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The use of Geoprocessing to Map Wild Bird Traffic in Pernambuco

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ABSTRACT

Wild bird trafficking in the state of Pernambuco has negatively impacted the local biodiversity and accentuated the ecosystems' imbalance. This crime has proven itself as a threat to the Brazilian and global biodiversity, which causes the extinction of several species, especially the avifauna, considered the most trafficked group. The goal of this research was to carry out a mapping of wild bird trafficking and seizures in Pernambuco, Brazil, in the period from 2016 to 2021, using geoprocessing techniques. Trafficking and seizure data of wild birds obtained from the Independent Company for Environmental Policing of Pernambuco (CIPOMA-PE) were used. A descriptive analysis and the elaboration of maps using the Jenks method has shown that the most trafficked bird has been from the papa-capim species (*Sporophila artesiaca*), showing that this bird is a highly acquired species in trafficking throughout the period. Besides that, the study has revealed through mapping that, the municipalities that have the highest numbers of bird trafficking are cut through or are close to the main highways in the state of Pernambuco. Thus, we emphasize the importance of creating an effective and efficient strategy to combat wild bird trafficking, based on geoprocessing techniques, as well as public policies aimed at strengthening the existing environmental laws at the municipal, state, and national levels.

Keywords: Geotechnologies, Thematic Mapping, Wild Animals, Northeast Region, Bird Seizures.

Uso do Geoprocessamento para mapear o Tráfico de Aves Silvestres em Pernambuco

RESUMO

O tráfico de aves silvestres no estado de Pernambuco tem impactado negativamente à biodiversidade local e acentuado o desequilíbrio dos ecossistemas. Esse crime tem se mostrado como uma ameaça à biodiversidade brasileira e mundial, que provoca a extinção de diversas espécies, sobretudo da avifauna, considerada o grupo mais traficada. O objetivo da pesquisa foi efetuar um mapeamento do tráfico e de apreensões de aves silvestres em Pernambuco, Brasil, no período de 2016 a 2021, utilizando técnicas de geoprocessamento. Foram utilizados dados de tráfico e de apreensões de aves silvestres obtidos junto a Companhia Independente de Policiamento do Meio Ambiente de Pernambuco (CIPOMA-PE). Uma análise descritiva e a confecção de mapas utilizando o método de Jenks demonstrou que a ave mais traficada foi a espécie papa-capim (*Sporophila artesiaca*), mostrando que essa ave é uma espécie de grande aquisição no tráfico ao longo do período. Além disso, o estudo revelou através do mapeamento que, os municípios que possuem os maiores números de tráfico de aves são cortados ou estão próximos das principais rodovias do estado de Pernambuco. Desta feita, destacamos a importância da criação de estratégias de combate efetivo e eficaz ao tráfico de aves silvestres, a partir das técnicas de geoprocessamento, bem como políticas públicas voltadas para o fortalecimento das leis ambientais já existentes em âmbito municipal, estadual e nacional.

Palavras-chave: Geotecnologias, Mapeamento Temático, Animais Silvestres, Região Nordeste, Apreensões de Aves.

Introduction

Wild animal trafficking is an issue that triggers actions and debates in the sphere of public power and important segments of civil society in Brazil. It is worth pointing out that birds are the most targeted in this type of crime due to their beauty and their songs, as well as their diversity, being the most sought-after animals for their profitability and for being preferred by buyers (Mendes, 2020; Menezes and Fontgalland, 2022). The commercialization of these animals is done by criminal organizations that act in a structured network, using the routes for the disposal of the captured animals (Pontes Filho et al., 2021), moving profits around US\$ 7 to 25 billion per year (Almeida and Calandrini, 2021).

The shipping of these animals is done in a cruel way, since they are taken in very small and stuffy compartments, spending hours in these boxes without food and water, in closed tubes, in small cages, or in travel bags, usually being sedated and injured to prevent them from escaping, and many of them eventually do not reach their destination alive (Cavalcanti and Nunes Dos Santos, 2019; Chaves and Devezas, 2019; Wyatt et al., 2022a; Saldanha and Peixoto, 2021; Wyatt et al., 2022b). Cruelty reaches the extreme when birds are killed as there is no public institution able to take in and recover them so that they can be returned to their natural habitat, as occurs in Norway, where birds are euthanized by veterinarians at the behest of the authorities (Sollund, 2021).

Birds are the most seized animals by environmental institutions and agencies, accounting for 80% of the seizures, and the mortality rate in Wild Animal Sorting Centers - CETAS - is also quite high (Silva, 2020). In face of this degrading reality, initiatives aimed at the protection have arisen after the promulgation of Federal Law No. 9605, in force on February 12, 1998 (Environmental Crimes Law). The Law incorporates the course of wild animal trafficking and has the purpose of restraining acts of purchase and sale, encompassing acts of hunting or capture, transport, keeping, and captivity, as well as negotiation/trading (Sollund, 2022).

