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## Contents

# Song dialects of Redwing *Turdus iliacus* in Helsinki area, Finland

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Redwing *Turdus iliacus* typically uses only one type of song strophe per individual, setting it apart from most other thrush species such as the Eurasian Blackbird *T.merula*, Song Trush *T.philomelos* and Mistle Thrush *T.viscivorus*, which possess a diverse vocal repertoire. What distinguishes the Redwing is its remarkable variation in song across different areas, marked by sudden changes, resulting in the formation of distinct song dialects. This study investigates the Redwing's song dialects, drawing on sound recordings collected in the vicinity of Helsinki, Finland, spanning the years 2009 to 2020.

## Geographical variation of bird song and dialects

The geographical variation of bird song has received significant attention and research. This concise summary draws primarily from the works of Catchpole & Slater (2008) and Podos & Warren (2007).

Crucial aspects of the song structure in oscine passerines are culturally acquired, either from the bird's ancestors or a group of individuals within the local population. This process gives rise to slight errors during song transmission, resulting in the accumulation of geographic variations in the songs. Additional factors contributing to geographical variation include genetic changes impacting anatomy or neurology, cultural selection favouring specific singing styles, and natural selection leading to local adaptations.

Dialect formation represents a specific type of geographical variation, where a group of birds shares a general song structure that distinguishes them diagnostically from other groups, which also share similar song between the individuals. While dialectal variation is common, it is not the prevailing form of geographical variation in passerine birds. Birds with more complex and variable vocalisations may experience changes in different aspects of their songs in different boundaries, making the formation of true dialect borders less apparent. However, for birds like the Redwing, which possess only one song type, the dialectal structure is particularly evident.

In all animal species, dialects emerge only in those where vocal imitation plays a significant role in vocal learning. Learning can occur prior to dispersal from the birthplace or afterwards, such as when establishing a territory. Certain species retain the ability to learn new songs throughout their lives. In the former case, the vocal dialect inherits traits from the parental population or, in some cases, directly from the biological ancestor. Migratory species typically exhibit larger dialect areas compared to sedentary ones, although the stability of dialects does not necessarily correlate with migratory behaviour.

Different types of songs can offer advantages in varying environmental conditions, which can contribute to the formation and persistence of dialects. While this phenomenon has been observed in passerines, it appears to be relatively uncommon. Another factor influencing dialect formation is song matching among neighbours, either in reciprocal interactions or through learning from specific individuals. In some cases, it has been demonstrated that females exhibit a preference for the song type they are familiar with when selecting a mate or territory, thereby contributing to song matching and localised song types. Additionally, aggressive territorial defense can lead to song matching between rival individuals. However, in many instances, the evolution of dialectal structure may have occurred without a clear functional purpose. It could be a by-product of dispersal and vocal learning processes, lacking a specific adaptive function.

## Terminology

In this context, the term "song" is used in a general sense, referring to an individual's territorial vocalisation characterised by a series of strophes. A strophe represents the longest segment of the song repeated continuously with minimal variation. Within a strophe, there are notes, which are continuous sounds without pauses (also referred to as syllables or elements). At the beginning of a strophe, there may be

a prenote, which is typically short and/or weak. Prenotes can be easily omitted from the strophes or may not be present in some similar strophes. It is important to consider this concept when comparing different strophes, as prenotes need to be treated differently to identify corresponding notes.

The term "dialect" refers to a specific type of strophe shared among multiple singing birds, distinguishing it from other dialects belonging to different bird groups. The term "song type" is used interchangeably with "dialect" in this context.

## Redwing song

Redwing is a strophe singer, which repeats a similar sequence of notes with consistent intervals. This is a common song type observed in passerines, although other local *Turdus* species in Northern Europe have more variable and longer strophes.

The main part of the Redwing's song (the motif part of Espmark et al 1989), typically comprises two to as many as twenty distinct, clear, and loud notes. When the number of notes is higher, they tend to be shorter in duration. Individual notes within the song exhibit various characteristics, such as frequency modulation or lack thereof, descending or ascending patterns, and occasionally additional frequency layers (although the last is less common in Redwing songs). The length of the notes also varies significantly. Many examples illustrating these variations can be observed in the sound spectrograms provided with the dialect descriptions.

