numbers; this has been documented in news outlets (Silva, 2015); and the area is notably studied because of reports about contamination with high levels of arsenic and fluorine (Espino-Valdés, 2009). This information has been constantly checked by the local media for being connected to high rates of cancer in the inhabitants of the region (Dueñas, 2012).

The data and information provided by citizen science birdwatching which supported this research is important for decision-making regarding environmental issues, although there is no evidence of such use at a local, regional or even national level. There is a need for spreading and communicating results of the kind discussed in this article. We argue that such a need is imperative, due to the variations in the sightings of species, which evidence the decrease and increase of certain species and may lead to environmental concerns; these are issues that should be part of an educational program for everyone within the region (Granados & González, 2019).

Formal education about environmental issues provides the opportunity to connect the traditional knowledge of communities (holders of a profound knowledge about environmental surroundings) and scientific knowledge, for which universities may act as intermediaries. Activities related to the environment and the results provided by this research may help to expand the global-local roles in the ecosystem processes of nature and species' migratory movements, as well as alleviating the human and socio-environmental issues that currently affect us.

The existence of dissemination processes for such kinds of results and the creation of formal and informal educational programs are important to raise awareness about the environment and work toward improving it and making it more sustainable. Moreover, we propose that we need to go beyond, as two fundamental necessities have to be addressed: a) the creation of scientific observatories, as publicly accessible systems to retrieve environmental and ecological data and information; and, as a result b) defining mechanisms for promoting the generation of citizen science, with the participation of both scientists and the civil society.

The extensive data used in this research, which is already recorded, can be considered as a starting point to implement scientific observations about birdwatching through the appropriate and clear presentation of the data and deriving useful information from it. This will allow people and institutions to take decisions based on the search and discrimination of the relevance of such data (Angulo, 2009) in an ecological information system. The proposal of such system has the aim to continue with its compilation, treatment and diffusion through the use information technologies, whose effects can be demonstrated in the reflection and knowledge about the topic and for aiding environmentally friendly decision-making, which avoids putting in danger the ecosystems. Such kinds of initiatives require the participation of formal institutions like governments, universities or scientific centers for their organization.

Birdwatching activities in Mexico, as in the state of Chihuahua, offers much to those people involved in the development of citizen science, for gathering data, and disseminating knowledge related to these issues. In this context, citizen science has been increasingly used to collect biodiversity data and to inform the management and preservation of the environment (Callaghan et al., 2018).

In other contexts, the concept of citizen science has been used as a way to democratize scientific knowledge (Kullenberg & Dick, 2016). Moreover, it represents important actions that can be undertaken, especially when financing turns out to be limited, irregular or inexistent; therefore, it becomes a reliable and feasible alternative for monitoring species (Gouraguine, 2019).

Citizen science is important for society and researchers should seek to develop more collaborations with citizen scientists, as it: (1) encourages the development of a scientific culture and brings science to the society; (2) expects to make citizen scientists, through the participation of volunteers who gather or process data for research and decision-making; and (3) provides more value to the citizen observation capacity than that of any sophisticated equipment by itself (Finquelievich & Fischnaller, 2014; Gura, 2013). The citizen, without being a trained scientist, becomes a prosumer, that is, a producer-consumer of information.

References

Angulo, N. (2009). ¿Qué son los observatorios y cuáles son sus funciones? *Innovación Educativa, 9*(47), 5-17.

Bird, T., Bates, A., Lefcheck, J., Hill, N., Thomson, R., Edgar, G., Stuart-Smith, R., Wotherspoon, S., Krkosek, M., Stuart-Smith, J., Pecl, G., Barrett, N., & Frusher, S. (2014). Statistical solutions for error and bias in global citizen science datasets. *Biological Conservation*, (173), 144-54. https://doi.org/10.1016/j.biocon.2013.07.037

Boakes, E., McGowan, P., Fuller, R., Chang-Qing, D., Clark, N., O'Connor, K., & Mace, G. (2010). Distorted views of biodiversity: Spatial and temporal bias in species occurrence data. *PLoS Biology, 8*(6), e1000385. https://doi.org/10.1371/journal.pbio.1000385

Callaghan, C., Martin, J., Major, R., & Kingsford, R. (2018). Avian monitoring: Comparing structured and unstructured. *Wildlife Research, 45*(2), 176-184. https://doi.org/10.1071/WR17141

