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STUDY ON URBAN ROCK DOVE (*COLUMBA LIVIA*) MOVEMENTS IN THE CITY OF MADRID USING GPS DEVICES

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Abstract The rock dove is the most abundant of the urban pigeons in the city of Madrid, as well as in most cities around the world. The great adaptability of this species to urban environment has promoted an enormous increase in its populations in many cities worldwide and, consequently, in its impact on humans. In this context and, within the municipal service for the management of rock pigeons in Madrid, a study of the mobility of this species using GPS was started in 2024. The GPS devices are placed on the bird's back and attached to a harness designed using a 3D printer. The data is obtained via Bluetooth signal and includes, in addition to spatial coordinates, height, ambient temperature, light intensity and battery charge level. All the data obtained can be viewed on a mobile phone, tablet or PC. At first, a pilot test was carried out with one specimen of the species to develop the necessary operations and validate them. The study then began with five specimens of *Columba livia* simultaneously in a specific area of the city representative of the urban centre of Madrid. This process has been replicated at different times of the year to understand the influence of seasonality in a city with a continental Mediterranean climate. The results obtained, greatly influenced by the abundance of water, food and shelters, have served to deepen the knowledge of the urban rock doves and optimize strategies for its management, one of the great challenges of urban wildlife management today.

Key words Rock dove, mobility, geolocation, food, urban environment, GPS

INTRODUCTION

The rock dove (*Columba livia* Gmelin, 1789) is a species originally from Eurasia whose natural habitat is cliffs and rocky areas. Its diet is mainly based on seeds of cereals, legumes and herbaceous plants (SEO/BirdLife, n.d.). Because of the modification of landscapes by humans, the establishment of pigeons in rural areas (management of land as sources of cereals) and urban church towers, multi-story buildings has been favoured as a suitable synanthropic habitat.

The success of this species has been attributed to: absence or scarcity of predators; easy availability of shelter in a wide variety of spaces (cornices of buildings, overhangs, bridge structures, etc.) and continuous supply of food with high nutritional content by humans. Structural modifications to cities have allowed the creation of warm shelters for pigeons to cope with cold stress. Wild pigeons in urban areas can breed throughout the year, depending on the availability of food and the climate. In this context, it is estimated that there is currently one pigeon for every twenty citizens of a large city, and this has been favoured by access to food in high-income countries (Spennemann and Watson, 2017).

The presence of intentional feeders is the main source of food for these animals. In Europe, different profiles and reasons for feeding them have been identified, such as imitation, empathy or cultural environment (Calbaceta and Barrientos, 2019). However, they are considered a public health problem due to the economic impact on private facades and public infrastructure, as well as the viral, bacterial and fungal diseases that they can transmit to people (ANECPLA, 2013) (Zúñiga et al., 2017).

Geographic information systems (GIS) facilitate analysis and decision-making in the management of different public health problems, such as greenhouse gases, air pollution, sightings of potentially harmful fauna, etc. For this reason, in 2016, research was carried out using GIS tools that allowed the Madrid City Council to obtain an accurate estimate of the urban pigeon population and effectively manage activities related to its control. Knowing the density data of pigeons has been important for generating surveillance and control strategies. Likewise, with respect to movement, GIS technology can provide information on the most strategic points and the reasons why pigeons remain in cities (Cámara et al., 2016).

In this context, and within the municipal service for the management of the wild pigeon in Madrid, a study of the mobility of this species using GPS was started in July 2024, concluding in August (midsummer in Madrid). The geolocation devices were placed on the back of the bird and fixed using harnesses designed with a 3D printer. The data was obtained through a Bluetooth signal and included, in addition to the spatial coordinates, other parameters such as height, ambient temperature, light intensity and battery charge level of the GPS devices. All the data obtained could be viewed on a mobile phone, tablet or PC, from which, through observation and mobility analysis methods, it was possible to learn about the behaviour patterns of the birds, determine the hours of greatest mobility, behaviour by season, temperatures, nesting pattern and usual concentration points, among others. This study was replicated between the months of November and December 2024 (late autumn and early winter in Madrid) to compare the results in different climatic periods.