A notable feature is the alternation of higher and lower notes, as well as shorter and longer notes within the strophe. The strophe is often preceded by shorter prenotes, which may be absent in other versions of strophes within the same dialect. The entire main part of the strophe can either ascend or descend in pitch. Due to this extensive variation, the song of the Redwing is highly variable, sometimes making it challenging for less experienced observers to identify the species.

Following the loud main part, there is a quieter section consisting of numerous twittering or warbling notes, referred to as the twitter-like part (Espmark et al 1989). While this warbling part exhibits less variation between dialects, it shows more variability within individual Redwing strophes. For the purpose of defining and comparing dialects, this warbling part is ignored, consistent with earlier studies on the same subject (Bjerke & Bjerke 1981, Espmark *et al* 1989).

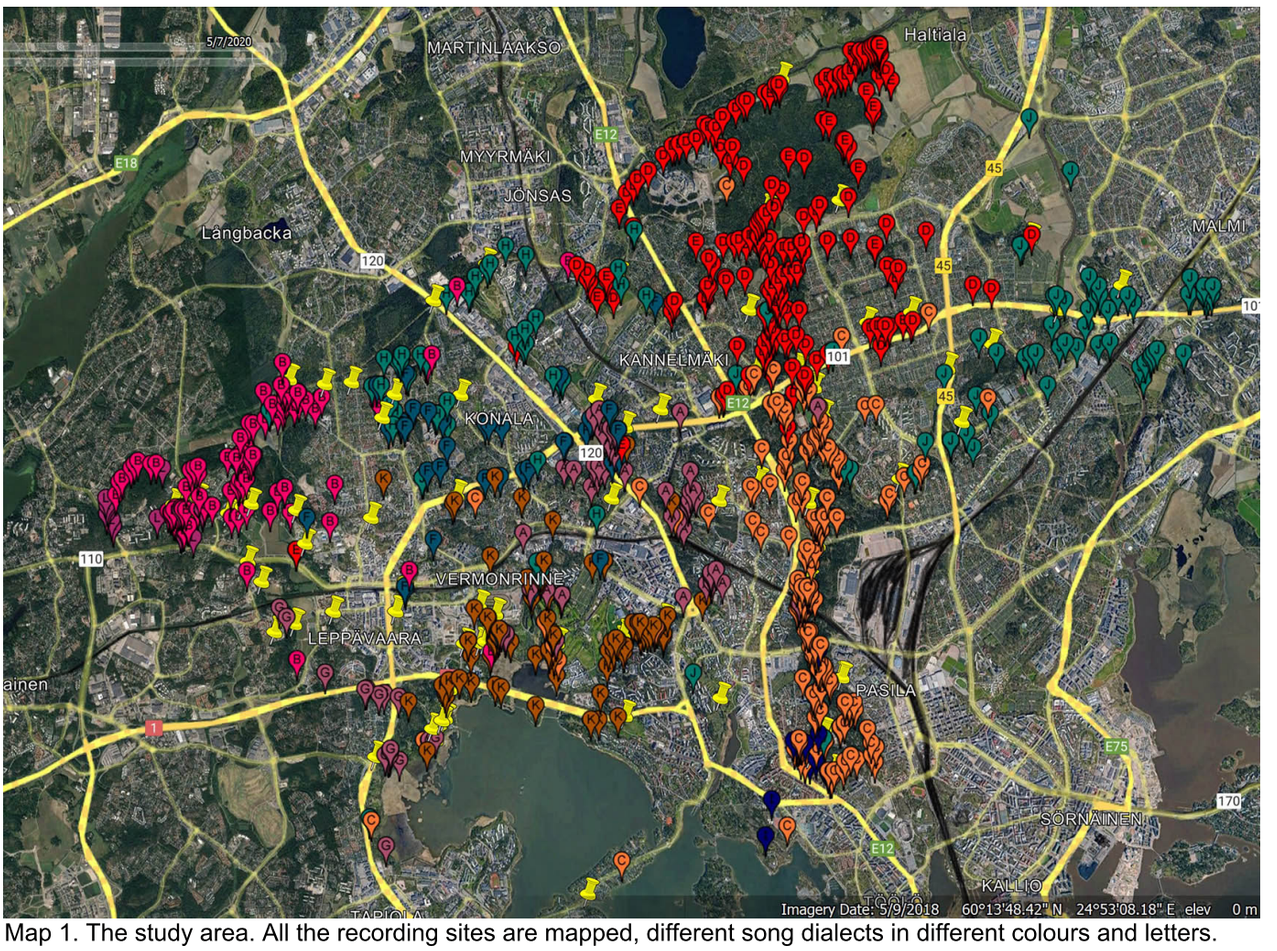
In their study, Bjerke & Bjerke (1981) focused on Redwing dialects within a 965 $km^2$ area in southern Norway, encompassing diverse habitats including both rural and urban areas. They identified a total of 27 dialects, with 17 dialects completely confined to the study area. On average, the distribution area of the dialects was approximately 41.5 $km^2$, ranging from 2 $km^2$ to 158.8 $km^2$. Within dialects, there was a high level of conformity in song patterns, with most birds exhibiting only one type of strophe. The researchers encountered only eight males with atypical songs during the breeding season.