Another relevant initiative to curb this practice is Bill 1.304/2019 which is being processed in the Brazilian legislation, an initiative by Senator Zenaide Maia, approved by the Environment Commission (CMA), which provides for increased penalties and fines for environmental crimes. The text of this bill modifies Law 9.605/98 and the Penal Code, specifically Decree Law 2.848 of 1940. As such, punishments will be directed at

those who cause pollution that harms human health, causes the death of animals, or significant destruction of the flora (BRASIL, 1998).

The current laws may be lenient, but sanctioning stricter laws may not be a coherent strategy, since much of the population lacks knowledge about the real consequences that wildlife trafficking can have on the environment (Skidmore, 2022). Given this, in recent years, tools have been used to help combat this crime, and one of them is the spatial analysis using geoprocessing.

Spatial analysis can be conceptualized as a quantitative study of the distribution of events that are geographically referenced, and is operated to define spatial patterns of dispersion that contribute to the prediction and control of diseases, for example (Fischer et al. 2019; Shrestha et al. 2022; Song et al. 2020). Mapping is a form of analysis, which generates information on social, historical, geographical, and environmental complexes. Still, one of the spatial verification techniques is geoprocessing, which is based on the collection, processing, and display of data, geographically referenced. One of the systems that use this technique is the Geographic Information System (GIS), which is an electronic data processing structure. The importance of geoprocessing for the work in question can be perceived since it provides the planning of preventive and control actions, and assists in mapping and combating crimes against wild birds, since from such analysis, environmental education and enforcement activities appropriate to local needs can be carried out (Paiva et al., 2020).

The importance of this research is justified as the use of geoprocessing techniques, and areas that are prone to the crime of wild bird trafficking will contribute to the development of public policies to combat crime (Silva et al., 2020; Silva et al., 2022). Thus, the mapping of wild bird trafficking can be used to carry out more intense inspections in the regions most impacted by this type of crime, as well as to assist the authorities in the structuring of agencies and equipment for agents. In this manner, it will be possible to act strategically in areas with a higher flow of captures and seizures. The implementation of new geotechnologies has already been occurring in several Brazilian states, making it essential for governments to equip and use geographic analysis to improve the performance of police forces (Rodrigo-Comino et al., 2020).

Therefore, the purpose of the present study was to conduct a mapping of wild bird trafficking in Pernambuco, Brazil, in the period from 2016 to 2021. The purpose of this work is to contribute to the performance of police forces and to assist in the

elaboration or updating of policies supported by geoprocessing techniques.

Methodology

Study area

According to the Brazilian Institute of Geography and Statistics - IBGE, (2021), the State of Pernambuco (Figure 1) has a territorial

extension of 98,075.90 km², comprising 185 municipalities, with a division into five mesoregions: Metropolitan Region of Recife, Mata Pernambucana, Agreste Pernambucano, Sertão Pernambucano, and São Francisco Pernambucano. Still, its population is estimated at 9,674,793 inhabitants, being seen as the seventh most densely populated state according to the 2010 census, representing 4.7% of the population (IBGE, 2010).

