Creating their own ecological niche: feral pigeons in urban areas

The use of ecological knowledge to create a management plan for urban pigeon population

Figure 1. Pigeon morning.

H.C.L. (Cathalijn) Konijnenberg
5553172
h.c.l.konijnenberg@students.uu.nl
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Supervisor:
Dr. Vivian Goerlich-Jansson
Department of Population Health Sciences
Utrecht University

Abstract

This thesis focusses on the problems regarding feral pigeons in the urban habitat. These problems include the corrosive effects of pigeons droppings on buildings and noise complaints. The aim of this thesis is specify suggestions for the management of urban feral pigeon populations, based on the ecological information regarding feral pigeons (*Columba livia domestica)*. To provide an answer to the research question several ecological theories are examined, such as the carrying capacity, the Lotka-Volterra model and the ecological niche. After an examination of the ecological characteristics of feral pigeons, an overlap is detected in the needs of the feral pigeon and the offerings of urban habitats. The preference of the feral pigeon for urban habitats can be explained by the lack of predators, the ample availability of nesting spaces and the constant supply of food.

After defining the problem and specifying the contributing factors, the second half of the thesis focusses on population management options that would reduce the population size of feral pigeons in urban habitats. Since current tactics are not sufficient, long-term or keep animal welfare in mind, a new solution needs to be found. The findings of this thesis suggest that the most effective and lasting method of population management is based on ecological knowledge of the habitat and the species. To reduce the number of feral pigeons in urban habitats, the habitat has to be altered in a way that it becomes less desirable for the species. A first step could be the banning of large-scale bird feeding and making food waste less accessible to feral pigeons. However, there is no perfect global solution. Every urban habitat differs and has different specific ecological characteristics, therefore to successfully propose a population management plan, specific ecological research has to be conduct for every city that has problems regarding their feral pigeon populations.

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1) Introduction

When you picture the inner part of a major city, you might think of specific buildings, the chatter of a market place and there is a great chance that you envision a few pigeons hopping around. For some, pigeons are an integral part of urban areas, for others pigeons are part of a problem. Besides contributing to the idyllic scenery of cities, pigeons are thought of as dirty and spreaders of disease. This dislike for pigeons can for example even go as far as the declaration of a 'Pigeon War', as done so by the mayor of London ("Why do we hate pigeons so much?", 2007). In his efforts to reduce the number of pigeons in London, the mayor actively banned the feeding of pigeons in certain areas in the city. While this solution seems relatively cruelty-free, another measure to keep areas pigeon-free is less so. First the city of London and later the television and news company BBC, made use of hawks as a repellent for pigeons. The theory behind using hawks was that they would deter the pigeons and prevent nesting on buildings. Although it was not the plan to harm or kill any pigeons, on rare occurrences this did happen (Swinford & Walton, 2013).

Those aforementioned measures did help reduce the number of pigeons in London, however there were concerns about its impact on animal welfare as well the general public's dislike of the measures. The concerns about animal welfare were based on the fact that the hawks in some occasions did harm the pigeons, which led to injuries and suffering. In London, this approach led to the founding of an organisation called Save the Trafalgar Square Pigeons (STTSP). This organisation's goal was to create a humane long-term strategy regarding the pigeon problem, since a ban on feeding could lead to starvation (Background - Save The Trafalgar Square Pigeons, n.d.). However, scientific backing for this claim is scarce.

The examples as stated occurred in London, but the issue of urban pigeons is widespread. In many city centers problems related to pigeons exist, such as bird droppings accelerating destruction of buildings (Weber, Haag & Durrer, 1994). Therefore, the call for long-term effective management measures is widespread. The scientific foundation of such a long-term management strategy may be found within the science of ecology. Since ecology has a focus on the interaction between organisms and the environment, its findings can be used to find a solution for the problems regarding pigeons in an urban environment. Therefore, the aim of this thesis will be to find out how knowledge of specific ecological characteristics of urban pigeons can be used to form a management plan for urban pigeon control, all the while keeping animal welfare in mind. This translates into the following research question:

What suggestions for the management of urban feral pigeon populations can be made based on the ecology of pigeons?

To be able to propose potential population management approaches, first a thorough exploration of applicable ecological concepts is performed. Then, after defining the species characteristics and ecology of feral pigeons, these findings will be compared with the ecological factors urban areas have to offer. Finally, based on the results, a possible new management approach can be constructed, that is not only more effective, in short-term and in long-term, but will also value the animal welfare of the feral pigeon. For this thesis, the criteria of animal welfare are defined as having access to good food and good housing, having good health and showing appropriate behaviour (Botreau et al., 2007).

By answering this research question, the need for more information about urban pigeons will be met and a more scientific profound solution for nuisances caused by those pigeons can be formed. As stated by Rose, Nagel & Haag-Wackernagel (2006), with more information about for example feeding patterns, a better understanding of the common factors that influence urban pigeon behavior can be obtained. This information could then subsequently be used to form a management plan, to control the urban pigeon populations in a way that is acceptable for both humans and animals.

2) Ecology

Defining urban ecology

In this paragraph, different aspects and characteristics of ecology will be presented, with a focus on population ecology and urban ecology. In the next chapters, those characteristics will be applied on the topic of feral pigeons and their urban habitat. Urban ecology examines organisms and their environment in an urban setting (Campbell et al., 2015). This discipline is a relatively new aspect of ecological research, for some it was even considered 'inferior' to the natural environments (Niemelä, 1999). For the last several centuries, mankind has started to conglomerate more and more into urban areas thus creating cities. While the formation of cities comes associated with the removal and destruction of habitats, they may also form a new habitat for some species (Niemelä, 1999). The city as an ecosystem is heavily fragmented and disturbed, has a high density of man-made structures of which some have strong heat-retaining abilities (Aronson et al., 2014). Furthermore, urban areas disturb the ecological resource cycles and this leads to an agglomeration of resources and nutrients (Aronson et al., 2014; Nuorteva, 1971).

Built environment expands rapidly into the country side, which is already being threatened by intense agricultural activities (Kelcey & Rheinwald, 2005). The expectations concerning the growth of human population living in urban areas vary. In 1999 calculations indicated that in 2005 over 60% of all population would be living in urban areas (Niemelä, 1999), while the 2005 book of Kelcey & Rheinwald states that nearly half of all human beings live in the city. The most up to date and trusted numbers currently are those of the United Nations. Urban population has experienced an increase from 30% in 1950, to 54% in 2005 and the expectation is that in 2050 66% of human population will live in urban areas (United Nations, 2015, as cited in Herrera & Castells, 2019).

