# Birds in domestic gardens

A study on the feasibility of modelling their presence

Sjerp de Vries & Victor Mensing

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In deze studie wordt verkend of het mogelijk is om de aanwezigheid van vogels in privétuinen zodanig nauwkeurig te modelleren dat de modeluitkomsten bruikbaar zijn in onderzoek naar de toegevoegde voorspellende waarde van de aanwezigheid van vogels in de woonomgeving, d.w.z. naast die van het groen in diezelfde woonomgeving, voor het welzijn van de bewoners. Hierbij gaat het enerzijds om de, bij voorkeur landelijke, beschikbaarheid van gegevens over omgevingskenmerken met voorspellende waarde voor de aanwezigheid van vogels. Anderzijds gaat het om voldoende gegevens over de feitelijke aanwezigheid van vogels om zo'n model te kalibreren (en bij voorkeur ook te valideren). Met name dit laatste staat hier centraal.

This study explores the feasibility of modelling the presence of birds in domestic gardens with a sufficiently high degree of accuracy to be of use for investigating the added predictive value of bird presence in residential environments, in addition to that of greenery in those environments, for the well-being of the residents. On the one hand, this feasibility concerns the (preferably nationally) available data on environmental characteristics with predictive value for bird presence. On the other hand, it concerns the availability of sufficient data on actual bird presence to calibrate (and preferably validate) such a model. In particular, this latter concern is an issue which is explored in this report.

Keywords: human well-being, biodiversity, bird richness, greenery, urban environments, private gardens

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# Verification

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Wageningen Environmental Research (WENR) values the quality of our end products greatly. A review of the reports on scientific quality by a reviewer is a standard part of our quality policy.

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# Preface

The authors wish to thank Jip Louwe Kooijmans (Vogelbescherming Nederland), Henk Sierdsema and Dirk Zoetebier (both SOVON) and the NDFF Serviceteam for the information and (MUS) data provided.

# Summary

In this study, the feasibility of modelling the presence of birds in domestic gardens is explored for the purpose of research on the relationship between biodiversity and human health and well-being. Modelling should take place with a sufficiently high degree of accuracy to be of use for investigating the added predictive value of bird presence in urban residential environments, in addition to that of the vegetation in those environments, for the well-being of the residents. On the one hand, this feasibility concerns the (preferably nationally) available data on environmental characteristics with predictive value for bird presence. On the other hand, it concerns the availability of sufficient data on actual bird presence to calibrate (and preferably validate) such a model. The latter issue in particular is explored here. With regard to the first issue, the idea is to make use of highly detailed data on the amount and type of vegetation in domestic gardens and in the wider residential environment. This dataset is currently under development.

Several national datasets on bird presence are considered, especially datasets for birds in urban environments. The dataset resulting from the Meetnet Urbane Soorten project (MUS) appears to be the most useful, even though it does not offer the highest number of data points (locations). This usefulness is primarily based on: a) MUS's focus on the urban environment; b) the systematic way in which the data are gathered (the MUS protocol), making results for different locations comparable; and c) immediate availability of the MUS data. Availability was especially relevant for further exploration within the present project. Other datasets might also prove useful if the original data become available, i.e., without spatial aggregation.

There is already a model for bird presence in the urban environment, called 'Stadsvogelindicator' (City Bird Indicator). However, the accessible information on this model is too limited to be able to evaluate whether this model satisfies the aforementioned accuracy requirement. Its predictive power is unknown. There might be more extensive documentation available, but this could not be ascertained within the timeframe of the project. Moreover, personal communication with one of its developers suggests that, nowadays, a more precise model should be feasible because of the availability of better, more detailed information on relevant environmental characteristics, especially regarding the amount and type of vegetation.

The conclusion is that modelling the presence of birds in the urban environment at a spatially detailed level seems possible, given the (soon-to-be) available data on relevant environmental characteristics on the one hand and data on the actual bird presence on the other hand. Notable is that the amount and coverage of data on actual bird presence in urban environments is better than anticipated. At the same time, the amount and coverage of data on human health has also increased in recent years. This increase makes it plausible that there are enough data points in the (spatial) intersection of the two datasets to be able to conduct a statistical analysis with enough power to detect meaningful associations without resorting to modelling bird presence.

# 1 Background

Recent decades have seen growth in studies of the benefits of contact with nature on human health and well-being. Within this domain, the definition of 'nature' tends to be broadly interpreted and may encompass all kinds of vegetation, from protected areas to street trees, and the definition may also include fresh and salt water bodies. Within this domain, nature is also often referred to as 'green' and 'blue' space. By now, it is clear that overall contact with nature, or having nature nearby, is positively associated with human health and well-being. Nearby nature is often defined in terms of its presence in the residential environment. There is some evidence indicating that the distance decay is rather large and occurs even within a 500-metre range (Egorov et al., 2017). Presumably, nearness implies a high frequency of contact with nature, with beneficial consequences. Other studies show positive associations of well-being with a varied green window view from home (Honold et al., 2015), a green garden at home (De Vries et al., 2017), the presence of street trees (Taylor et al., 2012) and/or other streetscape greenery (Van Dillen et al., 2012). When it comes to health promotion, it is therefore reasonable to expect that having a green garden is a relatively important component of one's local supply of green space. At present, a study is being conducted that investigates precisely this hypothesis.[1]

Although positive associations between nearby nature and human health have been firmly established, little is known about the mechanisms by which these associations come about and the relative importance of the different mechanisms (Frumkin et al., 2017; Markevych et al., 2017). The same is true for which type of nature (and with which characteristics) is especially beneficial for human health and well-being. One of the characteristics under investigation is the biodiversity of the available, nearby nature (Marselle et al., 2019), with biodiversity often being (rather pragmatically) operationalised in terms of species richness (De Vries & Snep, 2019). In addition to the biodiversity of the vegetation, biodiversity may also exist in the fauna that is present within the residential environment. Especially in urban domestic gardens, birds may be one of the most relevant types of fauna to study for two reasons:

- there is likely to be considerable variation in the presence of birds in domestic gardens; they are neither very rare nor overly common
- if present, birds are likely to be noticed

It may be noted that birds may not only be experienced by sight, but also by sound. In general, senses other than the visual have received far less research attention. This relative lack of attention should not be taken as a sign that these other senses are less important with regard to the well-being effects of contact with nature (Franco et al., 2017).

To study the contribution of bird richness in urban domestic gardens to human health and well-being, large-scale data are required on the level of bird richness in such gardens, with the aim of teasing out the contribution of the bird richness, in addition to that of the amount of vegetation present inside and outside the garden and other relevant factors (such as socioeconomic status). One way to overcome a lack of actual data on bird presence in domestic gardens is to model this presence. This project is about exploring the feasibility of developing a model for bird richness in domestic gardens that is accurate enough to be of use for analysing its relevance for human health and well-being. But before looking into the feasibility of modelling bird presence in domestic gardens, a brief overview is first provided regarding the (limited) literature on the connections between the presence of and/or experiencing birds and human well-being.