Bjerke & Bjerke (1981) also examined the intraindividual variability of Redwing songs throughout the season. They found that variability was minimal in the main part of the song, with some variation observed in the onset of the song strophe. Near the boundaries of dialects, most males maintained the use of their own dialect, although there were a few cases where individuals sang both dialects, albeit infrequently. While no clear records of hybrid songs were documented, there were indications suggesting their potential occurrence. The researchers also observed minor changes in the distributions of dialects over the seven-year study period.

Espmark *et al* (1989) observed considerable variation in song conformity among local populations of Redwings in Norway and Sweden. They noted that song conformity did not significantly correlate with the density of singing males but appeared to be associated with breeding success, although the exact explanation for this correlation remained challenging. The researchers also reported that approximately 17-30% of adult birds and 1-4% of fledglings returned to the same area for breeding in the following year. Based on their estimates, they projected that the local population would undergo replacement in approximately four years.

## Status of Redwing and the study area

In the suburban areas of Helsinki, four species of thrush Turdus are common breeders: Eurasian Blackbird, Fieldfare *T.pilaris*, Song Thrush and




Map 1. The study area. All the recording sites are mapped, different song dialects in different colours and letters. The yellow markers indicate unique songs, which do not belong to any known dialects. A – HAGA, B – KAKA, C – KEPUE, D – KEPUP, E - KEPUX, F – KONAL, G – LAAJA, H – MAKA, I – MELA, J – OUKY, K – TALI.

Redwing. The fifth breeding species in the region, Mistle Thrush, does not venture into suburban areas but breeds exclusively in the surrounding natural forests. All of these thrush species are migratory, although a significant population of Blackbirds spends their winters in the area.

Each thrush species exhibits slightly different habitat preferences. The Redwing thrives in habitats characterised by spruce *Picae abies* edges, particularly near open patches such as larger gardens, agricultural areas with a garden-like layout, or even forest stands adjacent to agricultural fields. It is less common in continuous woodlands, areas dominated by densely built suburban houses with scattered spruce trees, or regions devoid of spruce altogether. Redwings do not inhabit treeless areas, densely urbanised locations with tall buildings and limited tree cover (e.g., city centers), or managed city parks. However, they readily occupy small spruce woods found between blocks of flats, often with natural undergrowth. The suburban areas of Helsinki provide ample preferred nesting sites for Redwings, making them a common and widespread species.

In 2008, a more extensive study was conducted to identify suitable patches for a longer-term investigation. An area located at the southernmost part of the Central Park was chosen, and data collection took place from 2009 to 2013 within that designated area. From 2014 to 2020, the study expanded to encompass a larger region, which included the original pilot area and extended to the north of it.

Map 1 displays all the recording samples plotted within the study area, which extends from the eastern part of Espoo municipality to the northern parts of Helsinki, covering approximately 74 km$^2$. The surrounding regions to the west, northwest, and north consist mostly of similar suburban areas, which also harbour a