Cornell Lab of Ornithology. (2019). *Citizen Science Central: History*. http://www.birds.cornell.edu/citscitoolkit/about/history

Crall, A., Jordan, R., Holfelder, K., Newman, G., Graham, J., & Waller, D. (2013). The impacts of an invasive species citizen science training program on participant attitudes, behavior, and science literacy. *Public Understanding of Science*, (22), 745-64. https://doi.org/10.1177/0963662511434894

Dueñas, L. (2012). Delicias, con los más altos niveles de cáncer y sin políticas de ayuda. *La Crónica de Chihuahua*. http://www.cronicadechihuahua.com/Delicias-con-los-mas-altos-niveles.html

Ehrlich, P., Dobkin, D., & Wheye, D. (1988). *The birder's handbook. A field guide to the natural history of North American birds*. Simon and Shuster

Espino-Valdés, M., Barrera-Prieto, Y., & Herrera-Peraza, E. (2009). Presencia de arsénico en la sección norte del acuífero Meoqui-Delicias del estado de Chihuahua, México. *Tecnociencia, 3*(1), 8-18. https://vocero.uach.mx/index.php/tecnociencia/article/view/739

Finquelievich, S., & Fischnaller C. (2014). Ciencia ciudadana en la sociedad de la información: Nuevas tendencias a nivel mundial. *Revista Iberoamericana de Ciencia, Tecnología y Sociedad, 9*(27), 11-31. https://www.redalyc.org/pdf/924/92431880001.pdf

Freitag, A., Meyer, R., & Whiteman L. (2016). Strategies employed by citizen science programs to increase the credibility of their data. *Citizen Science: Theory and Practice, 1*(1), 2. https://doi.org/10.5334/cstp.6

Geoghegan, H., Dyke, A., Pateman, R., West, S., & Everett, G. (2016). *Understanding motivations for citizen science. Final report on behalf of UKEOF*. University of Reading, Stockholm Environment Institute (University of York) and University of the West of England. https://www.ukeof.org.uk/resources/citizen-science-resources/MotivationsforCSREPORTFINALMay2016.pdf

Gómez, H., & Alvarado, E. (2011). Breve historia de la observación de aves en México en el siglo XX y principios del siglo XXI. *Huitzil, 11*(1), 9-20. https://www.redalyc.org/articulo.oa?id=75615896003

Gouraguine, A., Moranta, J., Ruiz-Frau, A., Hinz, H., Reñones, O., Ferse, S., Jompa, J., & Smith, D. (2019). Citizen science in data and resource-limited areas: A tool to detect long-term ecosystem changes. *PLoS ONE, 14*(1), e0210007. https://doi.org/10.1371/journal.pone.0210007

Granados, L., González, F. (2019). Rumbos y extravíos de la educación ambiental. Destellos de un paradigma emergente. *Sociedad y Ambiente*, (19), 293-317. https://doi.org/10.31840/sya.v0i19.1945

Gura, T. (2013). Citizen science: Amateur experts. *Nature, 496*(7444), 259–261. https://doi.org/10.1038/nj7444-259

Haklay, M. (2015). 'Nature' editorial on citizen science. *European Citizen Science Association*. https://ecsa.citizen-science.net/blog/nature-editorial-citizen-science

Hurlbert, A., & Liang, Z. (2012). Spatiotemporal variation in avian migration phenology: Citizen science reveals effects of climate change. *PLoS One, 7*(2), e31662. https://doi.org/10.1371/journal.pone.0031662

Impey, O., MacGregor, A. (Eds.). (1985). *The origins of museums: The cabinet of curiosities in sixteenth- and Seventeenth- Century Europe*. Clarendon Press.