[1] https://topsectortu.nl/nl/een-groene-tuin-een-gezonde-tuin [A green garden, a healthy garden?].

## 1.1 Research on birds and human well-being

Cox & Gaston (2015) investigated the likeability of fourteen common garden birds (at feeders). They concluded that songbirds are preferred over non-song birds (see also Cox et al., 2018). However, they did not look at associations with well-being. It thus can only be assumed that greater likeability will result in more positive well-being effects when the birds are observed. Cox & Gaston (2015) also concluded that species richness was more important than species abundance. In another study, they arrived at more or less opposite conclusions. Cox et al. (2017) found that bird abundance, but not bird species richness, was associated with lower depression, anxiety and stress. In their study, they simultaneously took the amount of neighbourhood vegetation cover into account, which showed similar associations. Thus, bird abundance was independently associated with better health, including when the presence of nearby vegetation was controlled for.[2]

Ma & Shu (2018) performed an experimental study in which an open plan office was simulated. They found that, according to pre- and post-self-reports, pleasant sounds such as bird song and flowing water alleviated fatigue and attenuated annoyance. No effects were observed on physiological measures. Hedblom et al. (2019a) also performed an experimental study and also used a physiological measure. They found no evidence that bird song improves stress recovery more than traffic noise in terms of lower skin conductance. On the other hand, an earlier experimental study by Alvarsson et al. (2010) did find some support for nature sound, consisting of a mixture of tweeting birds and a fountain, reducing stress in terms of skin conductance level faster than either road traffic noise or the more quiet backyard noise of ventilation systems from nearby buildings.

In another experimental study, Van Hedger et al. (2019) investigated the effect of natural versus urban sounds on mood and cognitive performance. Natural soundscapes primarily contained sounds of birdsong, moving water, insects and wind. The urban soundscapes primarily contained sounds of traffic, café ambiance (with unintelligible speech) and machinery (e.g., the hum of an air conditioner). In this study, natural soundscapes significantly improved cognitive performance, whereas urban soundscapes did not. Zhang et al. (2017) observed a similar positive effect on cognitive performance.

With regard to mood, Hedger et al. (2019) concluded that neither soundscape differed in its effect, even though natural soundscapes were more liked than urban soundscapes. Earlier, Benfield et al. (2014) did observe a more positive mood after hearing natural sounds (birdsong and rustling leaves) than after hearing natural sounds mixed with anthropogenic sounds (either voices or motorised noise) or no sound at all (control). In this study (and in contrast to the previous study), a negative mood was induced prior to listening to the soundscapes, creating more room for mood improvements.

Cox et al. (2018) investigated relationships between two categories of birds (those providing cultural services and those providing cultural disservices) and human population density. According to Cox et al. (2018), species providing services tend to be aesthetically pleasing and have behaviours that people find interesting to watch, while species providing disservices are often omnivorous and larger bodied. This study is mainly of interest because of the distinction between types of birds, with some types providing cultural disservices rather than services. A list of bird species in each category, specifically for Northern Europe, is provided.

Ratcliffe et al. (2016) looked specifically at bird sounds. They had people score the sounds of fifty types of birds in terms of their perceived restorative potential (PRP), which is the likelihood that listening to the sound would be helpful in recovering from being tired and stressed. Such a list can also help to identify bird species that are more likely to generate greater well-being and those that are less likely to do so. In a follow-up study, Ratcliffe et al. (2018) tried to relate this PRP to acoustic qualities of the bird sounds, among other things. They concluded that over 40% of the variation in PRP could be explained by the following objectively-assessed qualities: being harmonic, having a high frequency and having a low sound level.

[2] It may be noted that, in the analysis, another covariate was self-reported: overall health. Theoretically, this covariate is likely to have reduced the contribution of other predictors, such as bird abundance and vegetation cover.

# 2 Data on birds in cities and gardens

For model development, data on actual bird presence and richness are needed to calibrate the model and to assess its predictive validity. In this chapter, we discuss which datasets are available and which one of these is likely to be most useful for our purposes.

## 2.1 Available datasets

In the Netherlands, there are several data sources with a national coverage of fauna. The data are usually gathered by means of citizen science and give insight into the prevalence of species in the areas assessed. In some cases, the projects have a protocol on how the observations are to be conducted. Other projects do not have such a protocol. Datasets without a protocol are not taken into consideration. Furthermore, we focus on the presence of fauna in urban environments. Most of the available national datasets on fauna in urban environments are brought together in the National Database Flora and Fauna (NDFF). In the NDFF, information is also available on how the data were collected (the protocol) and on how the data were validated (https://www.ndff.nl/overdendff/validatie/protocollen/).

The following available national datasets contain potentially useful data:
- Waarneming.nl & Telmee.nl (protocol for isolated observations)
- Jaarrond Tuintelling
- Nationale Tuinvogeltelling
- Meetnet Urbane Soorten

These four datasets are presented below. How useful the data are as a basis for model development is discussed later on.

### 2.1.1 Waarneming.nl & Telmee.nl

This dataset contains isolated observations of all types of species, which can also to take place in the garden of observer. The dataset contains mainly observations of birds, as well as almost every other taxonomic group, including mammals, plants and insects. Especially appealing and rare but easily identifiable species are recorded in this dataset. There is no fixed list of species to observe specified in its protocol. Consequently, the dataset contains no information on which species have not been observed. Furthermore, the information available per data point is difficult to compare, due to the low level of standardisation: there is a large variety in observers and observations. For more information on this dataset, see the following websites:
https://www.ndff.nl/overdendff/validatie/protocollen/101-000-losse-waarnemingen-waarneming-nl/,
https://www.ndff.nl/overdendff/validatie/protocollen/100-000-losse-waarnemingen-ndff-invoerportaal/.

### 2.1.2 Jaarrond Tuintelling (JRTT)

The JRTT data gathering started in 2013. Participants can have their garden registered as a data point. They can conduct ‘time-of-day’ counts and/or weekly counts. For ‘time-of-day’ counts, the observer indicates when and how long he has been observing (e.g., for five minutes) and the maximum number of exemplars per species that he has observed. So, the choice of moment and duration of observing is free, but recorded. The observer also indicates which groups of species he has been looking for. Thus, if he has been looking for birds but did not observe any, this non-observance is also registered in the data. This method of registration allows observed numbers to be linked to the time spent on observations.

In weekly counts, the participant records the maximum number of simultaneously observed exemplars per species during a week. However, contrary to the 'time-of-day' counts, it is not known how much time was spent on observing birds during that week. At the moment, the JRTT has over 17,000 participants. Observations can be conducted throughout the year. However, most participants do so only during spring and summer. Within the NDFF, the JRTT data are only available per raster cell of 250 by 250 metres. For more information on this dataset, see the following link:
https://www.ndff.nl/overdendff/validatie/protocollen/102-002-jaarrond-tuintelling/.