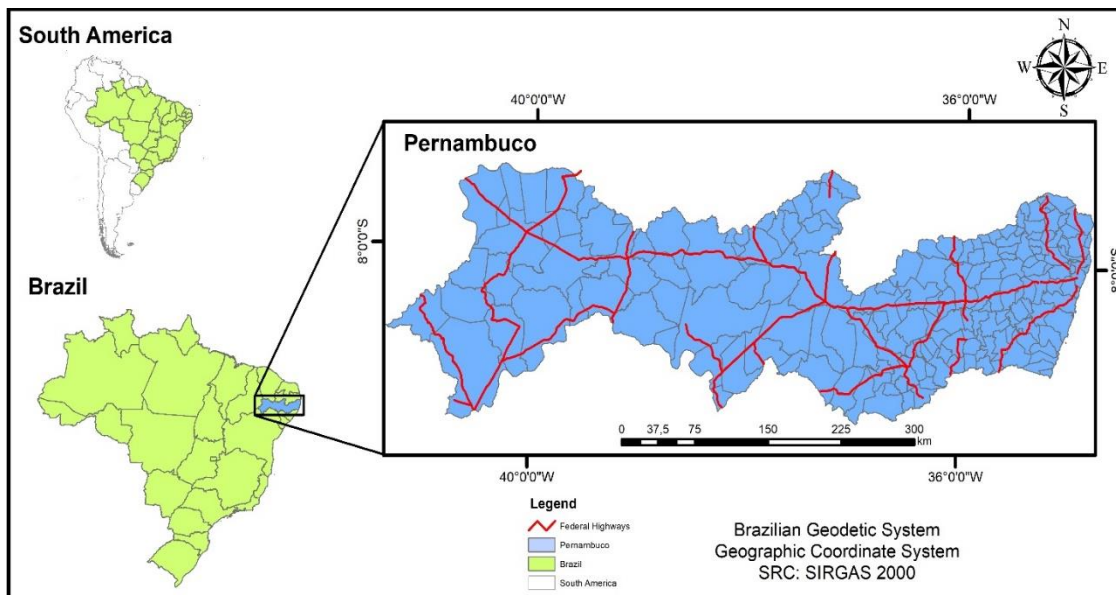


Figure 1. Location of the State of Pernambuco.

Data source

The data on trafficking crimes and seizures of wild birds were obtained from the 1st Independent Company for Environmental Policing - CIPOMA, which was created in 1990 in order to preserve the natural resources and to improve the quality of life of the population (CIPOMA, 2022).

For the analysis, we considered data on trafficking crimes and seizures of wild birds from environmental inspections, seizures at open fairs, and seizures resulting from complaints. This information is from the 184 municipalities of the state of Pernambuco (except for the municipality of Fernando de Noronha) in the period from 2016 to 2021, totaling a period of six years.

The vector data were obtained from the Brazilian Institute of Geography and Statistics - IBGE. Descriptive analysis was performed using Microsoft Excel. Data geoprocessing was performed through the open-source software Qgis 3.18.5.

Method

The study consists of a descriptive statistical analysis of the data and the use of Geoprocessing. For the construction of the graphs,

the data from the compiled spreadsheets were selected, where the ten most trafficked wild bird species were listed for each collected year in the period from 2016 to 2021. As for the use of geoprocessing techniques, the mapping of the trafficking and seizure of wild birds in the state of Pernambuco was carried out, using the Jenks method. The Jenks method was chosen since the data set does not have statistical normality. Therefore, one of the advantages of using such a method is the ease of mapping values that are not equally distributed throughout the arrangement of the data, which results in more balanced classes. And thus minimize the differences between the values exposed in the same class and maximize the differences between classes, that is, create homogeneous classes ensuring the heterogeneity between them (Carrión-Mero et al., 2022; Mihi et al., 2022).

Results and discussions

The data representation of the species was conducted by displaying the ten most trafficked birds in the state of Pernambuco during the period from 2016 to 2021. The following graphs are

presenting the annual unfolding of seizures of wild birds from trafficking, these birds are of the order of passerines, which are songbirds highly targeted by traffickers, for having beautiful song and beautiful plumage (Cavalcanti and Nunes Dos Santos, 2019). It is relevant to point out that even though keeping wild animals in captivity without authorization is illegal in Brazil (Federal Law No. 9.605/1998), this practice still occurs throughout the national territory (BRASIL, 1998).

Graph 1 presents the results for the years 2016 and 2017. It has been observed that the most trafficked bird in 2016 was the papa-capim (*Sporophila ardesiaca*), amounting to 719 birds

and the least trafficked was the canary (*Serinus canária*) with 79 birds. In 2017 the most trafficked Bird was the saffron finch, (*Sicalis flaveola*) with 752 birds and, the least trafficked sabiá (*Mimosa caesalpiniiifolia*) with 123 birds.

In the analysis of the first studied biennium (2016-2017) it was possible to note that for the species papa-capim (*Sporophila ardesiaca*), first place for the year 2016, there was a percentage reduction of -2.92%. Regarding the saffron finch (*Sicalis flaveola*) there was a percentage increase of 56.01%, being quite significant in the seizures of this species.



Graph 1. Annual analytical demonstration of the quantity of wild birds and the most trafficked species in the state of Pernambuco in 2016 - 2017.

The findings corroborate the research conducted by Santos et al. (2022), revealing that in the period from 2009 to 2019, the most trafficked species were also *Sicalis flaveola* (saffron finch), *Sporophila nigricollis* (papa-capim). In addition, the findings have revealed that the largest flow of wild bird trafficking has occurred on the main highways of the state of Bahia. In the same study, another point to be highlighted is that some of the trafficked birds are endangered and are therefore a major concern for the environmental agencies of the state of Bahia. These most trafficked birds, according to Almeida Junior (2021), come from different scenarios, such as seizures, and are birds of great cultural interest for their singing ability.