This article aims to evaluate the results of the surveillance study on the behaviour of pigeons and the influence on it of intentional feeding in urban spaces. It analyses how this factor could be directly related to modifications in the behaviour of these birds, including alterations in their habitat, flight times and movement patterns, among others.

Based on the results obtained and their potential usefulness, new studies are planned to be carried out in the future, even introducing variables regarding the number of individuals studied, the type of urban environment or the time of year.

MATERIALS AND METHODS

The materials and methods implemented in both study periods were very similar, with some minor variations that did not affect the development of the study.

The first study began on July 9, 2024, with the capture of 9 specimens of wild pigeon on an island of Glorieta de Cuatro Caminos, lasting until August 13. This place is in the “central almond” of the city (delimited by the M-30 ring road), in the district of Tetuán. It is a large square, surrounded by medium-rise buildings and very busy with vehicles and pedestrians, which is representative of the urban environment of the city center. This area is also interesting due to its high population of pigeons.

In November, the same reference location was taken, capturing the specimens on November 26 and developing the study from November 29 to December 30. The captures were carried out using bait and a Caperlan PRF brand landing net and the individuals were transferred to the municipal facilities used as a dovecote in Encinar de San Pedro (in the Casa de Campo urban park), where the five specimens in the best apparent state of health and with the highest biometric measurements were selected. These specimens were the bearers of the GPS equipment and samples were taken from them with endotracheal and cloacal swabs for analysis of infections by Newcastle, Avian Influenza and Salmonella spp. The remaining specimens were kept as a control to compare the influence of the materials placed on the mobility of the pigeons under study.

The selected specimens were marked with plastic rings on one of their legs and special pigeon paint of different colours (depending on the colour of the ring) on the birds' chests. This was done to more easily identify the pigeons in their urban environment during the study. The GPS receivers were installed in harnesses specially designed to fit the pigeons' anatomy, made from PET (polyethylene terephthalate) or carbon fibre on a 3D printer. The NANO GPS receiver was fixed to these harnesses using Live Fish brand fishing line and cyanoacrylate-based glue, and the whole thing (weighing 9.90 grams) was attached to the pigeon's back with a Kevlar strap or polyethylene cord.

The GPS-equipped and control pigeons were cared for (fed, watered and sheltered) at the Encinar de San Pedro facilities in Casa de Campo for 72 hours. When the receiver and harness were installed on the birds, some initial problems were observed in flight; however, after 48 hours of observation, the pigeons had adapted to these devices and their flight was practically no different from that of the control pigeons.

The procedure was very similar for the November-December study. The geolocated pigeons were named for the study with the supplier's identification code (Interrex tracking) as follows:

- For the summer project: 784 with blue ring; 788 with green ring; 9d0 with red ring; 78f with violet ring; 9c1 with yellow ring.
- For the autumn-winter project: 9c7 with pink ring; 9d4 with red ring; 79c with yellow ring; 792 with violet ring; 9d5 with green ring.

Before installing the GPS receivers in the birds, a test was carried out with another GPS receiver that was permanently hung for several days by one of the authors of the study. This test served as a mobility test, to obtain the geographic location coordinates, check the charge of the solar battery and evaluate its response to different environmental stimuli. This test began on July 2 and ended on July 18. During this period, continuous charges were made to the solar battery as it is the time of year with the highest sunlight in Madrid. It was found that, in 24 hours, the battery charge of the device dropped to half its charge in the absence of sun exposure. This means that these devices work optimally with continuous exposure to the sun outdoors, as we will see later with the receivers in the study. The GPS is programmed to collect data on location, temperature, luminosity, etc., every hour, if the subject is active, and the solar panel is exposed to sunlight.

After the release of the pigeons with the GPS receivers, frequent searches were started both on foot and by electric vehicle, as well as data capture via the HUB receiver or gateway. This device is installed on a tripod that is moved manually for active search of the pigeons. The receiver has three antennas:

- Own GPS reception antenna.
- 4G antenna to communicate with the mobile phone network in the area and download the data to the server www.ecotopiago.com
- Bluetooth antenna. It is responsible for contacting the NANO GPS device placed on the pigeon and downloading the data that the bird accumulates daily. It has a maximum range of 10 meters for downloading data, which is useful in the case of specimens in the breeding process or very difficult to capture. After capturing the weak signal, a more detailed capture must be carried out, moving in increasingly smaller circles until receiving a minimum signal of 60 dBm to be able to download the data.