Ecological niches

In ecological research, the concept of an ecological niche is used as an organisational tool (Leibold, 1995). The niche of an organism is defined by Begon, Harper & Townsend (1996) as the limits, for all important environmental features, within which individuals of a species can survive, grow and reproduce. Therefore, the niche of an organism can be seen as a description of the "role" of a species in a community (Elton, 1927, as cited in Leibold, 1995). Niche theory can be divided in to two distinct components, firstly the environmental requirements of organisms and secondly the impact of organisms on the environment (Leibold, 1995).

Different kinds of niches can be defined, of which the fundamental niche is the most exclusive. The fundamental niche is the niche of a species when no competitors are present. This is in contrast with the realized niche, the nature of which is determined by which competing species are present (Begon, Harper & Townsend, 1996). Therefore, two species that are thriving when on their own, can decrease rapidly in population size when combined in the same habitat.

Habitats

Related to the ecological niche is the habitat in which an organism lives. In contrast with the niche, a habitat is an actual place and therefore can suffice in the requirements (Begon, Harper & Townsend, 1996). The niche of a species will likely be specified for one organism, in a habitat however different species occur and the requirements for their niches will be different, to limit interspecific competition. As shown in figure 2, the dispersion of a species is limited by many factors. One of the factors is habitat selection, however all the other aspects are what makes up the habitat in which the species will live.

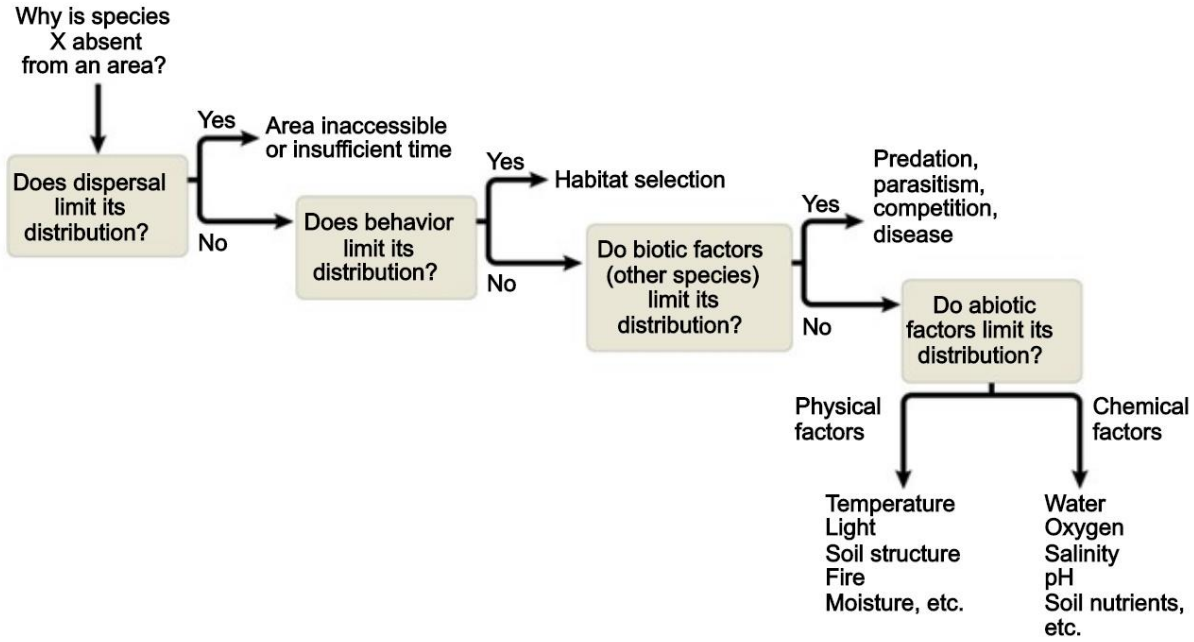

Figure 2. Factors limiting geographic distribution (Campbell et al., 2015).

For this study the focus is on urban habitats, which are man-made alterations to the landscape. The most important aspect of the urban habitat is that it is not in its original state. The species that used to inhabit the area were disturbed, which led to changes in the biodiversity of the area. According to Lancaster and Reeds (1979), a decline in species diversity over time is visible when urbanization of areas increases. Urbanization has led to a homogenized biota (Aronson et al., 2014). However, not all species suffered from the increase of urban habitats, cities can act as hotspots for threatened species. The Australian study of Ives et al. (2016) showed that cities contain more threatened species per unit area than nonurban areas. Therefore, urban areas can play an important role in biodiversity conservation management.

Synanthropic species

Some species of animals can be classified as synanthropic species. This term is used for animals that have adapted to and profit from living in close proximity with humans. A good definition of the term is stated by Giunchi et al. (2012): “the synanthropism of ferals is mainly a consequence of the food resources becoming available with the development of agriculture or otherwise mainly depends on the presence of buildings that constitute a vicariant habitat with respect to the natural one”. Feral pigeons therefore are a prime example of a synanthropic species, since they thrive exceptionally well in man-made areas. Whereas urbanisation is seen in many ways as a disturbance to the natural environment, for these species benefit from accumulated organic material that has not been returned into the ecological cycles (Nuorteva, 1971). The degree of attraction or avoidance of humans can be calculated as a synanthropic index, ranging from +100 to -100, which is the utmost avoidance

Carrying capacity

Another concept of ecology that is related to the research question is the carrying capacity of a population. This is influenced by for example the amount of available energy, shelter, refuge from predators, available nesting sites, water availability and nutrient availability (Campbell et al., 2015). Carrying capacity is used in the research into intraspecific competition, the competition between organisms of the same species. More specifically said, the carrying capacity is the density of a population when the birth rate equals the death rate (Begon, Townsend & Harper, 1996). The carrying capacity is often denoted as '*K*', which stands for the number of individuals that the environment can support in a given area. Also stated is that if the required resources exceed the available resources this will have a negative impact on the ecosystem. Examples of these negative impacts are a decrease in productivity, biodiversity and richness and an increased vulnerability to invasions (Chapman & Byron, 2018).