Institute for Environmental Diplomacy and Security for Environmental Diplomacy & Security. (2015). *The Ramsar Convention: A new window for environmental diplomacy? University of Vermont*. http://www.uvm.edu/ieds/node/941

Instituto Nacional de Ecología. Biblioteca de Sonidos Aves de México (2019). *Instituto Nacional de Ecología*. http://www1.inecol.edu.mx/sonidos/menu.htm

Johnston, K., Macías, A., & Castillo, R. (2015). Aves urbanas en el desierto sonorense: Estimando densidades poblacionales a partir de conteos de puntos. *Huitzil, 16*(1), 13-47. https://www.scielo.org.mx/pdf/huitzil/v16n1/v16n1a5.pdf

Kullenberg, C., & Dick, K. (2016). What is citizen science? A Scientometric meta-analysis. *PLoS ONE, 11*(1), e0147152. https://doi.org/10.1371/journal.pone.0147152

López, J., Ruiz, J., & Arellano, J. (2017). Diversidad de aves en gradientes urbanos, potencial uso recreativo y aviturístico en la ciudad de Guayaquil. *Turydes, 10*(22). https://dialnet.unirioja.es/descarga/articulo/7932281.pdf

Manzano, P. (2019). Manual del observador de aves. *Casa Chihuahua*. http://www.casachihuahua.org.mx/Expos/171006_Pajaros/ManualDelObservadorDeAves_PatriciaManzano.pdf

Mondaca-Fernández, F., Navarro-Sigüenza, A., Moreno-Contreras, I., & Jurado-Ruiz, M. (2017). Species richness, phylogenetic distinctness and conservation priorities of the avifauna of the 'Río San

Pedro-Meoqui' Ramsar site, Chihuahua, Mexico. *Biodiversity, 18*(4), 156-167. https://doi.org/10.1080/14888386.2017.1408032

Moreno, S. (2018). Violaron todas las prohibiciones en el Humedal de Meoqui. *El Heraldo de Chihuahua* https://www.elheraldodechihuahua.com.mx/local/violaron-todas-las-prohibiciones-en-el-humedal-de-meoqui-2017246.html

Moreno-Contreras, I., Mondaca, F., Robles-Morales, J., Jurado, M., Cruz, J., Alvidres, A, & Robles-Carrillo, J. (2016). New distributional and temporal bird records from Chihuahua, Mexico. *The Bulletin of the British Ornithologists' Club, 136*(4), 272-286. http://boc-online.org/bulletins/downloads/BBOC1364-PDFa.pdf

National Geographic. (2019). Citizen science. *National Geographic Society*. https://www.nationalgeographic.org/encyclopedia/citizen-science

Naturalista. (2019). Rascón Azteca Rallus tenuirostris. *Naturalista*. https://www.naturalista.mx/taxa/367476-Rallus-tenuirostris

Orbe, M., Quispe, L., Pezo, R., & Acosta, A. (2016). Diversidad de aves en ambientes urbanos y periurbanos de la ciudad de Iquitos y Bosque de Varillal, Loreto, Perú. *Conocimiento Amazónico, 7*(1), 3-13. http://repositorio.unapiquitos.edu.pe/handle/20.500.12737/3288

Ortega-Gaucin, D. (2013). Caracterización de las sequías hidrológicas en la cuenca del río Bravo, México. *Terra Latinoamericana, 31*(3), 167-80. https://www.scielo.org.mx/pdf/tl/v31n3/2395-8030-tl-31-03-00167.pdf

Palavecino, J., Vier, F., Villalba, L., Aguinagalde, S., Centurión, D., & Cirignoli, S. (2016). La observación de aves como propuesta en educación ambiental. *TEKOHÁ, 1*(4), 6-16. https://edicionesfhycs.fhycs.unam.edu.ar/index.php/tekoha/article/view/74

Pérez, L. (2019). Estudio jurídico-ambiental sobre la construcción del nuevo aeropuerto internacional de la Ciudad de México. *Actualidad Jurídica Ambiental*, (88), 4-34. https://dialnet.unirioja.es/servlet/articulo?codigo=6939351

Planetary Science Institute. (2019). History of Citizen Science. *CosmoQuest*. https://cosmoquest.org/x/about-cosmoquest/history-of-citizen-science

Pocock, M., Chapman, D., Sheppard, L., & Roy H. (2014). *Choosing and using citizen science: A guide to when and how to use citizen science to monitor biodiversity and the environment*. https://www.ceh.ac.uk/sites/default/files/sepa_choosingandusingcitizenscience_interactive_4web_final_amended-blue1.pdf

Ramírez, L. (2016). *Distribución temporal de aves acuáticas en la sección Vado de Meoqui del río San Pedro, Chihuahua, México* [M.Sc. Thesis, Universidad Autónoma de Chihuahua]. http://repositorio.uach.mx/156