Figure 1. GPS device attached to the harness and technicians placing the assembly on a pigeon.

Data collection for the project in summer was carried out between 06:56 hours on 12 July (GMT+2) and 07:23 hours on 13 August (GMT+2). In the second study, data were collected between 11:00 hours and 13:00 hours, from 29 November to 30 December (GMT+1).
The first part of this study was carried out during the dog days, the time of year that usually has the highest maximum and minimum temperatures. In July, an average temperature of 24.4ºC was recorded, while in August it was 25ºC. These data are very relevant because pigeons do not need to take shelter indoors to conserve heat, which makes them receptive to satellite location for longer than in other colder times (Agencia Estatal de Meteorología / State Meteorological Agency, 2024a).

During the month of December, average temperatures have been above their normal values (reference period: 1991 to 2020), resulting in a warmer month than usual, with an average temperature in the Community of Madrid of 6.5ºC (State Meteorological Agency, 2024b).

RESULTS AND DISCUSSION

The samples taken for the analysis of notifiable diseases in the pigeons, carried out during the placement of the devices, were negative for infections such as Newcastle, avian influenza and Salmonella spp. These analyses were carried out in the VISAVET laboratories, at the Faculty of Veterinary Medicine of the Complutense University of Madrid.

After collecting the data received by the GPS, they were processed using the Ecotopia Go application, which allows them to be downloaded in different formats, facilitating the process for their analysis. Once downloaded, the different parameters provided by the GPS were analysed. The data obtained correspond to the activity generated by the pigeons and recorded by the GPS so that, the more movement occurs, the more activity is recorded.

To determine the level of activity, the data on the number of positions recorded by the GPS device of each bird were taken as a reference. When the individuals studied are inactive (whether breeding, taking shelter, etc.), this device does not receive new information on light, temperature or coordinates. Therefore, it is assumed that, in the hours in which no data has been recorded, there has been no activity, and they have not moved.

The processing of the data shows that practically all the pigeons were grouped together or moved to the same place (Glorieta de Cuatro Caminos). Through direct observation, it was possible to verify that in the time interval of data collection between 11:00 hours and 13:00 hours (GMT+1), it was very common for there to be people intentionally feeding the pigeons.

We should highlight pigeon 784 from the summer study, which was the one that provided the most locations (610 locations). It recorded activity during all hours of the day (Fig. 2). It was also shown to perform flights at very high altitudes, even reaching 1212 metres in height. This behaviour may be typical of a male without a partner (without characteristic incubation or breeding time slots), which performs display flights with the aim of attracting a female. They may also be flights performed with the aim of getting some fresh air and cooling off, since this is a time of very high ambient temperatures.

Pigeon 78f recorded little mobility until the beginning of the afternoon, as did 9d0. Regarding the latter, notable locations were recorded, since its only two foci of activity are both located about 500 metres from the Glorieta de Cuatro Caminos (although it does come here occasionally) (Fig. 4), unlike the rest of the pigeons, which present their main activity in this area. Regarding specimen 9d0, the first point was located on the roof of a building and the second at an intersection near a water source, which would mean that the first is where its nest is located, and the second would be the feeding point to which it travels. In addition, this individual presented peaks of activity at different times, unlike the rest of the pigeons in which the activity was concentrated in only one time slot. These results suggest that, since the nest and the areas it frequents were at a certain distance (500 m.) from the Glorieta de Cuatro Caminos (area frequented by the rest of the pigeons), it could be a pigeon in breeding season, with very limited activity to search for the necessary food. Another hypothesis to consider is that there was another intentional feeding routine in that area.

During the summer study, pigeons 788 and 9c1 had two activity foci, one of which coincides with the Cuatro Caminos roundabout, between which they moved continuously, and which were located at between 400 and 600 meters (Fig. 3). Therefore, it is assumed that the square is the most frequent feeding point, while the other location would be the place where they nested.