As shown in figure 3, a link between the resource density and fitness components can be found. The continuous line, marked with *b*, represents the birth rate and the dotted line is the death rate of a species. The fitness components relate to the influence that specific ecological characteristics have on the species. If the species has a higher fitness, it is more adapted to its surroundings. Species therefore occupy areas wherein their fitness is maximized (Morris and Davidson, 2000). When the resource density is high enough, the birth rate exceeds the death rate and the population size will grow. An equilibrium is achieved at the point noted as *R*,* where the available resource density leads to an equal level of birth and death rate. In short, the changes in population size can be summarized as the number of births plus immigration minus deaths minus emigration (Campbell et al., 2015).

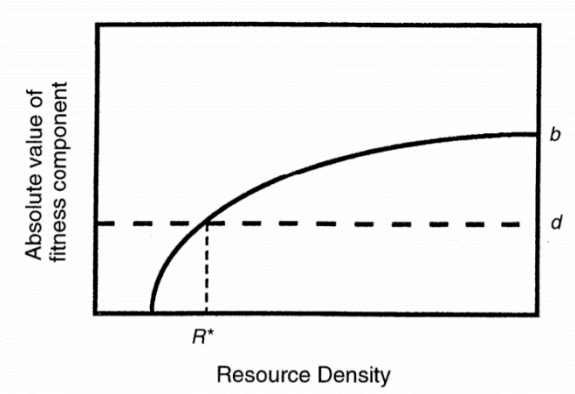

Figure 3. Resource-dependent and -independent fitness components (Leibold, 1995). The dotted line (d) represents the death rate of a species and the continuous line (b) the birth rate, with the resource density on the X-axis and the fitness component value on the Y-axis.

Lotka-Volterra model

The Lotka-Volterra model is a fundamental theoretical model concerning population ecology. The equation describes the relationship between predator and prey populations. This interspecific relation is based on a predator or consumer removing individuals from the population. As shown in equation 1, the exponential growth (*r*) of the prey (*N*) is hindered by the presence of the predators (*P*). However, the effectiveness of the predator is influenced by the attack rate (*'a*), since not all attacks of the predator will lead to a dead prey.

Equation 1. Lotka-Volterra prey equation

$$\frac{dN}{dt} = rN - a'PN$$

The second part of the Lotka-Volterra model focuses on the predators and the changes in their population size. The predator birth rate (*fa'PN*) is formulated out of the rate of food consumption (*a'PN*) and the efficiency with which food is used to produce offspring.

Equation 2. Lotka-Volterra predator equation.

$$\frac{dP}{dt} = fa'PN - qP$$

When combining the results of the two equations in to one graph, an underlying interdependency becomes clear. This means that when the prey population size increases, an increase in predator population size follows. This shows the tendency for coupled oscillations, fluctuations around the neutral state (Begon, Harper & Townsend, 1996).

Finally, the equations can be combined with the carrying capacity (*K*), to form equations that can predict under what circumstances the respective species increase or decrease in abundance.

Equation 3. Lotka-Voltera model equation species 1.

$$\frac{dN_1}{dt} = r_1 N_1 \frac{(K_1 - N_1 - a_{12}N_2)}{K_1}$$

Equation 4. Lotka-Volterra model equation species 2.

$$\frac{dN_2}{dt} = r_2 N_2 \frac{(K_2 - N_2 - a_{21}N_1)}{K_2}$$

3) Pigeons

Definition of the feral pigeon

To form a cohesive management plan concerning urban pigeons, a specific definition of the urban pigeon has to be formed. The Princeton Encyclopedia of Birds calls pigeons 'among the most successful of all birds', seeing how pigeons live almost everywhere where humans live (Perrins, 2009). In literature, pigeons inhabiting urban areas are mostly called feral pigeons (Murton, Thearle & Thompson, 1972). In some research the pigeons are called urban pigeons, but those are the same species as the feral pigeon, *Columba livia* (Sol & Senar, 1995). Charles Darwin did already describe the pigeon in his writings in 1868, in which he stated that the diversity in colour, size and body shape of domestic pigeons could be attributed to the fact that the feral birds were descendants of variations of rock pigeons (Johnston, 1992).

According to the Dutch organisation for bird research, Sovon, the urban pigeon (*stadsduif* in Dutch) is known by the Latin name of *Columba livia forma domestica* (Sovon, n.d.). This name indicates the domestication of a formerly wild animal. They state that although feral pigeons live in 'close coherence' with humans, the pigeons are not dependent on them. This is in stark contrast with other types of pigeons such as homing or messenger pigeons, who do not forage on their own anymore. The earliest rock doves were domesticated to be bred as a source of food around 5.000 to 10.000 years ago, in Middle Eastern and Southwest Asian regions (Murton & Westwood, 1966). Not all present-day feral pigeons descend from escaped domesticated pigeons of that region however. North-American populations are relatively younger in their evolution, since those feral pigeons were at first introduced after the colonization of the continent (Johnston, 1992). As seen in figure 4, this origin history makes for a distinct split in the tree diagram of the genetic lineage of the feral pigeon. Also visible is how the feral and the domestic pigeons are all originally related to the wild rock dove, *Columba livia*.

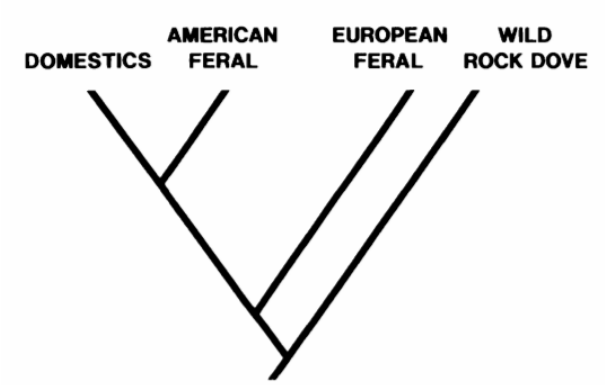

Figure 4. Evolutionary origin of feral pigeons (Johnston, 1992).

Selective breeding by mankind has changed some of the characteristics of the pigeon. Contrary to their originally wild counterparts the feral pigeon is not very aggressive. Due to this loss of aggressiveness feral pigeon populations can obtain relatively large population densities (Haag-Wackernagel, 1995).