### 2.1.3 Nationale Tuinvogeltelling (NTT)

The NTT started in 2003. In this project, observations take place in the last weekend of January. Participants select half an hour during which they observe their garden and count birds from the comfort of their home. There is a fixed list of 25 common bird species to be counted, to which the observers can add other species. There are no data available on bird presence in the breeding season. The NTT dataset is not included in the NDFF databank. In 2019, the NTT had over 77,000 participants. For more information on the NTT, see the following link: https://www.tuinvogeltelling.nl/

### 2.1.4 Meetnet Urbane Soorten (MUS)

The MUS project started in 2007 and focuses on breeding birds in urban environments. There is a fixed list of 40 bird species to be counted, to which observers can add species. Participants can select an area in which they are willing to conduct counts. These areas are based on (four-digit) postcode areas. Within each area, the organisation (SOVON) randomly selects twelve locations that are at least 200 metres apart. Participants have to select at least eight of these twelve locations to conduct counts. Counting takes place three times in three different periods: April 1 – 30, May 15 – June 15 and June 15 – July 15. In the first two periods, the counting takes place in the early morning; in the third period, counting takes place in the evening. Within each period, each selected location is observed for exactly five minutes. The number of exemplars per species that is observed during those five minutes is recorded. During recent years, the MUS had about 750 participants, with each participant observing at least eight locations. For more information on the MUS, see the following link:
https://www.ndff.nl/overdendff/validatie/protocollen/14-002-meetnet-urbane-soorten/.

## 2.2 Suitability of the available data

Of the four datasets, the Waarneming.nl & Telmee.nl dataset is considered unsuitable because of the relatively unsystematic way in which the observations take place. To a lesser degree, a lack of suitability also holds for the JRTT: the results for the different data points are not directly comparable, due to differences in moments and durations of the observations.

Of the remaining two datasets, the NTT dataset contains more data points than the MUS dataset. Furthermore, the counts are about birds being observed in gardens, whereas the MUS data points are located outside of domestic gardens, although within the built-up environment. However, this latter advantage should not be overstated, in that a bird habitat is considerably larger than the size of the average Dutch domestic garden. Consequently, the presence of birds is not determined by the characteristics of one's own garden alone. Moreover, people without their own garden are also likely to observe and appreciate birds. It may therefore be even better to look at bird presence in the vicinity of one's home than specifically and only at bird presence in one's own domestic garden.

On the other hand, the MUS dataset is more systematic in several respects. The location of the data points is systematically spread across the built-up area by design, and counts take place at each point three days a year within a specific, narrow timeframe for each day. Finally, the counts are more likely to be conducted by people with a better knowledge of birds than the average participant in the NTT project. This higher level of knowledge is likely to result in better comparable and more reliable data.

A different type of argument is that, because of the NTT project taking place in wintertime, bird presence may be strongly influenced by whether or not there is a bird feeder (with food) present in one's garden (or on one's balcony). This type of information is not available as input for modelling bird presence. Additionally, participants in the NTT project are perhaps on average more likely to have such a bird feeder in their garden than the people who are not participating, making the gardens included in the counting less representative for other gardens. A final difference is that in the NTT project, counting is solely based on the birds that one *sees* in one's own garden. As mentioned above, bird *sounds* are also likely to be relevant. In the MUS project, counting takes place outside, and birds that one hears but does not see are also included in the counts. For these reasons, we choose to focus on the MUS dataset for the purpose of model calibration. Other datasets, such as the NTT and JRTT, might still prove to be useful, for example for model validation purposes. In that case, however, the original data should be(come) available, e.g. without spatial aggregation.

## 2.3 The MUS dataset in more detail

For most MUS data points, the count data for a specific point are likely to be available for several years. By combining the data for the same point over multiple years, even more robust figures can be generated. However, since not all data points will have complete count data for several years, the number of available data points will decrease due to such a procedure. To explore how many data points have complete count data over several years, the MUS dataset was acquired from the NDFF, with some (format) corrections and additions provided by SOVON. We decided to look only at the two counts conducted in spring time. Table 1 shows the outcomes of this analysis.

***Table 1*** *Number of available MUS data points according to different criteria.*

| | **2 completed years out of 3** | **3 completed years out of 5** | **4 completed years out of 7** |
|---|---|---|---|
| MUS data points | 5338 | 4570 | 4268 |

NB: completed year: at least the two spring counts were completed.

Table 1 shows that even after an aggregation over several preceding years, there are enough data points left to calibrate a model predicting bird presence based on characteristics of the physical environment.

### 2.3.1 Spatial distribution of MUS data points

In addition to the sheer number of data points, their spatial distribution is also of importance. As has already been mentioned, according to the MUS protocol, data points are randomly distributed with a postcode area. A postcode area is never covered by more than one MUS participant. Therefore, the issue is which postcode areas are covered by the MUS participants. The density of covered areas is highest in the larger cities (see Figure 1 for an example). Coverage in smaller towns is highest in the provinces Overijssel, Gelderland, Zuid-Holland, Friesland, Groningen and Noord-Brabant. Thus, regions with a lot of inhabitants are relatively well covered. Figure 2 illustrates the distribution of MUS data points in four different regions.

