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Pigeons in Urban Landscapes: Population Control Using OvoControl®P at TransLink SkyTrain Stations

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Abstract

Pigeon (*Columba livia*) abundance in urban environments can result in human-wildlife conflicts such as excrement exposure, disease risk, and nuisance behaviour. Traditional methods of pigeon control (i.e., netting, spikes, lethal control, flying raptors) rely on exclusion and removal principles, which are not effective in the long-term. OvoControl®P is an avian contraceptive that may provide a humane management alternative and is registered by Health Canada Pest Management Regulatory Agency (PMRA) for pigeon control. The active ingredient, nicarbazin (0.5%), prevents egg fertilization in birds but eggs are still laid. To test its efficacy as a pigeon management method for a major public transit network, 8 TransLink SkyTrain stations in the Lower Mainland region of British Columbia, Canada were chosen as study sites between March 2020 and March 2021. Four control site stations dispensed cracked corn and 4 experimental site stations dispensed OvoControl®P. Trail cameras were installed at each station to confirm ingestion of product and estimate populations, while system track alarm trigger data were also reviewed. Over time, a decrease in pigeon numbers was observed at 2 of 4 stations treated with OvoControl®P, however, there was no significant decrease in pigeon populations within the time frames tested in groups receiving OvoControl®P after the introduction of treatment. The use of OvoControl®P within a major public transportation network has shown that it can be scaled and implemented, with logistical lessons noted. Results after 1 yr of treatment showed an increase in observed pigeons at stations treated with cracked corn, and small to no change in observed pigeons populations at stations treated with OvoControl®P. As contraceptive control measures require natural deaths to see a significant decline in pigeon populations, ongoing treatment at stations is recommended.

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INTRODUCTION

Pigeons (*Columba livia*) have a long history with humans as documented through their use in ceremonies (Shapiro and Domyan 2013), having acted as couriers in the United States (US) Army (Blechman 2007), and in shaping principles of operant conditioning in psychology (Skinner 1960). Currently, it is estimated that there are 165-330 million individual feral pigeons globally (Farfán *et al.* 2019). Pigeon populations have significantly increased in the last half of the 20th century in Europe and North America due to their success in urban environments (Johnston and Janiga 1995). Low levels of predation, flexible resource use, increased heat in urban environments due to human traffic, housing and businesses, and year-round breeding in most temperate climates (Pellizzari 2017), has contributed to their success. As pigeons thrive in urban environments, human-wildlife conflicts in the form of pigeon excrement, nuisance, and risk of zoonotic disease arise. Concerns regarding excrement can involve aesthetics; slipping hazards; damage to infrastructure; and disease, as when pigeon excrement dries, vectors can present as dust which can be inhaled (Pellizzari, 2017). In the US, pigeons were estimated to cost nearly US$1 billion annually in damages over 20 yrs ago (Pimentel *et al.* 2000), with current estimations unknown.

Human-wildlife conflicts are of significant concern for TransLink, the authority responsible for transportation needs in the Lower Mainland of British Columbia (BC), Canada. Pigeon abundance at SkyTrain stations can lead to excrement build up, which may increase maintenance costs needed to remove excrement, and track alarm triggers. Pigeons can fly through tracks which triggers alarms that halt the train due to the automated system being unable to distinguish pigeons from other objects that may fall through the guard rails of the tracks. Typically, these incidents involve costs associated with staff investigating the alarm, an inconvenience to customers that may lose service when this occurs, and safety risks to riders that could lose balance if the train were to stop abruptly (H. Nijjar, 2020, British Columbia Rapid Transit Company, personal communication). In 2015, a pigeon nest ignited on the tracks at a station and damaged a communications cable that required workers to work through the night to repair (Petralba 2015), causing a financial loss as free services were offered the following day (Crawford 2015).

The layouts of SkyTrain stations vary at each station, but stations typically provide elevated roosting areas for pigeons and have large open spaces and ceilings to allow trains access to the stations, which also enables pigeons to enter freely. SkyTrain stations typically have adjacent restaurants or dumpsters that are accessible to pigeons and provide feeding opportunities. Further, some commuters and residents feed the pigeons daily, despite signage discouraging feeding. These factors combined provide a thriving environment for pigeon populations.

Current pigeon population management methods fall under 3 categories: (1) exclusion methods, including spiking, netting, audio and visual deterrents, and the use of raptor presence; (2) lethal methods, including culling and the use of chemical agents (i.e., Avitrol); and (3) reproductive methods, such as physical egg removal and avian contraceptive (i.e., OvoControl®P). Many of these methods in categories 1 and 2 have been used by TransLink to address human-wildlife conflicts; however, conflicts persist without lasting mitigation.