Ecological characteristics of feral pigeons

Distribution and abundance

Species in the pigeon family are widely distributed across the globe. Only on the Hawaiian islands and the Central Atlantic ridge no species of pigeons are present. As examples of the distribution of feral pigeons in a densely populated country, data of the Netherlands is used. As shown in figure 5, most feral pigeon populations are clustered in larger cities and urban areas. Darker colours are indicating areas in which the feral pigeon is more common, with dark red as indicator as places where feral pigeons are the most common. When comparing this map to a map generated by data of the CBS

(*Centraal Bureau voor Statistiek*, the Dutch federal agency for statistics), an overlap can be noticed. In purple the metropolitan agglomerations in figure 6 are highlighted and especially the urban areas in the West of the Netherlands correspond to the areas with a high abundance of breeding feral pigeons.

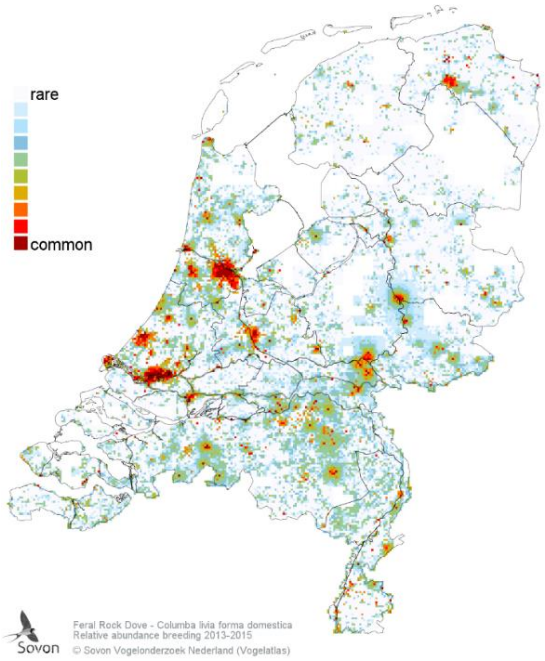

Figure 5. Relative abundance of breeding feral pigeons, 2013-2015 (Sovon, n.d.).

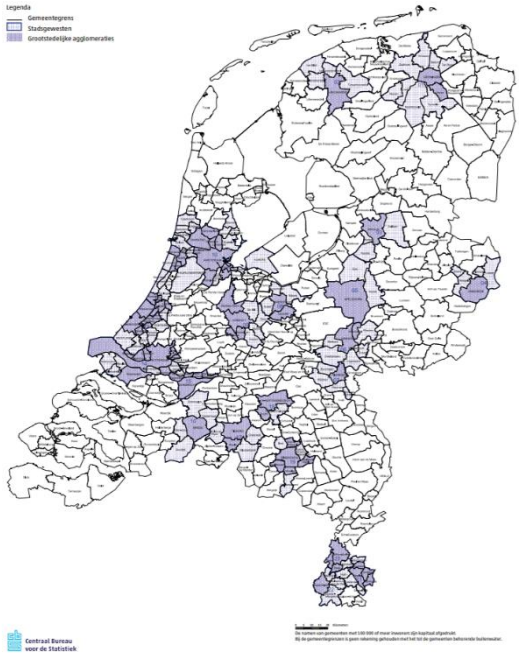

Figure 6. Layout of urban areas of the Netherlands (CBS, n.d.). Urban agglomerations are marked in purple.

To give an indication of the trends in abundance of wild birds in the Netherlands, Sovon has started a monitoring network concerning urban species called MUS (*meetnet urbane soorten* in Dutch). In table 1, the developments in number of pigeons in comparison with the base year 2007 are stated. Over the course of 12 years the number of pigeons decreased moderately. Currently, the feral pigeon has a slope of 0.97. The slope is the annual multiplication factor, which in this case means that feral pigeon populations decrease with 3% per year. This data is visualized in figure 7, which emphasizes the general decline in abundance.

Table 1. Decrease in abundance of feral pigeons in urban areas.

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Points	Slope	SE_of_Slope	Trend since 2007
Feral pigeon	100	101	103	84	97	83	72	85	78	78	75	73	70	3654	0.97	0.003	*Moderate decrease* (p<0.01) **

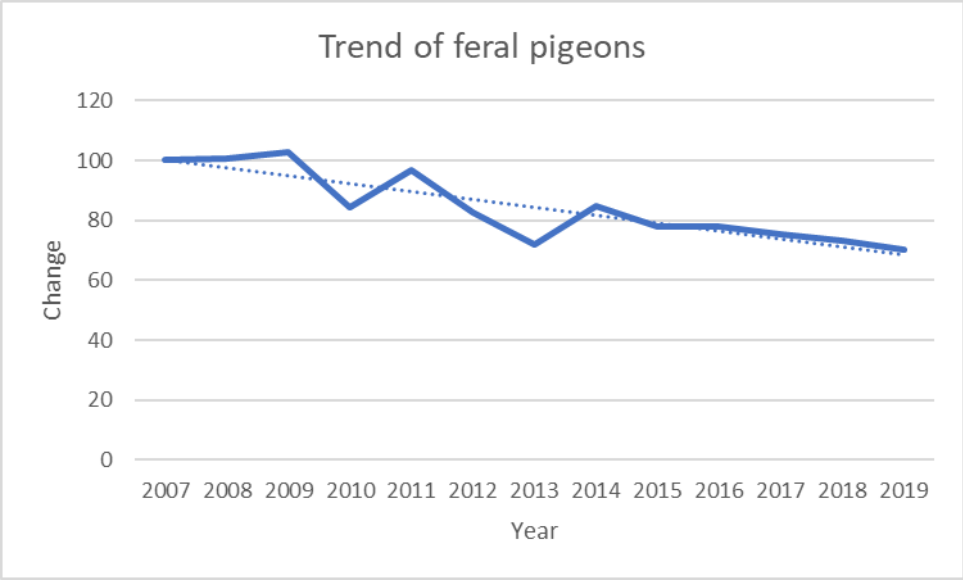

Figure 7. Graphic visualization of the trend of feral pigeon abundance.