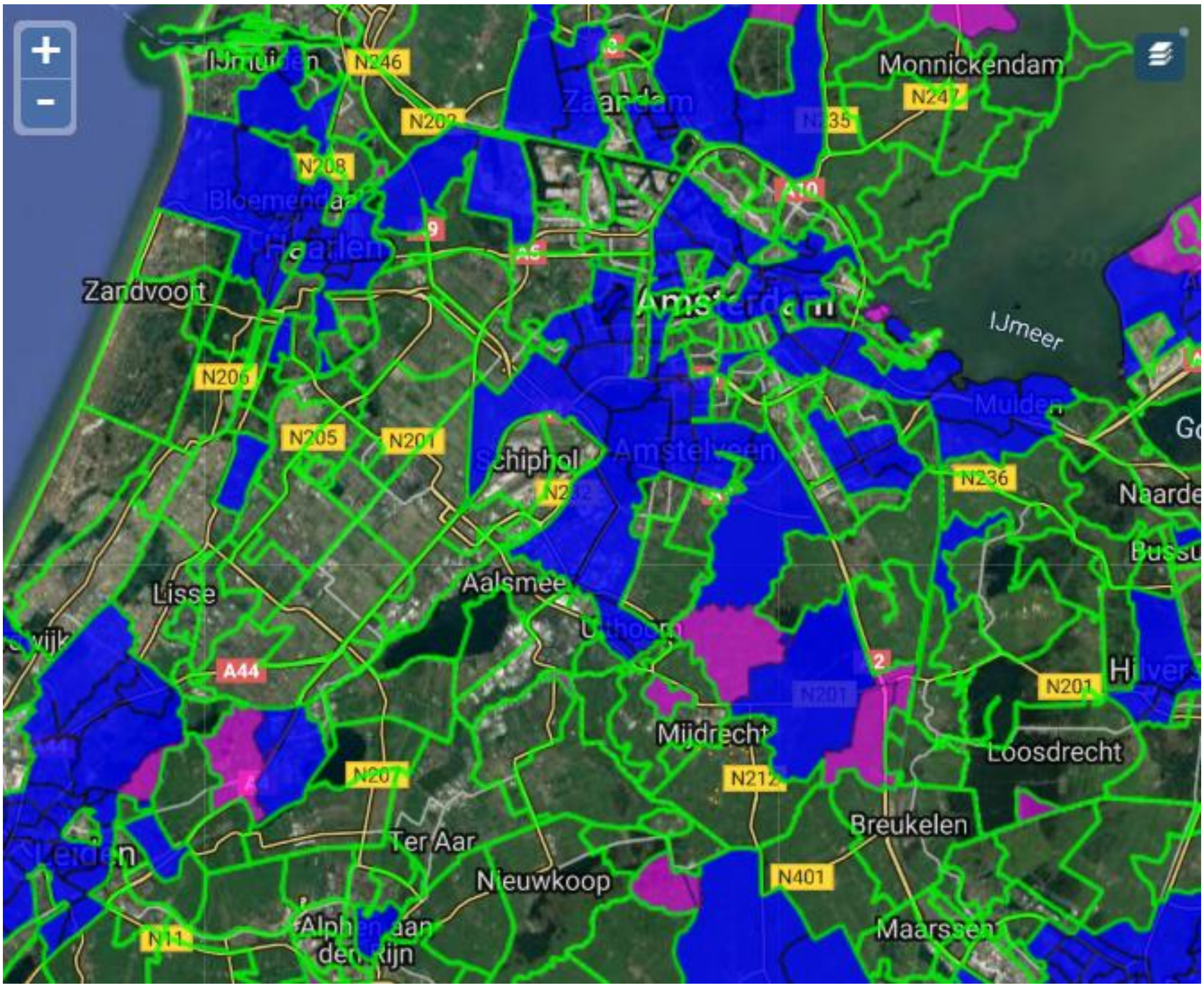


***Figure 1*** *MUS areas (green/black delineation), with already assigned areas in blue and non-urban areas in purple; other delineated areas are still open to new participants (Source: Google/SOVON).*


*Figure 2.a* Kaatsheuvel.

*Figure 2.b* Almere.


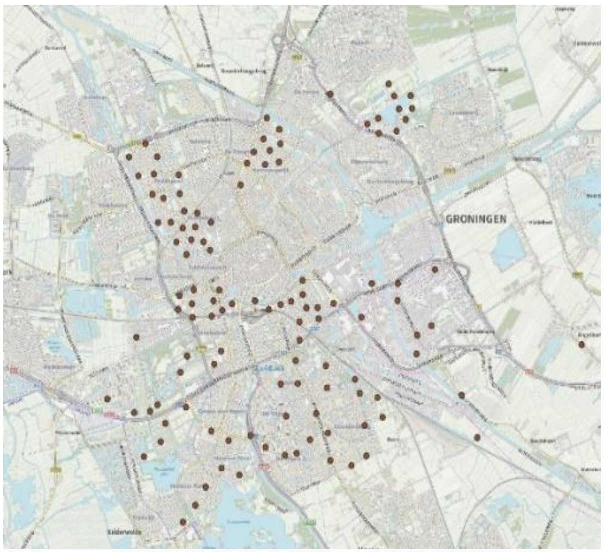


*Figure 2.c* Zoetermeer/Pijnacker.

*Figure 2.d* Groningen (city).

***Figure 2.a-d*** *Distribution of MUS data points in four different regions of the Netherlands.*

It is also of interest to see which forty bird species are included in the MUS fixed species list, as shown in Table 2. Among these 40 species, 20 are also included in the fixed list of the NTT. This inclusion may prove to be useful for future (cross)validation exercises.

*__Table 2__ Bird species included in the fixed species list of MUS.*

| No. | Dutch name | English name | No. | Dutch name | English name |
|---|---|---|---|---|---|
| 1 | Blauwe Reiger | Great blue heron | 21 | Nijlgans | Egyptian goose |
| 2 | Boerenzwaluw | Barn swallow | 22* | Pimpelmees | Blue tit |
| 3 * | Boomkruiper | Short-toed treecreeper | 23 | Putter | Goldfinch |
| 4 * | Ekster | Magpie | 24* | Roodborst | Robin |
| 5 | Fazant | Pheasant | 25 | Scholekster | Oystercatcher |
| 6 | Fitis | Willow warbler | 26 | Soepeend | Domestic duck |
| 7 * | Gaai | Jay | 27* | Spreeuw | Starling |
| 8 | Gierzwaluw | Common swift | 28* | Stadsduif | City pigeon |
| 9 * | Groenling | Greenfinch | 29 | Tjiftjaf | Chiffchaff |
| 10* | Grote Bonte Specht | Great spotted woodpecker | 30 | Tuinfluiter | Garden warbler |
| 11* | Heggenmus | Hedge sparrow | 31* | Turkse Tortel | Collared dove |
| 12 | Holenduif | Stock dove | 32* | Vink | Chaffinch |
| 13* | Houtduif | Wood pigeon | 33 | Waterhoen | Moorhen |
| 14* | Huismus | House sparrow | 34 | Wilde Eend | Mallard |
| 15* | Kauw | Jackdaw | 35* | Winterkoning | Wren |
| 16 | Kleine Mantelmeeuw | Lesser black-backed gull | 36 | Witte Kwikstaart | White wagtail |
| 17 | Kokmeeuw | Black-headed gull | 37* | Zanglijster | Song thrush |
| 18* | Koolmees | Great tit | 38 | Zilvermeeuw | Herring gull |
| 19 | Meerkoet | Coot | 39* | Zwarte Kraai | Black crow |
| 20* | Merel | Blackbird | 40 | Zwartkop | Blackcap |

NB: species marked with an asterisk are also included in the fixed list of the NTT (25 very common species)[3].

[3] Five species of the NTT list with 25 very common bird species are not included in the MUS list: boomklever, halsbandparkiet, koperwiek, kramsvogel and staartmees.

# 3 Modelling bird presence

## 3.1 Previously developed models

An attempt has already been made to model the presence of birds in Dutch cities. Kooijmans (2014) presents a national version of the 'Stadsvogelindicator' (City Bird Indicator, or CBI model).[4] Interestingly, this CBI model also made extensive use of the MUS dataset. The CBI model distinguishes seven categories of birds, mainly differing in their preferred type of habitat. The presence of each category, in terms of its abundance, is modelled based on the type of city district, intersected by a dichotomy of the Netherlands based on elevation: low versus high. Nine types of districts are distinguished, resulting in a total of eighteen district/elevation combinations.