It is worth emphasizing that some cataloged species are on the list of extinction, which makes the removal of these birds from their natural habitat even more aggravating, stressing that they are often trafficked as chicks, packed cruelly in very small compartments, in which they are kept without food and water, resulting in most cases in death even before reaching their destination (Saldanha and Peixoto, 2021). It is noteworthy that this crime significantly impacts endangered species, such as the Great-billed seed finch (*Sporophila maximiliani*), the Sun Parakeet (*Aratinga Solstitialis*), the Buffy-fronted seedeater (*Sporophila frontalis*) and the golden parakeet (*Guaruba guarouba*) (Costa et al., 2018).

Graph 2 shows the results for the years 2018 and 2019. In it, it can be seen that the most trafficked bird in 2018 was the papa-capim (*Sporophila ardesiaca*) with 2,336 birds and the least trafficked was the Bananaquit (*Coereba flaveola*) with 155 birds. As for the year 2019, the

most trafficked bird was also the papa-capim (*Sporophila ardesiaca*), with 692 birds, while the least trafficked was the sabiá (*Mimosa caesalpiniiifolia*) with 58 birds.

In the second biennium (2018-2019), a comparative analysis was made for the two most seized species, demonstrating a variation from the fourth cataloged species. It was perceived that for the papa-capim species (*Sporophila nigricollis*) there was a percentage reduction of -70.38%. The saffron finch (*Sicalis flaveola*) was the second most seized species, but there was a reduction of -47.33%, showing that the work of the environmental police in the fight against bird trafficking in the biennium 2018-2019 was successful.

On the other hand, in a study conducted by Cavalcanti and Nunes dos Santos (2019), the most learned birds were the Red-cowled Cardinal (*Paroaria dominicana*), the saffron finch (*Sicalis flavela*), the papa-capim (*Sporophila nigricollis*), and the ultramarine grosbeak (*Cyanoloxia brissonii*). All of these animals were found in the states of Pernambuco, Alagoas, and Ceará, and in Alagoas, we even found the endangered yellow-faced siskin.

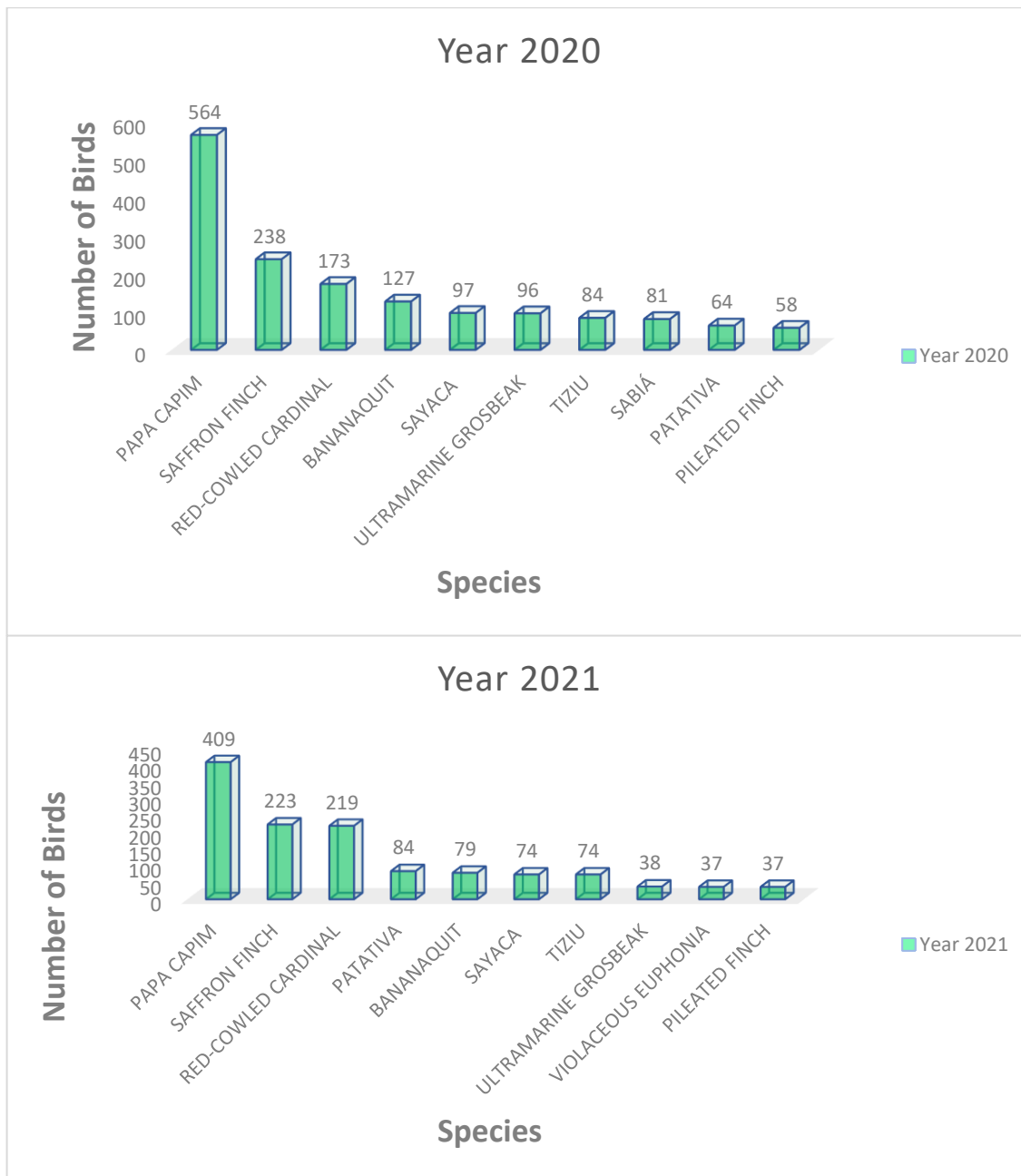
Unlike Brazil, in Bolivia, the most captured bird is the psittacidae class (parrots). Poaching has negatively impacted the population of such animals, which are often taken from their habitats at a young age, representing 94% of the trafficked bird species in that country, giving a total of 9,013 psittaciformes of 27 species distributed in the local market in the study year, among these species is the psittaciformes *Pionus chalcopterus* (Pires et al., 2016).