Reproduction and diet

To conclude this chapter on the species characteristics of the feral pigeons, the nesting and foraging habits are mentioned. The feral form of the Rock Dove originally lived on cliff ledges but now typically nests and roosts on buildings in urban areas (Perrins, 2009). As for breeding habits, the breeding season of the feral pigeon has been reported to range from late autumn to early winter; though they could breed during all the seasons of the year if the conditions were favorable (Ali et al., 2013). In optimal conditions a breeding pair of feral pigeons can produce twelve young per year. In these optimal conditions, adult mortality is relatively low at 11% and therefore a quick increase in population size is possible (Haag-Wackernagel, 1995).

Feral pigeons do not disperse much from their original breeding ground. Female birds however travel a larger distance when out foraging and prefer to travel a significantly larger distance in order to find more abundant and predictable food sources (Rose, Nagel & Haag-Wackernagel, 2006). When comparing foraging strategies, the great diversity between feral pigeon populations stands out. Rose, Nagel & Haag-Wackernagel (2006) conclude therefore that there might be a lot of variance in foraging behaviour between pigeon populations of different cities. Furthermore, only when in desperate need of food, foraging birds will fly several kilometers at most (Sovon, n.d.).

The diet of feral pigeons consists mostly of vegetable matter, seeds and fruit. The spread of agriculture has greatly benefited pigeons and the pigeon species adapted to eat seeds and grains. Since the birds are seedeaters, they are often in need of water. Unlike other birds, pigeons can drink actively by submerging their beak and suck up the water (Perrins, 2009).

4) Pigeons in urban habitats

In the previous chapters, ecological theories and the species characteristics of pigeons were presented separately. However, to answer the main research question of this study, a closer look into pigeons in an urban habitat is necessary. As stated by Lancaster & Rees (1979), more research is required when investigating the relationship between bird community structure and habitat complexity. This chapter examines how the ecological needs of the feral pigeon match the urban habitat and all that it has to offer.

Foraging

Whereas the rock dove picks mostly vegetation, such as weed seeds, the feral pigeon has a broader diet consisting also of such seeds but also a wide array of domestic scraps such as cooked rice and even chocolate (Murton & Westwood, 1966). Feral pigeons are not particularly picky in choosing their food. The diet of feral pigeons is less seasonally dependent than that of rock doves. This is mostly because the feral pigeon is more dependent on human feeding, especially in the winter. Even in spring, when food availability is starting to peak, most of the diet of feral pigeons does still consist of bread and other human food waste, even foods such as raisin cake (Murton & Westwood, 1966).

When comparing foraging strategies of feral pigeons near Basel, Switzerland, three types of foraging patterns can be identified. Sometimes the pigeons were foraging in the urban areas, streets, squares and parks, near their nesting site. A second foraging area was the agricultural regions near the city. A third foraging area was around the harbour, the docks and the railways (Rose, Nagel & Haag-Wackernagel, 2006).

Two distinct differences in the foraging behaviour of pigeons can be noted. The pigeons are either food-seekers or food-beggars. The food-seekers live less close to the urban center, and are less dependent on interaction with humans (Weber, Haag & Durrer, 1994). The food-beggars however are the pigeons who have learned to beg in order to receive food. To obtain as much food as possible the pigeons have developed specific food begging behaviour. This therefore means that they have become more and more dependent on human 'feeders'.

Urban environment

The feral pigeons that are central in this thesis are not the only species of pigeons occupying urban areas. Other pigeon species such as Woodpigeons (*Columba oenas*) and Stock doves (*Columba Palumbus*) are also nesting in European cities such as London. Where the stock dove does not interfere with the foraging behaviour of the feral pigeon, the woodpigeon does. Between the diets of woodpigeons and feral pigeons are many similarities and hence, there is a complete overlap in feeding grounds (Goodwin, 1960). This intraspecies competition is partially resolved by the fact that the two pigeon species spend different amounts of time at the varying feeding grounds, as is shown in figure 8. What can be concluded from this table is the preference of the feral pigeon for the busier areas, where more contact with humans is possible. Woodpigeons prefer the more natural areas, such as in trees and shrubs and large open spaces in parks. The feral pigeons however seek out more crowded areas, such as inside of stations and public squares. This could be due to the fact that feral pigeons are less afraid of humans, due to the fact that specific traits such as aggressiveness are less dominant. Secondly, in these busier areas there is a larger change of finding human feeders and obtaining food from them.

	Large open spaces in parks	Small open spaces especially in small parks and "squares"	"Squares" without grass	Private "squares" with grass but without "bread"	River's edge at low tide	Busy streets
Woodpigeons	xxxx	xxx	x	xxx	x	
Feral Pigeons	xxx	xxxx	xxxx	x	xxxx	x

	Quiet streets	Inside stations	Lighted streets and stations at night	In large trees	In small trees and shrubs and on privet hedges
Woodpigeons	x	x		xxxx	xxxx
Feral Pigeons	xxxx	xxx	xx	x	

xxxx = very large numbers xx = small numbers
xxx = considerable numbers x = few individuals only
The term "bread" covers all artificial foods provided by the general public

Figure 8. Comparison of feeding ground use between feral pigeons and woodpigeons (Goodwin, 1960).

The density of bird species was negatively associated with urban landcover. Which means that if the proportion of urban landcover is larger, the density of bird species is lower (Aronson et al., 2014). For the already thriving pigeons however, this means there is less competition and a smaller chance of becoming prey.

As examples of the nesting and foraging preferences of feral pigeons, Murton and Westwood (1966) stated that the feral pigeons most commonly nesting on large suitable buildings and forage for food in the streets, station yards, and small squares. However, when more green areas where available in the city, the feral pigeons would occupy those. Another study shows how the highest population of feral pigeon was recorded in old buildings (0.30 individuals/ha) and lowest in parklands (0.003 individuals/ha) (Ali et al., 2013). Not just the green areas in the urban area itself matter, but also the accessibility of the nearby farmlands. When it is easier for the pigeons to reach the nearby farmlands, that urban habitat would be preferred by the pigeons (Murton and Westwood, 1966).

That said, one of the possible positive characteristics of the urban environment that causes the feral pigeons the thrive could be the lack of birds of prey, combined with the pigeons' habit of nesting and roosting on buildings, and the fact that humans habitually feed them (Perrins, 2009).