Regarding the November-December study, the activity of 792 predominated, which provided a total of 181 positions during the study time (Fig. 3). It is relevant that it had a focus about 500 meters from the Cuatro Caminos roundabout (as did 788 and 9c1 in the summer study) (Fig. 5), where its nest would be located, and from which it moved continuously. This fact suggests that this individual would be in the breeding season.

Four of the pigeons in the second study shared a similar activity schedule (9c7, 79c, 792, 9d5), as they increased the data collected from 12:00 hours to 17:00 hours (GMT +1). However, pigeon 9d4 did not collect any data during the study month. This could be due to several reasons: no charge in the GPS device battery, inability to detect the pigeon in the area (due to moving to another area or activity at a time other than the data collection time), and even death of the individual.

To better visualize these results, graphs were made based on the amount of data collected at each hour of the day during the entire study month. From these, a general increase in activity was observed during a similar range in both study periods: from 14:00 hours to 20:00 hours (GMT+2) in the summer studio and from 12:00 hours to 19:00 hours (GTM+1) in the autumn-winter studio.

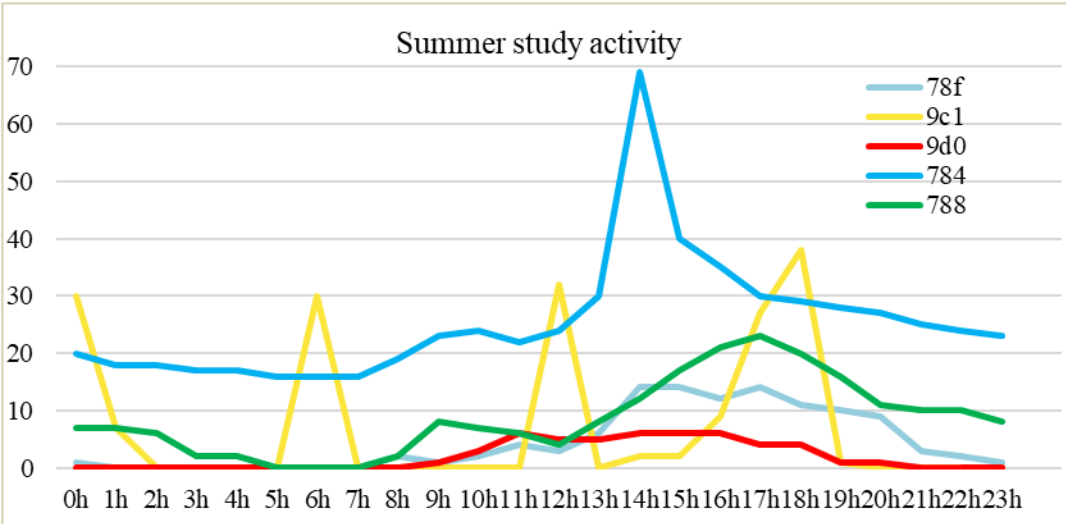

Figure 2. Number of positions (activity) recorded by each GPS during the summer period

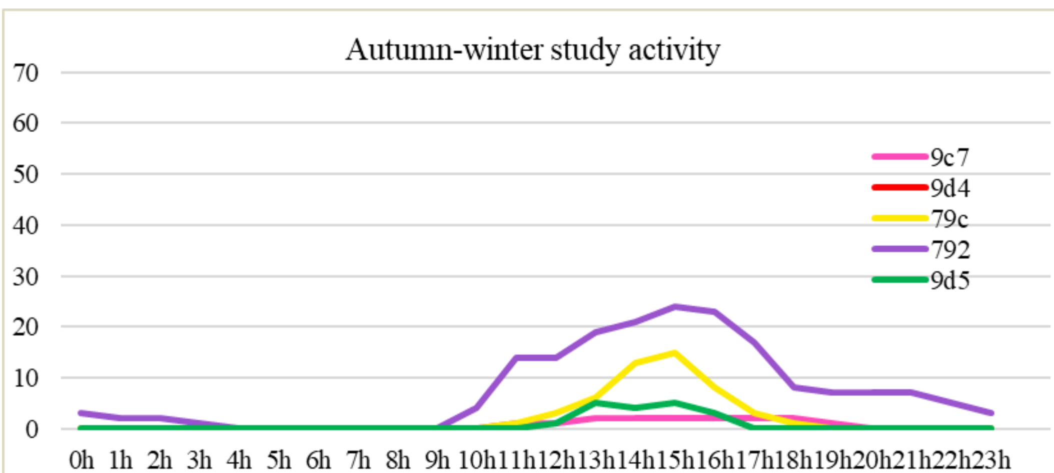

Figure 3. Number of positions (activity) recorded by each GPS during autumn-winter period