Graph 2. Annual analytical demonstration of the quantity of wild birds and the most trafficked species in the state of Pernambuco in 2018 - 2019.

Graph 3 presents the results for the years 2020 and 2021. It was observed that the most trafficked bird in 2021 was the Papa-capim (*Sporophila ardesiaca*) with 409 birds and the least trafficked was the Tico-tico (*Lanio pileatus*) with 37 birds. In the year 2020 the most trafficked bird was the Papa-capim (*Sporophila ardesiaca*) with 564 birds, and the least trafficked was the Tico tico/cravina (*Lanio pileatus*) with 58 birds. It was

noticed that in the comparative analysis of the second biennium (2020-2021) for the two most seized species, there is a variation from the fourth cataloged species. It can be seen that for the species papa-capim (*Sporophila ardesiaca*) there was a percentage reduction of -27.48%. Regarding the second most seized species, the saffron finch (*Sicalis flaveola*), there was a reduction of -6.3%.



Graph 3. Annual analytical demonstration of the quantity of wild birds and the most trafficked species in the state of Pernambuco in 2020 - 2021.

The findings for the second analyzed biennium are based on the study conducted by Sales et al. (2022), which has revealed a reduction on the number of wild birds seized, between 2018/2019. Besides, these findings show that in 2019 there was a percentage reduction in the amount of seizures in the state of Pernambuco. According to Anagnostou and Doberstein (2022), the specialization of environmental police officers for the operationalization of inspections is also an important factor, since there is a very large diversity in the actions, requiring intelligence work and agility in the investigations of such crimes. In Colombia, for example, environmental agencies

place seized birds in wildlife reception centers so that the physical conditions of the animals are evaluated and, when possible, they are released into nature; among the confiscated species are macaws, parakeets, and parrots (Restrepo-Rodas and Pulgarín-Restrepo, 2017). In Norway, negligent performance of enforcement agencies is observed, as well as poor records of crimes by Cites and lack of priority in investigations. The most serious in this country is the policy of euthanasia of seized animals, which constitutes a significant violation of the species (Sollund, 2021).

It is worth mentioning that in the first biennium (2016-2017) there was a change in the

first place between the analyzed years, which was the case of the saffron finch in 2017. The Red-cowled Cardinal (*Paroaria dominicana*) remained in 3rd place in the second and third biennium, as well as in 2016. In the following species, we noticed small variations in relation to the number of seizures

In the analyzed period from 2016 to 2021, the most trafficked bird was the papa-capim species, showing that this bird, has become a species of great importance for this type of crime. These results corroborate the research of Gama et al. (2008), in which it was found that the papa-capim species was the favorite of birders in the municipality of João Pessoa. According to Gama et al. (2008), the Papa-capim species is appreciated for its song and relative ease of maintenance, since it is a small animal, about 11 cm long, facilitating its handling. In other states, as in the case of Minas Gerais, the most received birds by the CETAS were the saffron finch (*Sicalis flaveola*) and the Green-winged saltator (*Saltator similis*), animals seized by the Military Police and also by IBAMA (Freitas et al., 2015).