Netting may be ineffective as front entrances for customers and openings for train movement cannot fully exclude pigeons. Spiking may have some effect initially, however, pigeons have been observed to make nests in spikes with a buildup of excrement and debris. The presence of raptors did not have a lasting effect at stations (Mangione 2018) and there has been public concern for lethal control methods (Pelizzari 2017). To address these concerns, OvoControl®P was recommended to trial as manufacturer claims suggest it may reduce pigeon populations by 50% annually in treated populations (Innolytics 2021).

OvoControl®P is an avian contraceptive with the active ingredient nicarbazin at 0.5% 5000ppm concentration (Innolytics 2021). Nicarbazin was used to control coccidiosis in broiler chicken feeds in the 1950s (Innolytics 2021). One possible mechanism of action is to disrupt the vitelline membrane in eggs, allowing the yolk and albumen to mix, creating an environment where a viable embryo cannot form (Sherwood *et al.* 1956; Yoder *et al.* 2005, 2006). Another possible mechanism is interference with egg fertilization related to the inhibition of the ZP-3 sperm receptor sites (Reinoso 2008). In either case, the resulting contraceptive effect on reproductive capacity was then considered for pigeon population control, first in the 1990s in Italy (Pelizzari 2017). Currently, nicarbazin is registered for the management of feral pigeon populations in Italy, Belgium, Mexico, and Costa Rica, where it is registered as a veterinary drug, and in the US, Canada, Colombia, Ecuador, and Australia, where it is regulated as a pesticide (Pelizzari 2017). Nicarbazin does not impact secondary consumers and is non-toxic to the environment, people, or other wildlife (Innolytics 2021).

There are few independent studies evaluating the efficacy of OvoControl®P in the field, however, 4 studies have evaluated the use of Ovistop® (nicarbazin at 0.08% or 800ppm; Acme DSrl Cavriago, Italy), the European formulation of the nicarbazin avian contraceptive. A study in Italy estimated population declines using mathematical models in various scenarios where consumption of nicarbazin was inconsistent and low, or consistent and high. They estimated a decline in pigeon populations after the first year of consumption, a range from 18% to 41%, depending on the consumption scenario (Giunchi *et al.* 2007).

A second study in Italy evaluated the use of Ovistop® over 8 yrs (2005-2011) in the city of Genoa, Italy by observing 4 non-migratory feral pigeon colonies with 3 treatment groups and 1 control group (Albonetti *et al.* 2015). There was an initial increase in the population called the 'magnet effect,' which occurred for an unspecified amount of time, although a reduction was observed over the following 4 yrs (35% to 45%), and a further decrease in the subsequent 4 yrs (65% to 70%). The authors stated that given the results, and that no external or exceptional factors were noted, Ovistop® seemed effective in reducing treated pigeon populations (Albonetti *et al.*, 2015).

In Barcelona, Spain, 23 stations were set up to dispense Ovistop® and 10 stations with untreated corn to serve as controls (Senar *et al.* 2021). The researchers found that feral pigeon density did not change after 1 yr at treatment sites and population sizes increased by 10% at control sites (Senar *et al.* 2021). They concluded that the feral pigeon population overall rose by 10% by the end of the study and subsequently advised against the use of Ovistop® as a pigeon control method in large cities, attributing the reduction in populations at feeders to poor palatability of Ovistop® (Senar *et al.* 2021).

In contrast, González-Crespo and Lavín (2022) evaluated the use of Ovistop® over 3 yrs (2017-2019) in response to Barcelona City Council changing pigeon management methods in favour of fertility control. The treatment was applied to 34 pigeon colonies and the authors reported a consistent decreasing trend of pigeon abundance by 55.26% (González-Crespo and Lavín 2022). The authors ultimately concluded that nicarbazin was effective at controlling the abundance of pigeon populations and did not impact non-target species (González-Crespo and Lavín 2022).

The manufacturer of OvoControl®P, Innolytics, conducted a study in San Diego, US that initially started with 150 birds at both a treated site and a control site. The researchers found that the treated site decreased in population size by 53% in the first year of treatment and 88% after the first 28 mo of treatment (MacDonald and Wolf 2009). Similarly, an Italian pest control company tested the efficacy of Ovistop® in Rimini, Italy and reported a 48% decline in pigeon populations after 14 mo of treatment, however, it is unclear if this study was conducted in partnership with the manufacturer (Freedom Co., Ranchio di Sarsina, Italy).