According to Sierdsema (2013, par. 4.3), the CBI model is based on a regression analysis per bird species, with a relatively high number (69) of characteristics of the environment surrounding the point where the counting took place as predictors (Sierdsema, 2013: Table 2; Kooijmans, 2014: Appendix 3). Among the predictors are the surface of green/vegetated space within 200 metres of where the counting took place, the surface of water within that same distance, the number of dwellings per type and the number of the dwellings per 'year of construction' category. Unfortunately, neither Sierdsema (2013) nor Kooijmans (2014) report on the outcomes of these regression analyses.[5] It is therefore not known how well bird presence could be predicted based on the 69 environmental characteristics (e.g., in terms of R-square), and which characteristics were the most contributory predictors for a specific species. As a next step, the CBI model divides the built-up environment into districts and distinguishes the eighteen types of districts. According to the description of the different districts, their classification appears to be mainly based on the age of the dwellings, the openness and location within the Netherlands.

While the CBI model is of interest, an initial look indicates that the spatial resolution of the final model, as presented, is not very high. For example, the municipality of Wageningen is divided up into twelve districts ('wijken'), with the whole of 'Noordwest' being one district. A district does not need to be homogeneous with regard to characteristics that are important for bird presence, such as the amount of different types of vegetation. After consulting with one of the persons involved in the development of this model, we are of the opinion that nowadays a more spatially refined model is feasible, as far as the available data to be used as input for the model is concerned.[6]

4 http://www.stadsvogelindicator.nl/

5 Kooijmans (2014, p. 94) mentions a scientific article: Sierdsema, H., Kooijmans, J.L., Kamplicher, C., Schoppers, J. & Kwak, R. (2014). Benchmarking urban bird habitats – a new way of promoting wildlife conservation in built-up areas. However, this article has so far been untraceable. According to Snep et al. (2016), the article was still under review at that time. It may never have been published.

6 Personal communication between Henk Sierdsema and Victor Mensing.

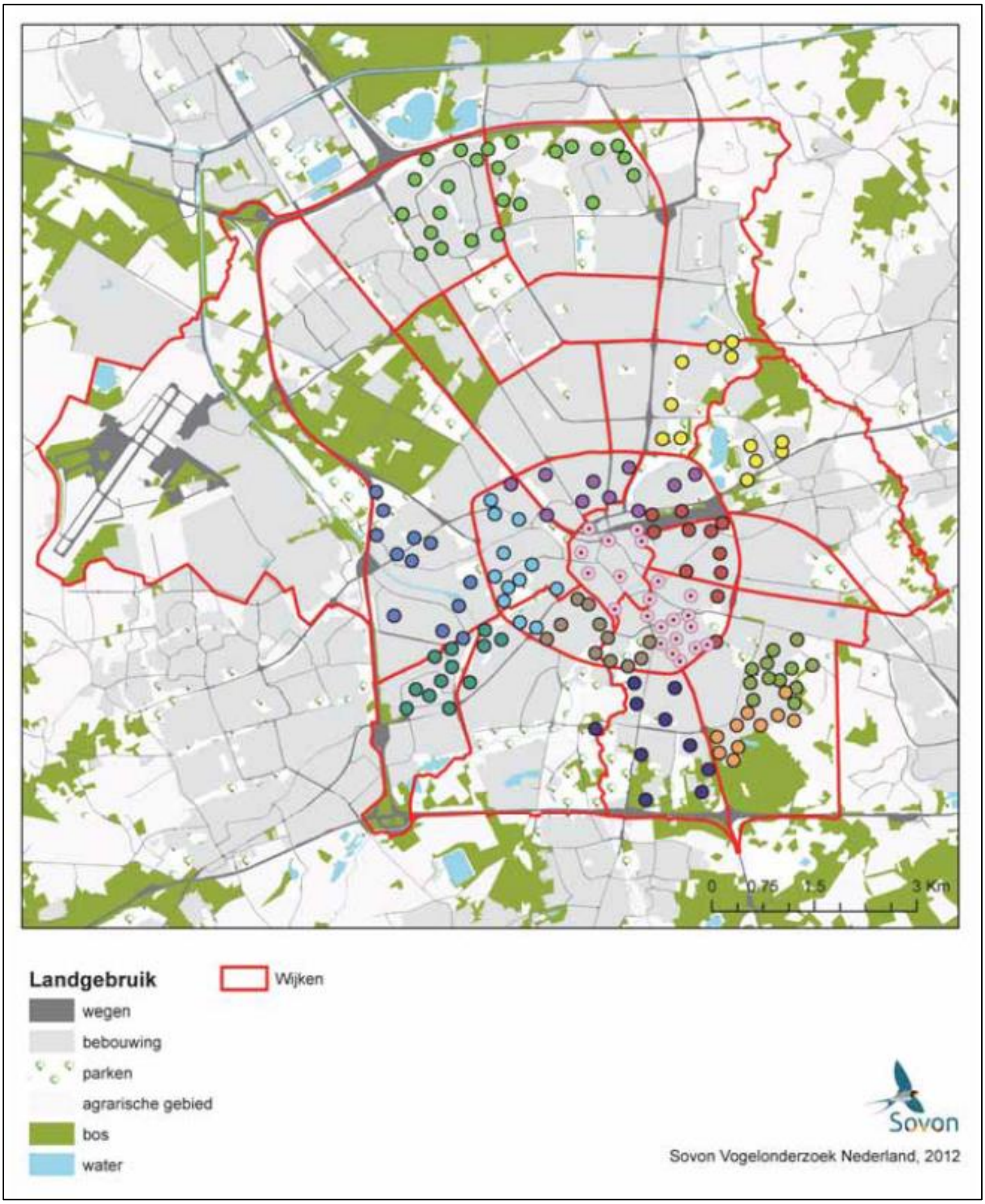


***Figure 3*** *MUS data points in Eindhoven, with different coloured dots for each MUS participant and boundaries of districts (in red) (Source: Sierdsema, 2013).*

However, there is some confusion regarding the term 'city district' ('wijk' in Dutch). This use of the term 'wijk' may be somewhat misleading, or rather the term seems to be used in different ways, at least by Sierdsema (2013); at times, 'wijk' refers to an administrative city district (CBS wijk; see Figure 3), while 'wijk' also refers to the surroundings of the point where the counting took place, limited to a 200-metre radius. Sierdsema (2013, pp. 9-10) also refers to the type of district being determined per MUS data point, with different types occurring within the same administrative city district. It is unclear whether Kooijmans uses the term in the same two ways or only in the latter way. Looking at a map provided on the CBI website

(Figure 4), the boundaries portrayed by the colour transitions do not coincide with district borders. Anyway, it is unclear why administrative districts were used as spatial units at all. It seems possible to assess the environmental characteristics used in the regression equations to predict bird presence for every location within a built-up area. Subsequently, the regression equation can be applied to each location. Such an application would generate a much more spatially detailed map, perhaps quite similar to that depicted in Figure 4.