Human interaction

Earlier on, the synanthropic index was mentioned. In this index, the feral pigeons have the maximum score of +100. This score indicates that the species has the least avoidance of man (Nuorteva, 1971). Even during the changing of the seasons no changes occur in the degree of synanthropy, see figure 9.

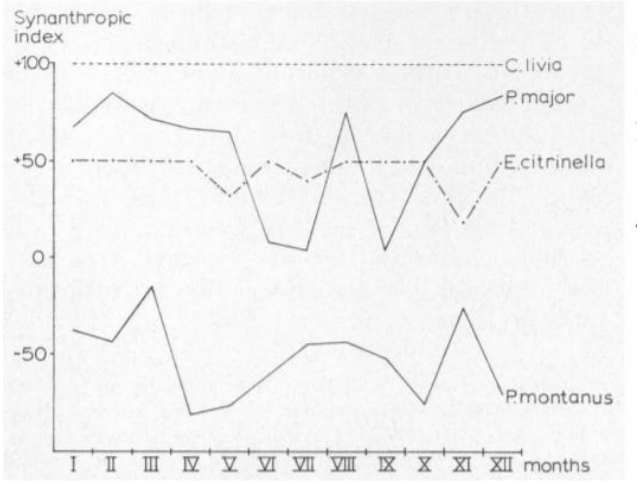

Figure 9. Seasonal influence on synanthropy (Nuorteva, 1971). The line of small dots represents the changes in synanthropy of the feral pigeon (Columba livia) *during the year.*

Pigeons living in human occupied areas have adapted to human activity, for example pigeons waiting for human feeders can be observed (Rose, Nagel & Haag-Wackernagel, 2006). Therefore, in many cities the timing of pigeon activities is due to human influence rather than natural rhythms.

The table below summarizes the influence the urban habitat has on the ecological factors of the feral pigeon.

Table 2. Differences in ecological factors between urban areas and rural areas for the feral pigeon (adapted from Williams & Corrigan, 1994; Goodwin, 1960).

	Urban area	**Rural area/original habitat**
Nesting	Buildings	Cliff edges
Food supply	Human feeders, nearby agricultural fields, scraps	Seeds, vegetable matter
Predators	General lack of predators, however threatened by human pest control programs	Increased chance of becoming prey of e.g. falcons and carnivorous mammals
Life expectancy/quality of life	Badly crippled young survive longer (even in to adulthood); lifespan of 3-4 years	Smaller populations and less diseases lead to a longer life expectancy

5) Management approach

To reiterate, a management plan is needed by governments due to the problems feral pigeons create in urban areas, such as the fear of transmitting diseases and parasites to humans, damaging buildings and statues through corroding feces, destroying vegetation when in search for food and a less common, but worth-mentioning, problem is that the vocalizations of pigeons can cause hysteric reactions by some (Haag-Wackernagel, 1995). The search for a sustainable and well-founded approach is not just an issue from nowadays. In 1995 it is already stated that governments were taking measures to reduce pigeon populations, without any scientific clarifications (Haag-Wackernagel, 1995). When using a management plan to influence a population, two main goals can be defined. Those are to control the designated species' population size and to minimize the disturbance to other species in the community (Begon, Harper & Townsend, 1996).

Current common tactics

Multiple types of population management tactics are currently being used to minimize the nuisance caused by feral pigeons. Some common types of the tactics are the use of repellents or poison or trapping and culling the pigeons. However, not enough research has been conducted into the effectiveness of these methods (Sol & Senar, 1992).

One of the most used methods of pigeon control is removing individuals from the population. This removal can be carried out by shooting or trapping the pigeons and killing them afterwards. As stated by Haag-Wackernagel (1995), these population control programs backfired. By eliminating part of the population only a temporary drop in population size is achieved. This smaller population gives way for juveniles, that otherwise would not have survived. Additionally, the use of toxic bait requires pre-baiting. This is the distribution of food without the paralyzing or lethal toxins, that way the pigeons become trusting of the bait. However, this attracts pigeons from other populations, who might even migrate to the original population (Murton, Thearle & Thompson, 1972). Therefore, these tactics work counter-productive. After the initial decrease in population size, the number of animals rises to its former level or even increases. This failure in fulfilling the goal of reducing the pigeon population size is probably due to intrapopulation control. Examples of this are the influx of pigeons from other parts of the city, an overall increase in breeding success and enhanced survival (Sol & Senar, 1992).

Another method of pigeon population control is the use of a contraceptive, for example by the name of Ornitrol. In an effort to reduce population sizes, the tactic is to minimize the amount of offspring each pigeon creates. The method does not inhibit the egg-laying capacities of the female pigeons, but reduces the number of fertile eggs. However, this method is not sufficient enough, since too many of the laid eggs still remain fertile (Erickson & Jackson, 1983). Another chemical compound to restrict the ovulation or fertility of feral pigeons might be invented in a future moment, but for now this does not seem a feasible solution.

Related to the topic of breeding, is the removal of eggs from nests. When removing eggs from nests, the pigeons are inclined to produce more eggs in a shorter period of time in an effort to be able to raise offspring. This leads to a lower quality of eggs, with for example a significantly lower proportion of yolk. These shorter egg-laying cycles also have a negative effect on the female birds, since the increase in physiological costs lead to a decrease in health. In an effort to reduce the negative health effects, the removed eggs can be replaced by replicas (Jacquin et al., 2010). On a small scale, egg removal is practiced in Basel, Switzerland. Specific public areas have been established for human feeders, to interact with feral pigeons. The pigeon populations kept at these locations are birth-controlled by removing eggs from the nests (Haag-Wackernagel, (1995). This is however on a small-scale and the removal of eggs on a larger, city-wide scale would be labor and cost intensive.

Animal welfare

Besides the lack of effectiveness of these population management programs, these tactics have little to no regard to the animal welfare of the pigeons. As mentioned in the introduction of this thesis, animal welfare is defined by the standards of having accessibility to good food and good housing, having good health and showing appropriate behaviour (Botreau et al., 2007). Specified to the case of the feral pigeon, populations management plans that have a harming effect on the pigeon, such as culling, are in contrast to the animal welfare goal of having a good health. Being in good health is comprised of several components, such as the absence of injuries, the absence of disease and the absence of pain induced by management procedures (Botreau et al., 2007). Therefore, the use of steel pins to prevent nesting as suggested by Williams and Corrigan is not desirable, as it often leads to injuries. Also the use of stressors that affect the pigeons behaviour in a negative way are unwanted. This is also in addition to the fact that when trying to remove pigeons from unwanted areas the act of frightening them by the using high frequency sounds has only a temporary effect (Williams & Corrigan, 1994).