All these investigations are important to urban animal welfare studies as animals considered pests typically have their inherent and ecological value diminished by this label, making their removal or suppression in favor of human interests appeared justified (Oogjes, G. 1997). Further, others have advocated that any method other than long-term management of human-wildlife conflicts will result in only short-term successes through culling or removal being repeatedly used, without a sustainable solution ever being reached (Clayton and Cowan, 2010). As nicarbazin has shown potential in managing pigeon populations in previous studies (Freedom Co., Ranchio di Sarsina, Italy; MacDonald and Wolf 2009; Albonetti *et al.* 2015; González-Crespo and Lavín 2022), including OvoControl®P in population management programs in similar conflict situations may be more humane and effective.

The aim of this study was to assess whether OvoControl®P can provide a viable pigeon population management option to TransLink SkyTrain stations. To test this, 8 stations were included in experimental design, 4 dispensing OvoControl®P and 4 dispensing cracked corn to serve as a control. Stations were monitored for approximately 1 yr with trail cameras to provide daily estimates of the number of pigeons ingesting the treatments. Track alarm trigger data was collected from TransLink prior to and during the experimental period.

STUDY AREA

Study areas included VCC-Clark SkyTrain station (49.266N, 123.079W), Renfrew SkyTrain station (49.259N, 123.045W), Metrotown SkyTrain station (49.225N, 123.003W), Stadium-Chinatown SkyTrain station (49.279N, 123.109W), 22nd Street Skytrain station (49.200N, 122.949W), Surrey Central SkyTrain station (49.189N, 122.847W), Joyce-Collingwood SkyTrain station (49.238N, 123.031W), and Lafarge Lake SkyTrain station (49.285N, 122.791W) in the Lower Mainland of British Columbia, Canada (Figure 1).

METHODS

OvoControl®P was approved for use in Canada as of April 2018 (Innolytics 2021), and proof of concept was required for TransLink before study approval. An initial station, VCC-Clark, was selected to serve as a pilot site from May 2019 to September 2019 due to the known pigeon activity and an excessive amount of track alarm triggers observed

Figure 1. Figure 1. Location of 8 SkyTrain stations in the Lower Mainland of British Columbia, Canada. Four stations (Renfrew, Stadium-Chinatown, VCC-Clark, and Metrotown) were experimental sites dispensing OvoControl®P, and 4 others (22nd Street, Surrey Central, Lafarge Lake, and Joyce Collingwood) were control sites dispensing cracked corn. Created using iMapBC (British Columbia 2022).

at this station. Video footage confirmed the pigeons were consuming the bait daily at VCC-Clark and expansion of the project was approved in September 2019 to 8 stations. VCC-Clark station was included in the expansion.

Eight SkyTrain stations were chosen as study sites with 4 stations dispensing OvoControl®P and 4 control stations dispensing cracked corn. Due to personnel and supply costs, only 8 out of 38 stations overall were selected. Station inclusion criteria included: the presence of a pigeon population; an area to set up feeder that is not accessible to the public; accessibility for regular maintenance; and no safety risk to the public. The 4 stations chosen to dispense OvoControl®P were randomly selected. Ethics approval was received from the Canadian Council on Animal Care at The University of British Columbia (A19-0001).

Stations were enrolled in the study for the duration of 1 yr from March 15, 2020 to March 17, 2021, with the exception of VCC-Clark station (November 15, 2019 to January 13, 2021). The Lafarge Lake station feeder was previously at Lougheed station, but it was relocated at TransLink's request due to uncontrollable rat (*Rattus rattus*, *Rattus norvegicus*) infestation caused by the location of the feeder on ground level. It was removed from analysis due to a shorter period of data collection (August 13, 2020 to March 15, 2021). Data was collected for 1 yr to compare to previous studies (Albonetti *et al.* 2015; Senar *et al.* 2021) and assess claims that OvoControl®P can reduce populations by 50% in the first year of use (Innolytics 2021).

Each station was monitored using a Moultrie A700 automatic infrared digital trail camera (PRADCO Outdoor Brands, Birmingham, Alabama, USA) pointed at the feeding sites on tripods. Camera distances varied from feeders with intention to conceal cameras from theft but to provide full frames of the feeding areas to ensure pigeons were ingesting treatment. OvoControl®P or cracked corn was dispensed from the Moultrie Deer Feeder Elite II Tripod feeder. Four stations received the treatment: VCC-Clark, Renfrew, Stadium-Chinatown, and Metrotown; and 4 stations received the control: Surrey Central, Joyce-Collingwood, Lafarge Lake, and 22nd Street. VCC-Clark enrolment ended prior to March 15, 2021 due to theft that resulted in damage at the station, but data was collected at this station for a whole year. Other reasons for missing data at this station can be attributed to equipment malfunction and human error in changing equipment.