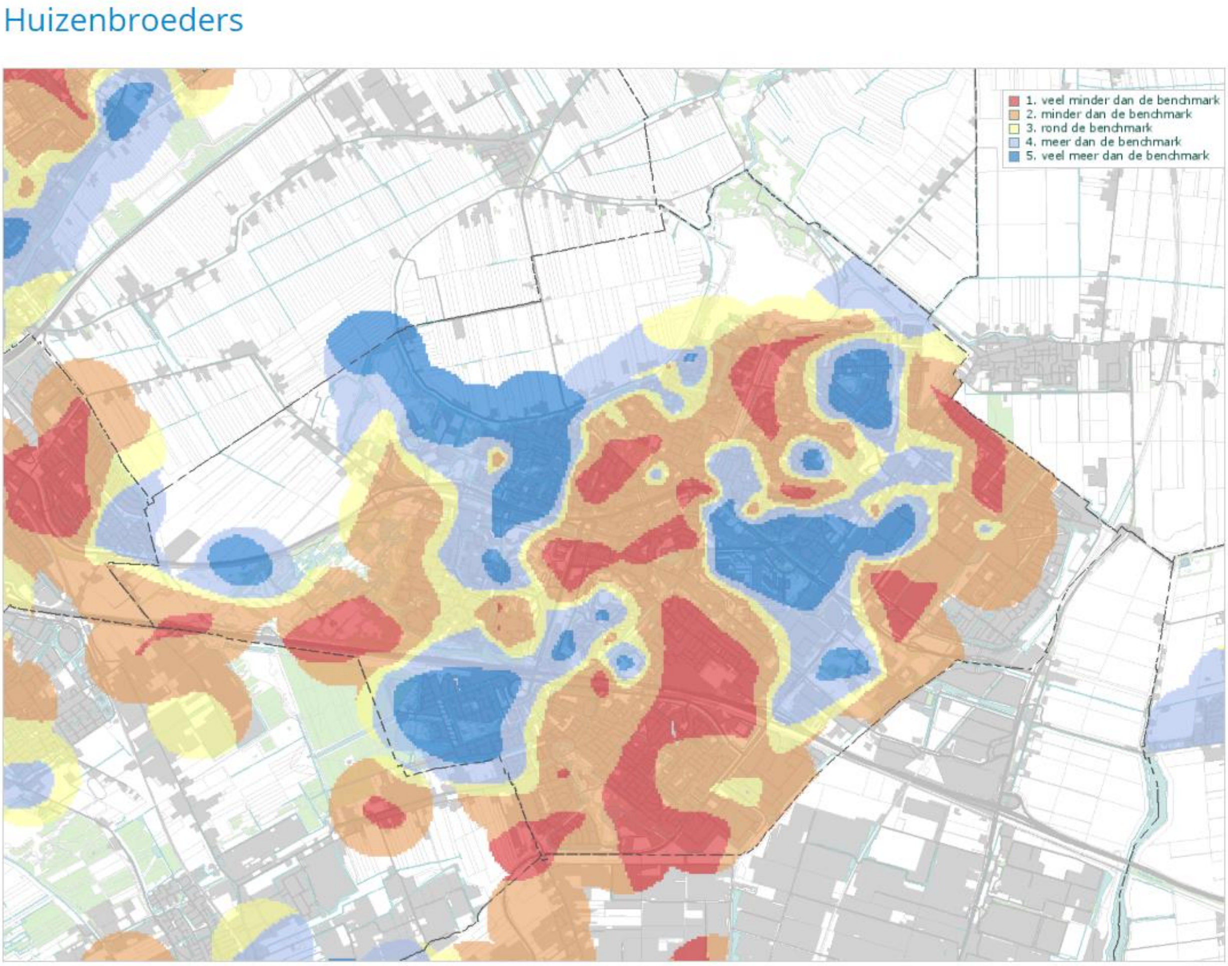


***Figure 4*** *Relative frequency of occurrence of a specific category of birds ('huizenbroeders') in the city of Zoetermeer, from low (red) to high (blue). Source: http://www.stadsvogelindicator.nl/voorbeeld.*

Cox et al. (2018) provide an example of modelling bird presence for a single urban area in the UK. They used the percentage of tall vegetation (> 0.7 metre) within 500 x 500 metre tiles, as well as the percentage of building cover within those same tiles to upscale observations of bird presence. Although its predictive power is also unknown, this model confirms that the presence of (tall) vegetation and building cover are assumed to be important environmental characteristics when it comes to bird presence. A very detailed dataset is being developed specifically for the amount and height of vegetation. The CBI model is a source of inspiration for other relevant factors, in addition to vegetation and building cover, such as building age, water presence and elevation level. Expert consultation can help in arriving at a set of potentially relevant characteristics regarding the habitat quality for different bird species.

## 3.2 Conclusions regarding the feasibility of modelling bird presence

Within this project, the aim of modelling the presence of birds in domestic urban gardens is to be able to investigate the hypothesis that this bird presence has an independent effect on the health and well-being of urban residents.[7] To be of use for this purpose, such a model has to satisfy several requirements. A first requirement is a sufficient level of spatial detail. Given that data on the amount of different types of vegetation (in height classes), as well as the presence and amount of water, are (or shortly will be) available at a high level of spatial detail, and given that these characteristics are the most relevant ones for modelling bird presence in urban environments, the main input variables are available at a sufficient level of spatial detail. A second requirement is that there are enough accurate data on bird presence in cities available to calibrate such a model. The exploration of the MUS dataset on bird presence in cities clearly suggests that the latter is the case, at least for most of the bird species that are included in the MUS dataset. These first two requirements are therefore likely to be satisfied. However, they are about the feasibility of developing the model. Eventually, the main requirement is that the calibrated model is able to predict bird presence at a spatially detailed level with a sufficiently high level of accuracy, to be used as input for research on access to nature and biodiversity on the one hand and human health and well-being on the other. This requirement is something that remains to be seen in practice.

A possible refinement of modelling bird presence would be to make a distinction according the attractiveness of the bird species. As mentioned in the literature review, not all species are considered equally attractive. The presence of some species is even considered unattractive. Therefore, making a distinction between the presence of more and that of less attractive species could provide valuable additional information. The MUS dataset contains data on the presence of different species. Thus, making this type of distinction is feasible. What is needed is a classification of the bird species included in the MUS dataset according to its attractiveness to citizens. In the next paragraph, a first step is taken in order to arrive at such a classification.

## 3.3 Possible refinement: categorising bird species

In trying to model the presence of birds in urban domestic gardens, we focus on species that are rather common in an urban context. Modelling the presence of species that are rarely observed in cities is likely to prove to be very difficult and unlikely to result in accurate predictions. Moreover, we consider the MUS database to be the most suitable one for empirically calibrating a model. Using this database also comes with limitations on which species to include in the model, in the sense that they have to be included in the MUS database.