The aforementioned tactics of baiting and using poison to decrease the number of pigeons, are not only harmful for these specific birds. The use of perches laced with contact poison can be, when handled incorrectly, hazardous to other birds, animals and people (Williams & Corrigan, 1994). The use of these toxic materials is not selective to just the feral pigeons and may therefore cause harm to other organisms and the environment.

Long-term effects

The population control methods mentioned above, have predominantly only short-term effects. It is highly likely that the problem only increases or that the management plan has to keep being repeated to have any lasting effect. Therefore, there is a need for a long-term solution. It is likely that information about the seasonal changes in population, their roosting sites, nesting sites, food and water points and facilitating building structures may help manage the feral pigeon population in urban environments for a longer period of time (Ali et al., 2013).

Secondly, there are often multiple populations of feral pigeons residing in a city and these populations function more or less as separate units. To make a population control management plan effective, it should be widely applied in the entire city in an effort to have an impact on the different populations (Murton, Thearle & Thompson, 1972).

6) Discussion

The aim of this thesis was to collect ecological information in order to find a management plan that can provide a solution for the problems regarding feral pigeons in urban habitats, such as the corrosive effects of their droppings on buildings. This management plan would be based on ecological theories, the ecological characteristics of the feral pigeons and the overlap found by comparing the ecological needs of the feral pigeons and the offerings of the urban habitat.

In the previous chapters different aspects concerning the problem of feral pigeons in urban habitats have been explored. In this chapter the findings of those aspects, the species characteristics of the feral pigeon, the ecological theory and the management side of the problem, will be combined and compared in order to form an answer to the main research question. To reiterate, the aim of this thesis was to find a management plan for pigeon population control in cities, based on the ecological needs that account for the preference for urban areas by feral pigeons.

Ecological foundation

All of the different possible measures influence in some way the equations of the Lotka-Volterra model, as described in the chapter on ecology. When taking a closer look at the equation below, it describes how a smaller carrying capacity (*K*) would only sustain a smaller population size. Therefore, to effectively alter the population size, ecologically speaking, the carrying capacity has to be lowered.

Equation 5. Lotka-Volterra equation for species 1.

$$\frac{dN_1}{dt} = r_1 N_1 \frac{(K_1 - N_1 - a_{12}N_2)}{K_1}$$

If there are less resources available, then the birth rate of the species will drop and the death rate will rise. In this case this would mean that less food has to be available and, recalling equation one, the numbers of predators and their effectiveness should increase.

The equation presented above also proves the ineffectiveness of subtracting individuals out of the population, either done by culling or removing eggs from nests. When the number of individuals in the population reduces, more resources become available for the remaining individuals. This in turn leads to a growth in population size. Therefore, a lasting solution must cause a permanent change in the carrying capacity of the population and should thus prevent coupled oscillations.

Ecological factors

A concern in population ecology is preventing the occurrence of an extinction vortex in vulnerable populations (Campbell et al., 2015). However, for the task of managing a population, this extinction vortex could be considered a helpful plan. By amplifying specific factors of the extinction vortex, the population size can be reduced. As shown in figure 10, a higher mortality and a lower reproduction rate are some of the factors that lead to a smaller population. Combined with the information shown in figure 2 in the chapter on ecology, several restricting aspects of the distribution and size of the pigeon population can be defined.

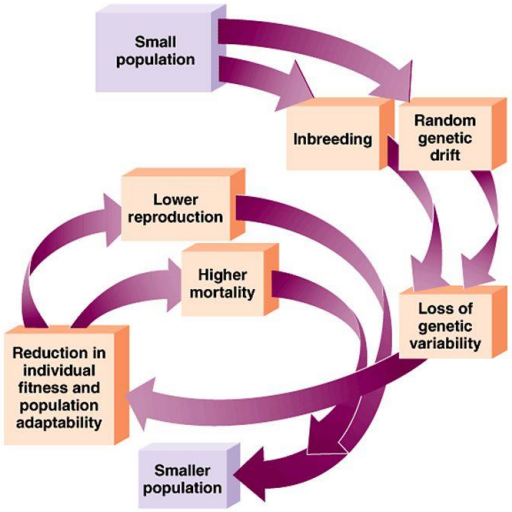

Figure 10. Extinction vortex (Campbell et al., 2015). The influences of different ecological factors on the decrease of population size are visualized.

As shown in the figure above, higher mortality and lower reproduction can be obtained by a reduction in individual fitness and population adaptability. As seen earlier in the chapter on ecology, a lower resource availability corresponds with a lower fitness. This, combined with the fact that chemical factors such as water availability are also a limiting distribution factor, points out that alterations in resource availability would have lasting effects on the population size.

Biotic factors such as parasitism and diseases are also important in the distribution of a species. However, this would be of no use for an animal welfare friendly management plan. The use of diseases to lower the population size would go against the animal welfare goal of maintaining a good health.

At last, the most useful limiting distribution factor to be used for pigeon population management plans is habitat selection. When a habitat is not preferred by the pigeon, it does not qualify for occupation.

Habitat alterations

The most ideal management plan to minimize the problems regarding feral pigeons is based on changing the habitat in the urban areas and in the rural areas. One way of reducing the population size, is by reducing the ecological capacity of the area (Haag-Wackernagel, 1995). The feral pigeon strives in urban areas, because those areas match their ecological needs, concerning foraging, nesting and watering for example. When changing those positive aspects of the urban habitat, the feral pigeon loses its ecological preference for the urban habitat. Practically speaking this means for example the addition of 'porcupines wires' on buildings, to prevent nesting and resting spots (Williams & Corrigan, 1994). But since pigeons are very adaptable and learn quickly, adaptations to breeding sites will not work effectively. The pigeons prefer breeding in hollows, but if those are not available they will accept nesting sites in less ideal locations such as in niches in neon signs (Haag-Wackernagel, 1995).