Stations selected to dispense OvoControl®P initially dispensed cracked corn for a minimum of 2 wks (baiting period) as per Innolytics best practices for OvoControl®P to habituate the birds (Innolytics 2021). The baiting period was prior to treatment introduction dates of January 8, 2020 for VCC-Clark station and March 15, 2020 for all other stations and was analysed as the 'Before' period. Feeders were programmed to dispense treatments at 07:00 daily and pigeon populations were monitored by cameras from 07:00-12:00 daily to capture activity and populations present around feeding time. This time was selected as pigeons typically feed in the morning (Johnston and Janiga 1995) and to ensure pigeons were ingesting OvoControl®P before alternative human foods were available, which might reduce their interest in OvoControl®P. Baited pigeons were expected to consume OvoControl®P within 3 to 5 min (Innolytics 2021). Each feeder could accommodate up to 150 birds and the amount dispensed daily was calculated using the recommended 5 g per bird per day, which accounts for roughly 15% of the pigeons' dry matter intake (Innolytics 2021).

Study sites were serviced by Terminix, TransLink's pest control company during the study period. Every 2 wks, a technician changed 32GB SD cards, replaced batteries, and refilled either cracked corn or OvoControl®P in feeders as needed. Maintenance by Terminix was necessary as OvoControl®P must only be handled by a licensed pest control applicator (British Columbia 2021), and many feeder sites were difficult to access. The daily number of pigeons ingesting treatment was estimated for each station from video footage obtained during the baiting period.

Daily pigeon counts were conducted by noting the largest group of pigeons seen in 15-sec video clips between 07:00 and 12:00. As it was not possible to count the entire population of pigeons present at SkyTrain stations, this sampling approach was employed to estimate the population consuming treatment (Elzinga *et al.* 2009). The following monitoring methodology was conducted: 32 GB SD cards containing footage of pigeon activity at stations were collected from Terminix biweekly and the videos were then sorted by date. Only footage between 07:00 and 12:00 were reviewed due to the baiting of pigeons to the feeder dispensing feed at 07:00 and feasibility of footage review. Each clip was paused at the frame with the most pigeons present in the frame and then pigeons were counted. To be counted as one sampling unit, at least 50% of the animal needed to be in the camera frame to ensure accuracy in identification (Elzinga *et al.* 2009). It is acknowledged that it is impossible to record every animal present at a station within a single camera frame.

Once data was recorded with daily values, the data were added to an Excel sheet for each station to conduct statistical analyses, and notes on other species observed in the video clips were recorded. This allowed us to measure interest, i.e., the number of times the camera was triggered, the total number of pigeons observed for that date, and the largest group size observed for that date.

Secondary data from TransLink was also used to assess pigeon activity at stations. Track alarms were triggered when an item, person, or animal fell within a distinguished region of SkyTrain tracks that were past the guardrails at each station. Track alarms were investigated by staff and categorized accordingly, track alarms categorized as 'Animal' or 'Unknown' were included in the study. Track alarms may have accompanying notes specifying the species of animal that caused the alarm, but in many incidents, this information is unknown. Data from each station on triggered alarms was obtained from the British Columbia Rapid Transit Company (BCRTC) between May 2018 (earliest date of available data) and March 2021, and filtered for data during the experimental period.

All analysis were conducted using R version 4.0.4 (R Core Team, 2015). After descriptive analyses were obtained, the association between station and the number of pigeons observed (maximum number in a group at one time, and total number), as well as the association between station and the number of daily track alarms were assessed by a zero-inflated mixed regression model, adjusted for day as random effect (Magnusson *et al.* 2020). The random effects, day and station were nested in the mixed model. Briefly, it is a two-component model with a count component and a zero component that models the excess zero counts. The model was then used to generate the marginal effect of stations for these outcomes (Lüdecke 2021).

The association between daily number of track alarms and the number of observed pigeons each day (maximum number in a group and total number) was also evaluated using a zero-inflated mixed regression model, adjusted for station and day as random effects. Finally, the number of pigeons observed before and after the introduction of treatment was compared between treatment groups as an interaction in a zero-inflated mixed regression model, adjusted for station and day as random effects. The station Lafarge Lake was removed from these analyses as there was no data prior to the treatment. The "Before" period started on November 15, 2019 and ended on March 15, 2020 (January 8, 2020 for VCC-Clark), when treatment was introduced. The "After" period started on April 15, 2020 (February 8, 2020 for VCC-Clark), as it would be expected at least a month would be necessary for the treatment to have an effect and ended on March 17, 2021 (January 13, 2021 for VCC-Clark). The data from March 15, 2020 to April 15, 2020 (January 8, 2021 to February 8, 2021 for VCC-Clark) was removed as it was considered a transition period ($n_{\text{observations}}$ = 217, from 62 d and 7 stations).