From an experiential point of view, a bird’s visual attractiveness is important, as well as its auditory attractiveness, i.e. the appreciation of the sound it makes. In a first attempt to classify the bird species, five bird experts were asked to rate each species on three characteristics: visual attractiveness, auditory attractiveness and annoying behaviour. Ratings should be based on how lay people would perceive the bird, not on the expert’s own opinion. Visual attractiveness scores had to be assigned based on appearance and displayed behaviour. Auditory attractiveness is based on song or otherwise pleasant sound. Annoying behaviour is focused on the bird displaying negatively appreciated behaviour. For visual attractiveness and auditory attractiveness, there are three possible scores:
0 = too rare occurrence in domestic gardens to be relevant or not attractive to look at/to hear
1 = somewhat attractive
2 = very attractive

[7] The term ‘effect’ is used here in a statistical sense, not in a causal sense. Technically, ‘effect’ is about an independent contribution of bird presence in the prediction of human health and well-being.

For annoying behaviour, there are two possible scores:
0 = too rare occurrence in domestic gardens to be relevant or no annoying behaviour
1 = displays annoying behaviour

In Table 3, the scores assigned to the bird species by five bird experts are presented. Species that score particularly high on a characteristic are marked in green for the two positive characteristics and in red for the negative characteristic.

***Table 3*** *Ratings for the 40 MUS species on three aspects by five experts (five ratings ordered from high to low).*

| English name | Dutch name | Visual attractiveness | Auditory attractiveness | Annoying behaviour |
|---|---|---|---|---|
| Great blue heron | Blauwe Reiger | 11110 | 00000 | 11110 |
| Barn swallow | Boerenzwaluw | 22211 | 22111 | 00000 |
| Short-toed treecreeper | Boomkruiper | 11100 | 21110 | 00000 |
| Magpie | Ekster | 21100 | 11000 | 11111 |
| Pheasant | Fazant | 11000 | 10000 | 00000 |
| Willow warbler | Fitis | 11100 | 22221 | 00000 |
| Jay | Gaai | 22211 | 10000 | 11100 |
| Common swift | Gierzwaluw | 22211 | 22211 | 00000 |
| Greenfinch | Groenling | 21111 | 22211 | 00000 |
| Great spotted woodpecker | Grote Bonte Specht | 22222 | 22111 | 00000 |
| Hedge sparrow | Heggenmus | 11110 | 22211 | 00000 |
| Stock dove | Holenduif | 11000 | 11100 | 10000 |
| Wood pigeon | Houtduif | 21100 | 11110 | 10000 |
| House sparrow | Huismus | 22211 | 22211 | 00000 |
| Jackdaw | Kauw | 21110 | 11100 | 11110 |
| Small black-backed gull | Kleine Mantelmeeuw | 00000 | 10000 | 00000 |
| Black-headed gull | Kokmeeuw | 00000 | 11000 | 00000 |
| Great tit | Koolmees | 22221 | 22211 | 00000 |
| Coot | Meerkoet | 00000 | 00000 | 00000 |
| Blackbird | Merel | 21111 | 22222 | 00000 |
| Egyptian goose | Nijlgans | 11000 | 00000 | 11110 |
| Blue tit | Pimpelmees | 22221 | 22211 | 10000 |
| Goldfinch | Putter | 22222 | 22221 | 00000 |
| Robin | Roodborst | 22221 | 22211 | 00000 |
| Oystercatcher | Scholekster | 11000 | 10000 | 00000 |
| Domestic duck | Soepeend | 00000 | 00000 | 00000 |
| Starling | Spreeuw | 21111 | 22221 | 11000 |
| City pigeon | Stadsduif | 11000 | 11000 | 11111 |
| Chiffchuck | Tjiftjaf | 11000 | 21111 | 00000 |
| Garden warbler | Tuinfluiter | 21000 | 22210 | 00000 |
| Collared dove | Turkse Tortel | 11100 | 21100 | 00000 |
| Finch | Vink | 22211 | 11111 | 00000 |
| Moorhen | Waterhoen | 10000 | 00000 | 00000 |
| Mallard | Wilde Eend | 11000 | 00000 | 00000 |
| Wren | Winterkoning | 22211 | 22221 | 00000 |
| White wagtail | Witte Kwikstaart | 22211 | 11000 | 00000 |
| Song thrush | Zanglijster | 22211 | 22221 | 00000 |
| Herring gull | Zilvermeeuw | 00000 | 11000 | 11100 |
| Black crow | Zwarte Kraai | 10000 | 00000 | 11110 |
| Blackcap | Zwartkop | 22110 | 22210 | 00000 |

In some cases, the five experts gave quite different scores. Bringing them together and having them discuss the scores could help to resolve differences and to achieve a higher level of consensus among the experts, with the criteria for scoring being refined at the same time. However, such an exercise is beyond the scope of the present project.

## 3.4 Is modelling needed?

Within this project, the purpose of modelling bird presence is to be able to assess the influence of bird presence in one's garden in addition to that of vegetation in that garden. At the moment, this same vegetation seems to provide important input for the modelling of bird presence. If so, then a strong relationship will exist between predicted bird presence and characteristics of the vegetation within a garden. This relationship will generate multicollinearity problems in the statistical analyses. However, there may be a way to avoid this problem. The number of (robust) data points available in the MUS dataset is larger than anticipated. Furthermore, the NIVEL healthcare registration database that is to be used in the study on garden greenery nowadays contains data of about two million Dutch inhabitants. This high number makes it likely that there are many addresses in the NIVEL healthcare registration database that are located within a relatively short distance of a MUS data point. Within MUS, 50 metres is assumed to be the observation horizon. Conversely, if the bird presence observed at such a data point may be considered representative for this wider environment, then the number of addresses associated with a nearby MUS data point may be enough to perform a statistical analysis with enough power to detect meaningful associations, if present.

To explore this issue, a couple of cases are examined. The first case is a postcode area in the city of Amsterdam, area 1072, containing 12 MUS data points (see Figure 5.a). This area has a size of 63.6 ha. In 2018, almost 14,000 people lived in this area. The 50-metre buffers for the MUS data points are 0.7 ha in size each. Assuming no overlap between the twelve buffers, and assuming the buffers are completely located within the postcode area, about 8.5 ha or 13.5% of the postcode area falls within a MUS buffer. If it is also assumed that the inhabitants of the postcode area are equally distributed within the area, then the same percentage of inhabitants lives within one of the twelve MUS buffers. In absolute numbers, this percentage would amount to over 1,800 people. Furthermore, if we assume that the people included in the NIVEL healthcare registration database are also equally distributed over the built-up areas in the Netherlands, then about one out of every eight inhabitants will be included in this database. Multiplying this percentage (12.5) by the absolute number of people included in a MUS buffer gives a rough estimate of about 230 people living within 50 metres of a MUS data point also being included in the NIVEL healthcare registration database. This number can be divided into approximately nineteen persons per MUS data point.