In 2018, there was a large seizure of 1,303 birds. From these arrests, 750 were of the papa-capim species, which as stated before, are highly coveted by traffickers. This seizure was made on BR-104, near the city of Caruaru in a vehicle coming from Bahia (interstate trafficking). Thus, it was possible to verify the condition of the birds that were packed in tiny boxes, destined to supply free markets in the cities of Caruaru, Recife, and the metropolitan region. It is worth noting that, according to Marques (2018), the transportation of most trafficked animals in Brazil is done overland in trucks, buses, and private cars, from the point of capture to the final consumer. This result confirms the need for more policing on highways to curb this type of crime, since, before reaching their destination, many of these birds die, due to transportation at high densities. Allied with this are the stress of capture, changes in diet, and climate

This surveillance, when aligned with geoprocessing, becomes a piece of important information in the fight against crimes of this nature since the use of the geographical position of the phenomenon provides the spatial visualization of data, which can facilitate the work of the environmental police. According to Oliveira et al. (2020), combining quantitative information with the use of maps will facilitate the understanding of the phenomenon of animal trafficking crime, thus becoming an important tool.

In light of the above, it has been evidenced that geoprocessing can enable the systematization

of information from spatial databases (Dos Santos et al., 2022). All the geographic information will add value to the produced documents. With this geospatial intelligence, it will be possible to perform more assertive surveillance of trafficking locations and thus anticipate actions and promote seizures of animals, as well as arrests of specialized gangs (Yazici, 2022).

In Figure 2 the results for the mapping of wild bird seizures for the years 2016 to 2021 were presented, using geoprocessing techniques. Overall, it has been observed that most municipalities in the state of Pernambuco only had minor seizures (ranging from 0 to 14) in the analyzed period of six years, municipalities that are located in the central portion, and in the western region of the state. The range of 15 to 56 seizures was also present in most of the eastern part of the state, highlighting the year 2018, with some seizures in the western portion of the state. On the other hand, the range from 59 to 136 seizures can be perceived range is concentrated in a part of the eastern region of the state, highlighting the year 2019 with seizures in Petrolina and Tacaratu, municipalities of the mesoregion of the state.

Another point to be discussed is the municipalities that had between 15 and 290 seizures. These municipalities are located mainly along the eastern portion of the state of Pernambuco, such as Jaboatão dos Guararapes, Cabo de Santo Agostinho, and Ipojuca. In addition, there are municipalities such as Caruaru and Garanhuns, which are among the ten most populous municipalities. It was also found that the city of Recife, was present in every year analyzed, with a number of 291 to 1,913 seizures in the period from 2016 to 2021.

It was observed that important Federal Highways in the state intersect the municipalities that had high bird seizures. These highways facilitate the trafficking of wild birds, as well as making it easier for the police to seize these wild birds.

In dealing with this matter, Cavalcanti and Nunes dos Santos (2019) have asserted that the Northeast region has a vast territorial extension, which facilitates the action of criminal organizations that structure themselves into a network formed by an entanglement of routes where the animals are disposed of. What can be noticed in this region is that many of these people have personal satisfaction in capturing, raising, and selling birds, thus transcending the commercial practice. Moreover, this is quite common in the state of Pernambuco, in which the trade in wild birds is related to the economic situation, absence

of education, cultural problems, and desire for quick and easy profit (Cavalcanti and Nunes dos Santos, 2019).

In Figure 3, it was shown the maps of occurrences of wild bird trafficking in the municipalities of the state of Pernambuco in the period from 2016 to 2021. It is noteworthy that most municipalities in Pernambuco, especially those located in the central and western parts, had

no occurrences of bird trafficking during the studied period (0 occurrences). In the interval of 1 to 2 occurrences of trafficking, a good part of the municipalities with this interval, were present in the portion, with the exception of the years 2016 and 2019 which had occurrences in other regions of the state.