RESULTS

A total of 3,218 observations were obtained from November 15, 2019 to March 17, 2021. The data came from 8 SkyTrain stations and was available for 489 d. Raw data is presented in Figure 2 displaying both the maximum number of pigeons observed at one time in 1 day (light-colored line), and the total number of pigeons observed in 1 d (dark colored-line). Missing data points in Figure 2 can be attributed to a variety of reasons including theft of cameras, equipment malfunction, or station changes caused by an increase in rats from feed being dispensed.

The maximum number of pigeons observed per day per station varied between 0 and 57 (median = 14, mean = 15.0, SD = 12.4). The number of daily track alarms varied between 0 and 6 (median = 0, mean = 0.3, SD = 0.5). The number of daily track alarms and maximum number of pigeons varied by station (zero and count components: $P<0.01$). The relationship between the maximum number of pigeons observed at one time and track alarm counts showed that more observed pigeons at a station on a day increased the odds of having no alarm, but there was no increased rate of higher counts if more pigeons were observed (Figure 3). This result was the same when comparing the total number of pigeons observed daily and track alarm counts (not presented).

Figure 4 depicts the treatment types, either cracked corn or OvoControl®P, and changes in the total number of pigeons observed 'Before' treatment and 'After' treatment ($P = 0.01$).

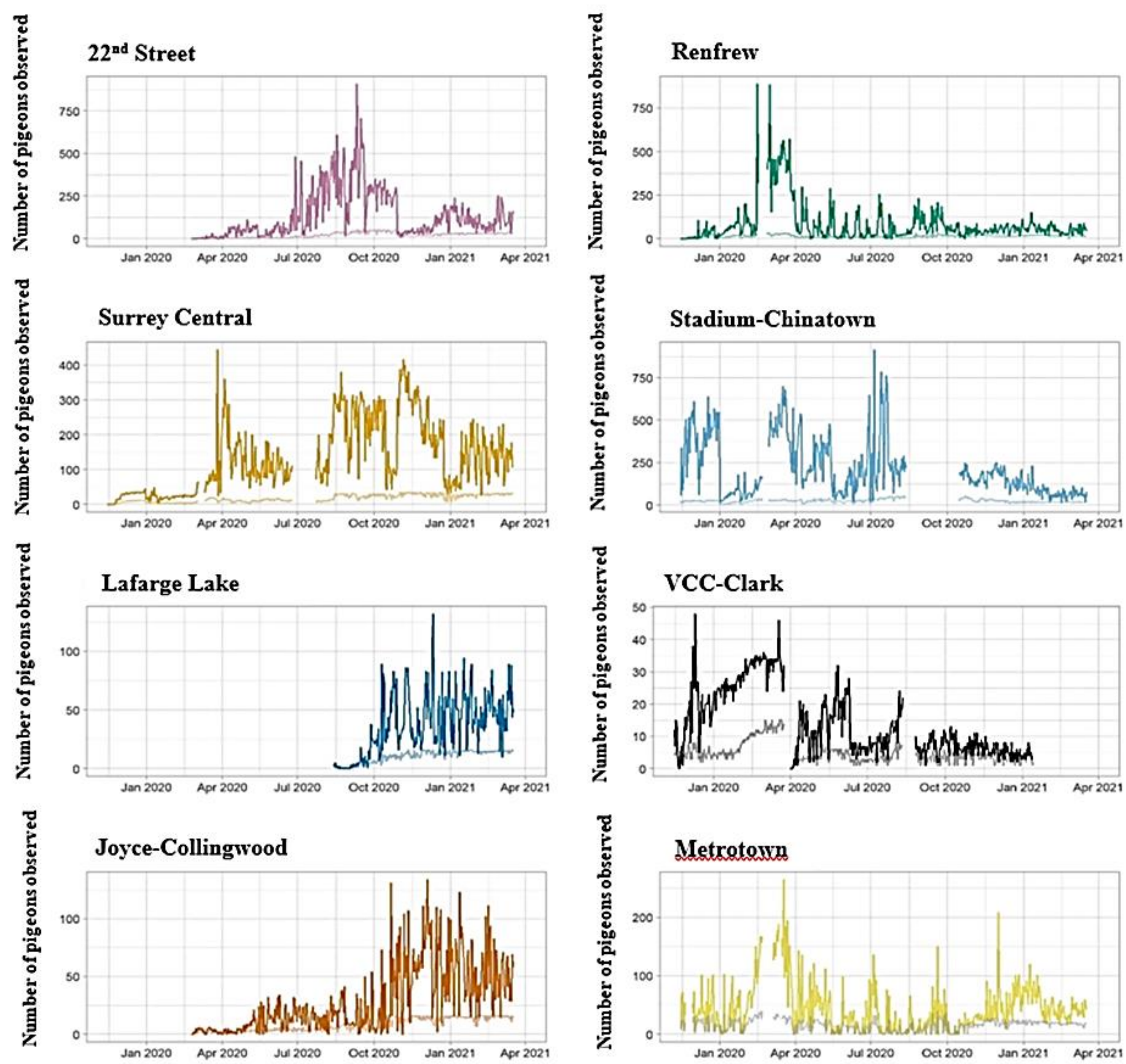

Figure 2. Maximum number of pigeons seen at one time in a day (light-colored line) and total number of pigeons seen in a day (dark-colored line) in 8 SkyTrain stations in Vancouver, Canada. Four stations (Renfrew, Stadium-Chinatown, VCC-Clark, and Metrotown) were experimental sites dispensing OvoControl®P, and 4 others (22nd Street, Surrey Central, Lafarge Lake, and Joyce Collingwood) dispensing cracked corn.

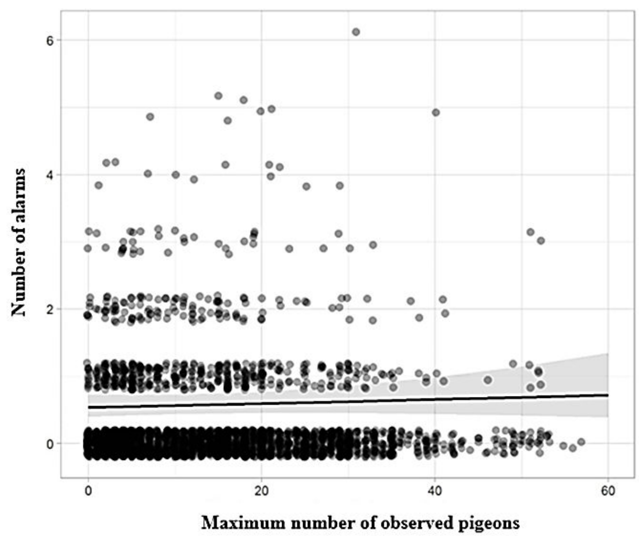

Figure 3. Predicted change in the number of daily alarms according to the maximum number of pigeons observed in a station (regression line ±95% confidence intervals), superposed to the observed data (points) in 8 SkyTrain stations in Vancouver, Canada from November 15, 2019 until February 28, 2021. The association was obtained from a zero-inflated mixed effect model including station and date as random effects ($n_{observations}$ = 3,099 from 472 d).