Roy, H., Pocock, M., Preston, C., Roy, D., Savage, J., Tweddle, J., & Robinson, L. (2012). *Understanding citizen science & environmental monitoring. Final report on behalf of UK-EOF.* Centre for Ecology & Hydrology. https://www.ceh.ac.uk/sites/default/files/citizensciencereview.pdf

Sanabria, I., & Sosa, P. (2018). Estudio preliminar de especies de aves presentes en zona urbana del Municipio de Tunja, Boyacá. *Cultura Científica*, (16), 34-51. https://doi.org/10.38017/1657463X.532

Sánchez-Aizcorbe, V. (2017). *¿Qué tan saludables se encuentran nuestras áreas verdes? Estudio piloto usando diversidad de aves como indicador* [Bachelor Thesis, Universidad Peruana Cayetano Heredia]. http://repositorio.upch.edu.pe/handle/upch/1326

Secretaría de Desarrollo Agrario, Territorial y Urbano. (2018). *Sistema Urbano Nacional 2018*. Secretaría de Gobernación. https://www.gob.mx/conapo/documentos/sistema-urbano-nacional-2018

Silva, A. (2015). En agroquímicos y pesticidas el uso es indiscriminado: Luis Carlos Gonzáles. *Código Delicias*. http://codigodelicias.com/ver.noticia.new.php?id=48967

Snäll, T., Kindvall, O., Nilsson, J., & Pärt, T. (2011). Evaluating citizen-based presence data for bird monitoring. *Biological Conservation, 144*(2), 804-810. https://doi.org/10.1016/j.biocon.2010.11.010

Szabo, J., Vesk, P., Baxter, P., & Possingham, H. (2010). Regional avian species declines estimated from volunteer-collected long-term data using List Length Analysis. *Ecological Applications, 20*(8), 2157-2169. http://doi.org/10.1890/09-0877.1

Tejeda, I., & Medrano, F. (2018). El potencial de la ciencia ciudadana para el estudio de las aves urbanas en Chile. *DU & P: Revista de Diseño Urbano y Paisaje*, (33), 59-66. https://dialnet.unirioja.es/servlet/articulo?codigo=6472318

Trumbull, D., Bonney, R., Bascom, D., & Cabral, A. (2000). Thinking scientifically during participation in a citizen-science project. *Science Education*, (84), 265-275. https://doi.org/10.1002/(SICI)1098-237X(200003)84:2

United States Geological Survey Patuxent Wildlife Research Center & Canadian Wildlife Service Research Centre. (2019). Instructions for Conducting the North American Breeding Bird Survey. *USGS Patuxent Wildlife Research Center*. https://www.pwrc.usgs.gov/bbs/participate/instructions.html

Venegas, D., Díaz, M., & Cruz, J. (2015). Avoceta americana (Recurvirostra americana): Primeros registros reproductivos en Chihuahua, México. *Huitzil, 16*(1), 28-32. https://www.scielo.org.mx/pdf/huitzil/v16n1/v16n1a6.pdf

Villaseñor, J., & Santana, E. (2002). El monitoreo de poblaciones: Herramienta necesaria para la conservación de aves en México. In H. Gómez, & A. Oliveras (Eds.), *Conservación de aves, experiencias en México* (pp. 224-262). COPARMEX.

Waibel, G., & Erway, R. (2009). Think globally, act locally: Library, archive and museum collaboration. *Museum Management and Curatorship, 24*(4), 323-35. https://doi.org/10.1080/09647770903314704

West, S., Pateman, R., & Dyke A. (2015). *Motivations and data submissions in citizen science*. Report to DEFRA. https://www.york.ac.uk/media/sei/documents/publications/projectreports/West-Pateman-Dyke-DEFRA-Data-Submission-in-Citizen-Science-Projects.pdf

World Health Organisation. (2019). Millennium Development Goals. *World Health Organization*. https://www.who.int/topics/millennium_development_goals/about/en

Wright, D., Underhill, L., Keene, M., & Knight, A. (2015). Understanding the motivations and satisfactions of volunteers to improve the effectiveness of citizen science programs. *Society & Natural Resources*, (28), 1013-29. https://doi.org/10.1080/08941920.2015.1054976