***Figure 5.a*** *MUS data points in postcode area 1072 (Amsterdam).*

Another case is postcode area 6601, located in Wijchen (nearby Nijmegen). This area has a total size of 379 ha, with 204 ha consisting of mainly built-up space (see Figure 3.b). In 2018, about 10,500 people lived in this area. We assume that 10,000 of them lived within the built-up area of 204 ha. This postcode area also contains 12 MUS data points. Following the same reasoning as in the previous case, the MUS buffers contain about 4% of the built-up area, resulting in about 400 persons estimated to be living within the 12 MUS buffers, of which 50 are supposedly also included in the NIVEL healthcare database. This number can be divided into approximately four persons per MUS data point.

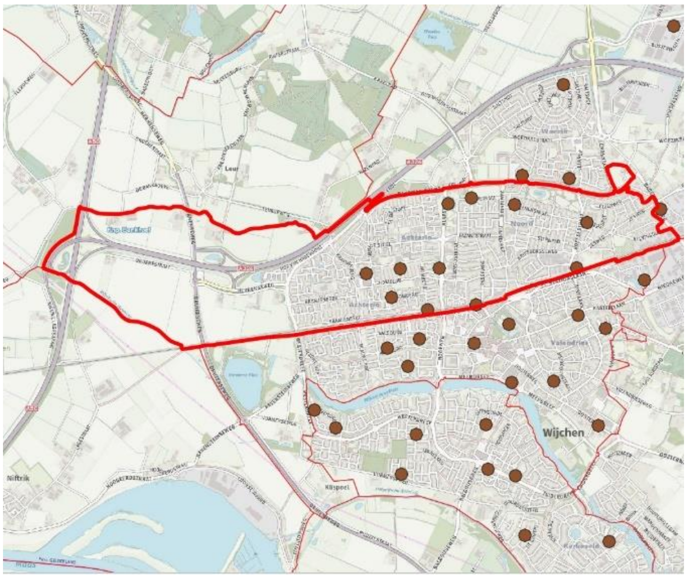


***Figure 5.b*** *MUS data points in postcode area 6601 (Wijchen, nearby Nijmegen).*

A third case is postcode area 3906 in Veenendaal. This area has a total size of 196 ha, of which 128 ha consist of predominantly built-up space. In 2018, about 7,000 people lived in this built-up area. The postcode area once again contains 12 MUS data points. These figures indicate that the 12 MUS buffers cover about 6.5% of the built-up area, with an associated 460 inhabitants. This coverage leads to an estimated number of about 60 people also being included in the NIVEL healthcare registration database, or about five persons per MUS data point.

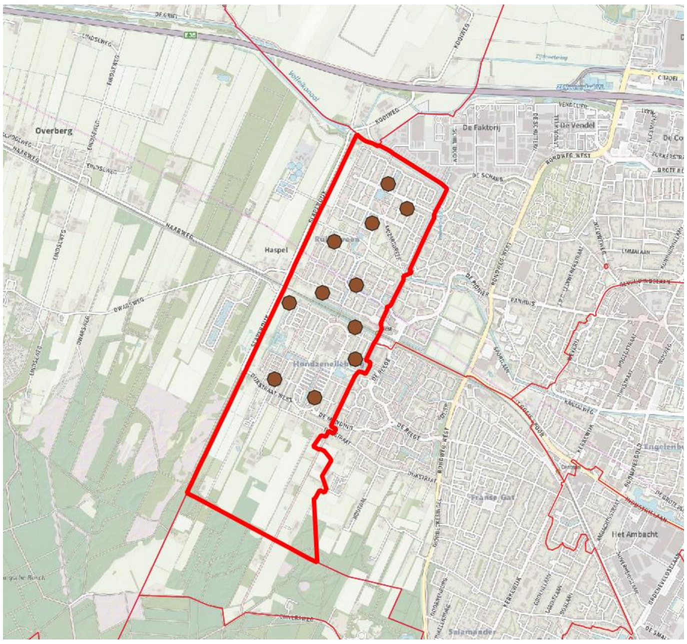

***Figure 5.c*** *MUS data points in postcode area 3906 (Veenendaal).*

The fourth and final case is postcode area 9566 in Veelerveen (near Vlagtwedde). This area has a total size of 916 ha, of which only 131 ha consists of mainly built-up space. In 2018, about 550 people lived within this built-up area. This postcode area contains only 8 MUS data points, the minimal number. The associated figures are that the 8 MUS buffers cover about 4.5% of the built-up area, containing approximately 24 persons, of which three are likely to be also included in the NIVEL healthcare registration database. This number is divided into less than 0.5 persons per MUS data point.

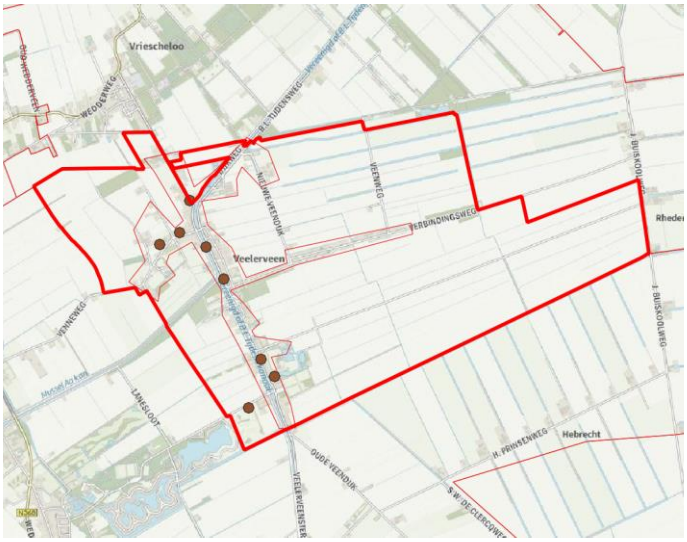


***Figure 5.d*** *MUS data points in postcode area 9566 (Veelerveen, near Vlagtwedde).*

### 3.4.1 Conclusions regarding using (only) actual data on bird presence

The four cases show that the number of patients included in the NIVEL healthcare registration database that live in the vicinity of a MUS data point varies considerably. A reasonable argument might be that a postcode area is more likely to be counted, and contain at least 8 MUS data points, when more people live within this postcode area. On the other hand, one might argue that people living in less urban areas may be more inclined to participate in the MUS project. Using an estimate that we consider to be conservative, of four patients per MUS data point, and at least 4500 MUS data points with robust data (see Table 1), a total number of 18,000 patients may be expected to live so near to a MUS data point that the figures of this data point may be expected to give a good indication of the bird presence in their garden, or, more broadly, in the immediate surrounding of their home. This number seems sufficiently high to conduct the aforementioned statistical analysis, looking into the added (predictive) value of bird presence, in addition to having a green garden, for one’s well-being.

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