Overall stations treated with cracked corn had a lower number of total pigeons in the 'Before' period and increased in the 'After' period. Stations treated with OvoControl®P did not statistically increase from the 'Before' period to the 'After' period. Results were similar when assessing the maximum number of pigeons observed at one time, rather than the total number of pigeons observed in the day.

DISCUSSION

Overall, stations that dispensed cracked corn were found to initially have low numbers of total pigeons observed in the 'Before' period and increased 'After' treatment. Stations that dispensed OvoControl®P did not change from the 'Before' period and the 'After' period. The small number of stations in addition to large differences in the total number of observed pigeons at different stations limit the possibility of finding statistical differences between the treatment groups. For example, a change in a station with 700 total pigeons observed daily (e.g., Stadium-Chinatown) might have a different impact than a change in pigeons at a station with 50 total pigeons observed daily (e.g., VCC-Clark). Further, there were a small number of pigeons in the 'Before' phase of analysis as bird populations tended to increase when they became baited to the control feeding stations which may have influenced results comparing the 'Before' and 'After' periods. As it is possible that not all pigeons present at a station were captured on camera, some pigeons may not have ingested the treatment.

As feral pigeons typically have a lifespan in urban conditions of 2−4 yrs (Johnston and Janiga 1995), it is not surprising that the groups treated with OvoControl®P did not see a significant change in observed pigeons in 1 yr. However, it is possible that these birds may not be reproducing, but a decline in their total populations may take longer to observe due to their lifespans. Nevertheless, the result that there was no increase at treated stations despite daily feeding, and an increase at control stations aligns with our predictions. Regarding palatability of OvoControl®P, pigeons appeared to descend on the feeder reliably at experimental sites and appeared to consume the dispensed OvoControl®P daily, however, it is difficult to determine if slight reductions in the daily numbers of observed pigeons could be attributed to poor palatability.