One of the factors contributing to a possible successful habitat is the absence of predators. In urban areas the number of predators hunting feral pigeons is small. This contributes to a low death rate and a influx in population size. The addition of predators such as peregrine falcons could temporarily decrease the pigeon population size, but it would not be very specific to only pigeon populations. Therefore, a less-invasive, though still threatening, management option is the implementation of fake predator imagery. This does not harm the feral pigeons, or other animals, but it would have a negative influence on their choice for the urban area as a safe habitat.

Besides worsening the conditions of the urban habitat, other alternatives have to be offered. A habitat that meets the ecological needs in a more prolific way will be preferred. Such an alternative habitat can be offered by preparing alternative nesting sites, where the pigeons are unbothered by human interference and near abundant food sources.

Human factor

The management of feral pigeon in urban areas is a serious issue in various countries because the regular supply of food encourages the population growth of feral pigeons (Ali et al., 2013). Second to that, pigeons are able to learn begging behavior and therefore increase their chances of food from humans (Weber, Haag & Durrer, 1994). Therefore, a solution to the problem should include not only the ecological side, but also the human sociological side of the problem.

First of, the human habit of feeding the feral pigeons increases the problem. The feeders are generally however not interested in stopping or reducing the food they offer. Those feeders are most often women and they claimed that it is their duty to take care of the pigeons: "The outsiders of the city take care of the pigeons" (Weber, Haag & Durrer, 1994). To find a solution to the urban pigeon problem, the human feeding behaviour has to change. An example of an effective pigeon population management program that takes that in mind is executed by the city of Basel. There, the focus is mostly on a decline in food availability, through informing the public on the damaging effects feeding has. Since raising awareness on this topic, feeders stopped partially or even entirely with offering food to the pigeons. The decline in food availability led to reduced breeding success and therefore the population size decreased. This in turn reduced the damages caused by the feral pigeons (Haag-Wackernagel, (1995).

Secondly, the problems coming from urban pigeon populations are defined by the human citizens of those areas. The high density of the populations can indeed cause problems for the pigeons, since it leads to a higher number of transmittable diseases and parasites. However, most of the problems are human-based and economically driven, such as the corrosive effects of pigeon droppings on buildings and the ravaging through vegetation in search of food. This raises however the question, to which extent the urban pigeon problem a pigeon problem is and not a human problem.

When analyzing the different options based on ecological knowledge mentioned above, it stands out that finding one specific solution for the problem is probably not possible. To decrease the pigeon population in an effective and lasting way, many different factors have to be influenced.

7) Final conclusions and future perspectives

Conclusion

This study had as aim to form a new kind of management plan for urban pigeon population control, based on ecological knowledge. When comparing the ecological needs of feral pigeons and the habitat that an urban area has to offer, an overlap is established. This overlap accounts for the fact that feral pigeons have a high abundance in urban areas and leads to problems according to the human inhabitants. previously used tactics such as culling and the emptying of nests are not only not founded by scientific research, they also do not work effectively. An effective long-term solution should therefore take the ecological characteristics, such as foraging behaviour and nesting site preference, into account. An example of such a long-term management option is changing the habitat in a way that it matches less with the ecological needs of the feral pigeon. This can be done by decreasing available food supply by for example regulations concerning feeding pigeons and collecting human food waste in a way that it is not accessible for the pigeons. Other suggestions are hindering the option to nest on older buildings and the use of predator-like imagery.

At last, it is important to emphasize the animal welfare of the pigeons. A forthcoming management plan should not only be most effective when it is implemented, but should keep the health and welfare of the animals in high regard. This is in contrast with some earlier mentioned management tactics, such as the shooting or poisoning of the pigeons. In addition to the above mentioned alterations to the habitat, other possible habitats have to be offered to minimize the negative effect on the animal welfare of the pigeons. An example of such an offered habitat is a specific human-pigeon interaction area, where nesting sites are available and the population size is monitored by removing eggs and supplying the female birds with egg replicas.

Future perspectives

To conclude this study, several ideas for follow-up research will be offered. To construct an all encompassing management tactic, a lot more has to be known about the urban area than just the generic information that comprises all urban areas. Therefore, I suggest to conduct a specific investigation in every city that needs a solution for their feral pigeon problem. An example of such a study can be found in the paper of Ali et al. (2013), in which they determined the changes in population density, sex ratio, age group, roosting sites, nesting sites, and food and water points of the feral pigeons in Rawalpindi and Islamabad. The pigeon populations were mainly regulated by these ecological factors, which means that a change in the availability of one of the specific factors influences the population density. By obtaining this information, the effectiveness of a future management plan can be raised significantly.

A last suggestion for further research is to increase the interest in the human sociological part of the urban pigeon problem. This thesis had a focus on the ecological approach to the problem, however for the most part is living in an urban habitat not a problem for the feral pigeon. The mentioned problems are formulated by the humans who are co-habiting with the pigeons in the urban areas. At the same time it is the human behaviour that amplifies the problem of large pigeon populations by feeding (Haag-Wackernagel, 1995). Therefore, a more thorough investigation into human feeding behaviour and the influence of urban wildlife on human citizens is advised.

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Figure 11. Pigeon overlooking Prague (n.d.).

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Photographs

Front page (figure 1):

- ZeroOne (Photographer). (2008, August 31st) *Pigeon Morning* [digital image]. Retrieved from https://www.flickr.com/photos/villes/2865830828

Acknowledgements (figure 11):

- [Untitled photograph of a pigeon in Prague]. (n.d.). Retrieved from https://www.pikist.com/free-photo-vfnwi

Appendix

1) Literature search strategy

Google Scholar search terms:

- Urban bird ecology
- Urban pigeons
- Feral pigeons ecology
- Ecology carrying capacity
- Ecological tools
- Carrying capacity pigeons
- Feral pigeons natural habitat
- Stadsduif natuurlijk habitat
- Natuurbeheer stadsduif
- Urban habitats pigeon
- Avian ecology urbanization
- Niche ecology hutchinson
- Ecological characteristics basics
- Pigeon culling
- Evolution of feral pigeons
- Wild rock dove
- Synanthropic species
- Urban density

WorldCat search terms:

- Ecological theory
- Pigeons ecology
- Urban pigeon ecology
- Feral pigeons
- Urban animals