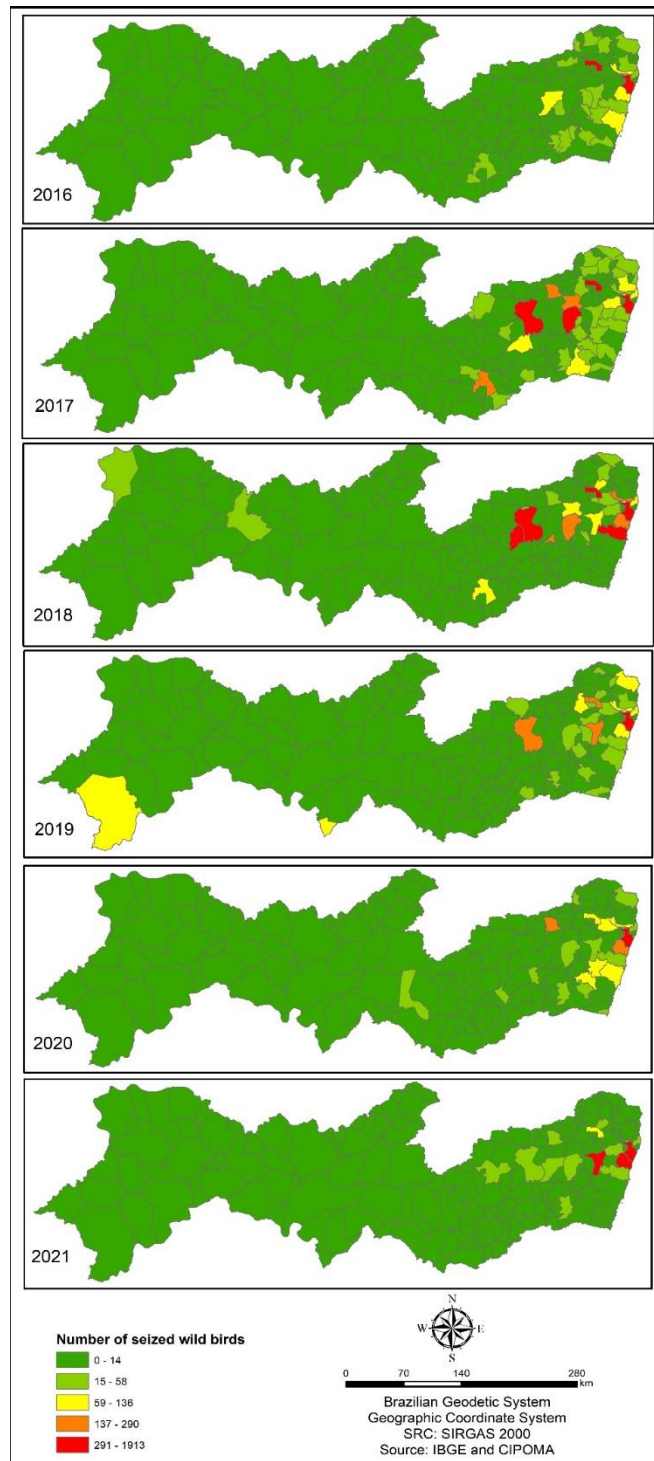


Figure 2. Maps of the number of seized wild birds from trafficking in the municipalities of the state of Pernambuco, from 2016 to 2021.