The result of increased odds of having no track alarm if more pigeons are present was unexpected and perhaps may be explained by observing where pigeons are choosing to roost and nest. This may have a greater effect on track alarm triggers rather than the group size of the pigeons. As it was not possible to definitively know which alarms were caused

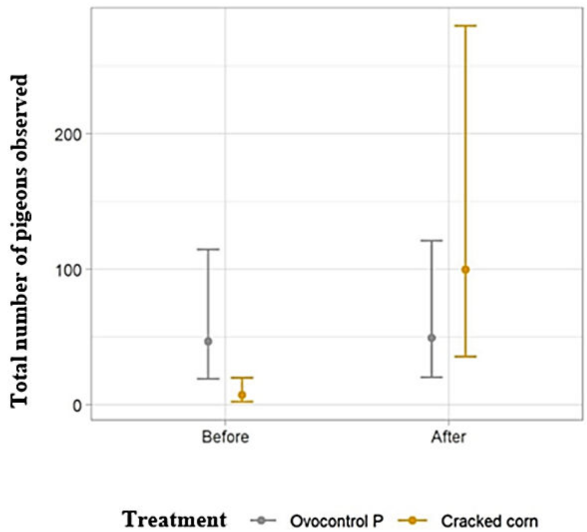

Figure 4. Predicted total number of pigeons observed in a day (± 95% confidence intervals) in 7 SkyTrain stations in Vancouver, Canada, before and after the addition of treatment. Four stations (Renfrew, Stadium-Chinatown, VCC-Clark, and Metrotown) were experimental sites dispensing OvoControl® P, and 3 others (22nd Street, Surrey Central, and Joyce Collingwood) were control sites dispensing cracked corn. Predicted values were obtained from a zero-inflated mixed effect model including the interaction between treatment and time-period (before or after treatment), and the station and date as random effects ($n_{\text{observations}}$ = 2,784 from 483 d and 7 stations).

by pigeons, it is possible that there is no relationship between number of pigeons and track alarm triggers. Currently, there is only literature to suggest pigeons remain relatively close to their roosting and nesting habitats (Rose *et al.* 2006), but no studies assessing the effect of moving food sources short distances to influence nesting and roosting sites. Inquiry into whether the placement of the feeders or artificial roosting sites at locations far from SkyTrain tracks would offer further understanding, as it could potentially aide in reducing track alarm triggers by encouraging pigeons to source food and roost in alternative areas.

Currently our results align with those found by Senar *et al.* (2021), which demonstrated an increase in pigeon populations at control sites dispensing cracked corn and no change in stations dispensing the active ingredient. However, other studies have found population declines over longer time periods (Albonetti *et al.* 2015; González-Crespo and Lavín 2022), therefore it is recommended that TransLink continue to apply treatment and monitor over longer periods.

A common concern regarding population management control is the inability to control free-ranging populations of animals that are open to immigration and emigration. Due to many wildlife species being free-ranging open populations, reproductive control has not been used or studied significantly as a method of population management given the inability to ensure animals remain in areas treated with reproductive control, and animals not treated with reproductive control do not move into the area (Malcolm 2008).

Information related to the dispersal and home range of pigeons is scarce with little data available about the rate of exchange between pigeons among cities (Giunchi *et al.* 2007). However, one study suggests pigeons can cover short distances outside of city limits, less than 10 km (Rose *et al.* 2006), and another proposes that feral pigeons characteristically have short (less than 0.1 km) natal dispersal distances (Johnston and Janiga 1995). Further, Richardson *et al.* (2016) found that there was minimal dispersal between colonies, the largest dispersal range being 6.1 km. Murton *et al.* (1972) suggest pigeons are relatively sedentary as 85-87% of marked pigeons in their study moved less than 0.09 km away from the marking point. Although dispersal research is limited, it is important to understand pigeon population dynamics when determining appropriate population control methods. Further, reviewing fertility control in other species of free-ranging wildlife may provide insight into the efficacy of fertility control in environments when animal populations are geographically unrestricted and success has been found in the following species, but with practical considerations: rats (Pyzyna *et al.* 2018), elephants (*Loxodonta africana*) (Delsink *et al.* 2006), white-tailed deer (*Odocoileus virginianus*) (Walter *et al.* 2002), elk (*Cervus elaphus*) (Powers *et al.* 2011), cattle (*Bos taurus*, *Bos indicus*) (Massei *et al.* 2018), and kangaroos (*Macropus giganteus*) (Wilson *et al.* 2013).