On the other hand, the data was also processed through the Google Earth application, in which a map could be generated from a KML format obtained in Ecotopia Go, which reflected all the positions recorded for each pigeon during the study, as well as the heights, speed, etc. From this map, the different hotspots of greatest activity where the pigeons are located can be observed.

Below, the mobility ranges of the pigeons in the study in summer are expressed (78f, 9c1, 9d0, 784, 788), where the route of the bird and its limits with respect to the Glorieta de Cuatro Caminos can be seen.

Figure 4. Map of positions of pigeons 78f, 9c1, 9d0, 784 and 788. The distances (m) between most distant positions for each bird are shown.

Figure 5. Map of positions of pigeons 79c, 9c7, 9d5 and 792. Distances (m) between the most distant positions recorded by each bird are shown.

In autumn-winter, in pigeons (79c, 9d5, 9d4, 784, 788) mobility is significantly reduced compared to the summer period, being around 500 m. around Glorieta de Cuatro Caminos.
According to these results, pigeons have a higher level of activity in summer than in winter, even though breeding and feeding are not limited by ambient temperature. The times of departure also vary (Fig. 1), since in winter the time of beginning of activity is two hours earlier than in summer. However, the hours of greatest activity remain similar, which are around 15:00 hours for both study groups. This may be since pigeons, depending on their physical requirements and the effects of the weather, could modify their departures to the most suitable moment, which could correspond to the time when intentional feeders arrive in the area. These birds can recognize faces and remember the times and specific points where they usually obtain their food.
Finally, we consider it relevant that the long distances travelled by the pigeons from Glorieta de Cuatro Caminos (a place of intentional feeding) to their nesting site is because in this square the high population pressure of wild pigeons for years has forced the neighbours of the area to install many exclusion elements against these birds (nets, spikes, etc.) in their buildings. This would be another anthropic factor that influences the mobility of pigeons in the urban environment.

CONCLUSION

This study on the mobility of the rock pigeon, carried out using geolocation devices, provides a more precise view of the behaviour of this species in the urban environment. The data collected allows us to determine the social status of the pigeons (with or without a mate, looking for one, etc.), whether they are breeding or incubating, the location of the nesting area, their feeding habits, and many other factors still unexplored.
The analysis of the movement patterns of the pigeons allows us to identify where they tend to group together, as well as to evaluate how environmental factors and, especially, anthropogenic interventions influence their behaviour and movement.
This method of work demonstrates how human intervention can affect the lifestyle of pigeons, as the results indicate that these birds can travel significant distances from their breeding area or refuge to group together in locations where intentional and sustained feeding by citizens takes place over time. Furthermore, the difficulties in nesting at Glorieta de Cuatro Caminos (many exclusion elements in the buildings) do not prevent the birds from moving from distant nests to reach this permanent feeding place.
Given the potential usefulness of these studies, it could be interesting to extend this study for a full year, given the behavioural differences recorded in the two studies. The analysis of seasonal variations would help to determine which factors are most influential in the behaviour of pigeons, such as weather conditions, changes in urban areas or holiday periods of the citizens who provide them with food.
The starting hypothesis and the data from the two studies indicate that the anthropic factor is very relevant in the mobility and general behaviour of urban pigeons, generating important alterations that differentiate them from pigeons that live in their natural environment. In this sense, the management of urban pigeon populations must be based on raising public awareness through various educational activities, focusing mainly on children and young people, due to their receptivity and degree of involvement and sensitivity.
Studies such as those described in this document allow us to deepen our knowledge of synanthropic birds and improve management plans for their populations, which is a key step towards achieving a balanced and sustainable coexistence between animals and people in our cities, where human populations are increasingly concentrated

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