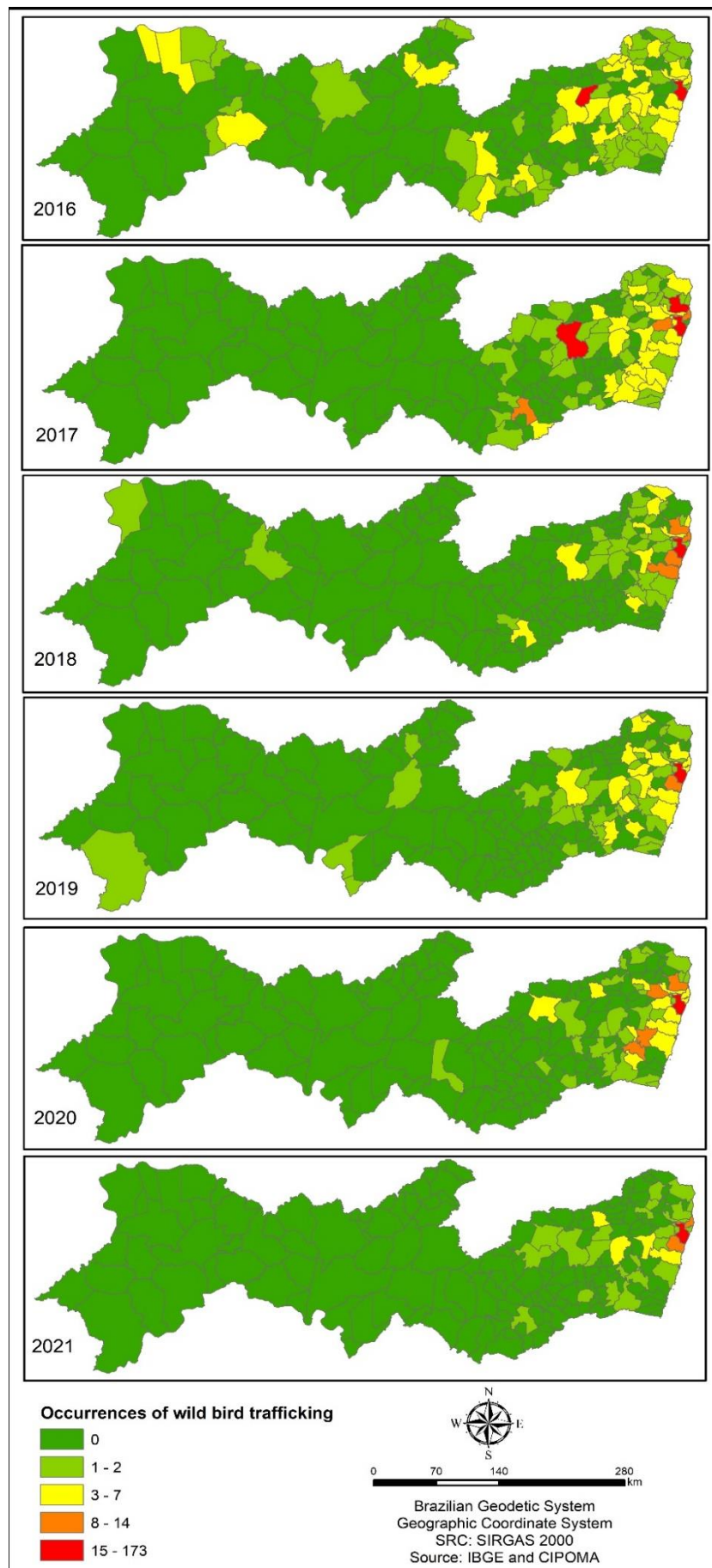


Figure 3. Maps of the quantitative occurrences of wild bird trafficking in the municipalities of the state of Pernambuco, period from 2016 to 2021.

The municipalities that had between 3 and 7 trafficking occurrences are present in the eastern portion of the state, with the exception of 2016, which had municipalities in the central and western portions. Also according to Figure 3, the results have revealed that the municipality of Recife remained with a number between 15 and 173 occurrences of seized bird trafficking for the six years. In addition, it is important to highlight the year 2017 for the municipalities of Garanhuns and Caruaru, which are crossed by federal highways in the state, thus facilitating the crime of wild bird trafficking.

The results of the wild bird trafficking mapping corroborate with the results found by Indraswari et al. (2020) in Indonesia, in which the mapping of bird trafficking and commerce occurring in this country was employed. The results from Indraswari et al. (2020) have revealed that seizures from trafficking occurred mainly on routes and in destination regions, and less near source regions. Indraswari et al. (2020) also stated that the seizures occurred in cities with the largest populations in Indonesia, as was the case in the main cities of the state of Pernambuco, such as those in the Metropolitan Region, as well as Caruaru, Garanhuns, and Petrolina.

Mendonza et al. (2022) found through the use of mapping, that most of the seizures occurred in the coastal area, home to 58% of Peru's human population, which is home to a second important group of wildlife markets. Besides that, the results of Mendonza et al. (2022) also revealed that in addition to major highways, airports and ports in Peru are recurrent targets for seizures of these animals, showing that the trade is not only national but also international.

Thus, it is important to highlight that measuring information in time and geographic space using geoprocessing is an important tool for the process of research, analysis, and presentation of wild bird trafficking. For Challender et al. (2022) the impact of animal trafficking on society needs to be studied in more detail and its protagonists identified. Thus, continuous analysis of the data on trafficking and seizures will serve to direct new and more detailed research on the situation of these species.

Conclusions and recommendations

In the present study, a descriptive analysis and mapping of the trafficking and seizures of wild birds in the municipalities of Pernambuco were carried out, using Geoprocessing, in the period from 2016 to 2021. The results have allowed for

the conclusion that the use of geoprocessing for mapping, proved to be significant for the understanding of the spatial distribution of the phenomenon in question. Thus, the continuous monitoring of changes occurring through mapping is crucial in order to identify changes in the patterns of trade routes of commercialized species and the emergence of new ones.

Summarizing, the results revealed a reduction in the number of birds trafficked over the analyzed period. The results have also revealed that the most trafficked bird over the period was the papa-capim species (*Sporophila artesica*), due to some characteristics such as its beautiful song and easy handling. Additionally, the study revealed through mapping that the municipalities that have the highest numbers of bird trafficking are crossed by or near the main highways in the state of Pernambuco.

Therefore, the ongoing analysis of trafficking and seizure data will serve to guide new and more detailed research on the situation of these species in ecosystems in order to map possible changes in their environment, and population size, among others. Such information will be relevant both for a detailed understanding of the implications of the illegal trade in wild birds in the state of Pernambuco, as well as to guide actions for the conservation of these species and their natural habitats.

Based on the results of the mapping, it is recommended that specialized police stations against environmental crimes be created in other parts of the state of Pernambuco as a part of a project to reduce animal trafficking. It is also suggested that the government of Pernambuco adopt more responsive tools, linked to geospatial assessment, in order to have more efficiency in the gathering of information, given the dimensions of the State of Pernambuco. Furthermore, it is suggested that for any future work on temporal analysis, a shorter interval for the measurement of occurrences, such as monthly, biweekly, or daily, should be used. In addition, the adoption of variables that can help understand the behavior of this crime, which is so little investigated in the international literature.

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