Regarding limitations of this research, they can broadly be attributed to time and approval constraints, and practical concerns in experimental set-up. Initial approval to expand the pilot study took approximately 9 mo. It was imperative to ensure that data would be collected for a full year so that results could be compared to claims made by Innolytics of a 53% reduction in pigeon populations after 1 yr of treatment (MacDonald and Wolf 2009), as well as previous studies that had conducted treatment periods for at least 1 yr (Albonetti *et al.* 2015; Senar *et al.* 2021). This delay resulted in Lafarge Lake station not having a full year of data. Ideally, data collection for this type of project would start earlier so that technical concerns that arise could be addressed and all experimental sites are able to obtain at least 1 yr of data.

Further, as excrement maintenance and pigeon presence were concerns at TransLink SkyTrain stations, data regarding customer complaints about excrement or pigeon presence was requested, as well as maintenance hours dedicated to cleaning pigeon excrement or work orders created to mitigate problems with the pigeons at various stations. However, due to security protocols and unavailability of data, this information was not obtained. It is recommended that data related to these direct concerns expressed also be collected in future studies, as it allows for comprehensive assessment in determining the efficacy of OvoControl®P in mitigating such concerns associated with pigeons.

There were numerous practical limitations with this research, notably theft of the cameras and damage, the attraction of non-target pest species, and human error. As SkyTrain stations are located in central areas with high volumes of people traffic, theft is likely to occur if equipment is visible or accessible to the general public. The occurrence of theft compounded study costs by requiring the purchase of replacement equipment and typically resulted in a loss of pigeon population count data for intervals of 1 to 4 wks.

Further, the attraction of rats was another practical limitation of this study. Typically, feeders that were placed on the ground, rather than roof tops, would attract rats in varying population numbers. It is important to consider the placement of feeders and the effect the potential location may have on attracting non-target species. Placing feeders on rooftops seemed most effective at mitigating this limitation, but depending on the structural layout of the SkyTrain station, this was not always possible.

As different technicians maintained the study sites, occurrences where SD cards were placed in cameras incorrectly or batteries were not replaced happened on 3 occasions, which led to a loss of pigeon population count data. Further, there can be inconsistencies in investigating track alarm triggers as reports can contain varying degrees of detail with classifying the cause of track alarm triggers as being either “Animal” or “Unknown”.

MANAGEMENT IMPLICATIONS

There are many opportunities for future research that could contribute to understanding the efficacy and implications of an OvoControl®P management system in various settings. This could include conducting treatment studies for longer periods of time and conducting treatment in various settings such as in residential homes or across municipalities. A study to test how representative pigeons captured in a fixed camera position are of the overall population would be beneficial to understand how palatable treatment is to pigeons. These findings could impact detection bias and provide insight towards population estimate accuracy. A study spanning multiple years evaluating the efficacy of OvoControl®P at mitigating human-wildlife conflicts at TransLink SkyTrain stations, similar to the study conducted by González-Crespo and Lavín (2022), would be beneficial to understand the long-term results and potential associated costs.

Understanding long-term effects could help inform pigeon control management decisions by large corporations nationally facing similar human-wildlife conflicts. Further, a study performed in similar length to Albonetti *et al.* (2015), approximately 8 yrs, would be beneficial in a municipal setting, such as in research conducted by Senar *et al.* (2021) and González-Crespo and Lavín (2022), to observe if there are further changes in population over a significant time period. As OvoControl®P is intended to be used continuously as a long-term management solution, it is imperative to understand the effects of the contraceptive for more than a year.

Additionally, testing the efficacy of OvoControl®P in a variety of settings would be beneficial to understand under what conditions it can be used as a successful management solution. As Senar *et al.* (2021) stated that nicarbazin was ineffective in a municipal setting, which contradicts the results found by González-Crespo and Lavín (2022), it would be beneficial to understand under what conditions treatment can work, if it can be effective in some cities with particular geographic features, but not others, or if the determining factor of successful population decline is only the length of treatment time. Further, it would be beneficial to know if OvoControl®P could provide mitigation to human-wildlife conflicts in small-scale settings such as residential homes, single buildings, or parks. Lastly, studies regarding the efficacy of free-ranging fertility control are scarce and lack longevity. Studies evaluating the use of contraceptives in free-ranging wildlife over the span of multiple years would be beneficial to inform human-wildlife conflict policy and support perspectives of co-existence and ethical wildlife control (Dubois *et al.*, 2017).

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