| | KEPUP | KEPUX | KEPUE | OUKY | KAKA | MAKA | TALI | KONAL | HAGA | LAAJA | VIHER | MELA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1st n freq range | 2486 | 2350 | 1480 | 1161 | 933 | 1477 | 2143 | 1604 | 1530 | 1323 | 1834 | 1433 |
| 1st n length | 0.291 | 0.253 | 0.137 | 0.101 | 0.148 | 0.15 | 0.343 | 0.24 | 0.223 | 0.048 | 0.297 | 0.466 |
| 1st n max freq | 5165 | 5061 | 4160 | 4618 | 3901 | 4221 | 4821 | 4095 | 4084 | 4400 | 4770 | 4075 |
| 1st n min freq | 2679 | 2710 | 2680 | 3457 | 2968 | 2744 | 2678 | 2491 | 2555 | 3077 | 2936 | 2642 |
| 2nd n freq range | 2535 | 2463 | 719 | 1331 | 1308 | 1170 | 779 | 1140 | 1261 | 1838 | 1421 | 1200 |
| 2nd n length | 0.303 | 0.272 | 0.15 | 0.208 | 0.068 | 0.099 | 0.213 | 0.139 | 0.08 | 0.06 | 0.281 | 0.22 |
| 2nd n max freq | 5100 | 5071 | 3831 | 4387 | 4716 | 4556 | 4277 | 4116 | 4574 | 4448 | 4165 | 4606 |
| 2nd n min freq | 2565 | 2608 | 3112 | 3056 | 3408 | 3386 | 3498 | 2976 | 3313 | 2609 | 2744 | 3406 |

Figure 1. Average measurements of the songs, one strophe for an individual

high population of breeding Redwings. Therefore, the studied Redwing population is not isolated but connected to these neighbouring areas. Towards the south, the area is bordered by the Baltic bay of Laajalahti and the urban section of the city, where Redwings are sparsely present. To the southeast of the study area, there is a sizable region occupied by a railroad depot and industrial apartments, which lack suitable habitat for Redwings.

Within the study area itself, the most favorable patches for Redwings are located along forest belts, particularly in the Central Park. The Helsinki Central Park predominantly consists of closed-canopy forests, partly composed of old-growth spruce and pine trees. However, the undergrowth in certain areas may be disturbed due to various factors. The Central Park also includes small-scale agricultural gardens maintained by hobbyist farmers, graveyards, and other relatively open areas. Towards the northern parts of the Central Park, there are larger commercial agricultural fields around Haltiala, which do not support Redwing populations.

In other urban areas such as Leppävaara, Munkkiniemi, Ruskeasuo, Pitäjänmäki, Konala, Haaga, and Kannelmäki, there are fewer breeding pairs of Redwings. Additionally, areas characterised by more extensive residential housing but fewer trees, such as Lintuvaara and Pakila, exhibit reduced Redwing populations.

## Collecting the material

During the full study years, the fieldwork involved cycling through the study area on multiple mornings, typically from before sunrise until a couple of hours afterward, for a total of approximately 10 to 20 mornings each year. The aim was to cover the entire study area at least once during the observation period and record the vocalisations of all encountered Redwings. However, if an individual had already been recorded earlier in the same spring, it was often skipped during subsequent visits. Additionally, due to time constraints, some individuals that were singing from distant locations were not attempted to be recorded.

It's important to note that Redwings do not sing continuously, even in favorable weather conditions and during the appropriate breeding season. Furthermore, there were instances where certain spots were visited only once, resulting in missed opportunities to record individuals. However, non-singing Redwings were frequently observed in the field, as the species tends to be relatively approachable and easily visible in this particular area. Areas with less promising habitat were not explored in close proximity, potentially leading to a failure to detect some potential singers.

In summary, considering the years with more extensive coverage, the estimation is that approximately half of the male Redwings holding territories in the study area were recorded during the observation period.

During the years with less extensive coverage, only a smaller portion of the study area, specifically the southern part of Central Park, was visited. However, these areas were surveyed more intensively using the same methodology.

Various types of microphones and recorders were utilised throughout the study, with recordings consistently being in digital format using lossless PCM. In certain years, a shotgun microphone was employed, while in other years, more general-purpose microphones integrated with the sound recorders were used. Some recordings were also made using a parabolic reflector.

While Redwings are common passage migrants in the area and often sing during spring migration, the focus of the study was on the regional breeding population. Migrants were predominantly excluded from the collected material. However, distinguishing between breeding birds and migrants can sometimes be challenging, and the dataset may include a few instances of birds that eventually bred elsewhere. Some unique strophes may originate from these individuals. Migrants resting in groups were disregarded during fieldwork, and birds singing from flocks were skipped. Migrants can be identified by their subsong-like vocalisations and active movement between trees while vocalising. In contrast, settled territorial birds typically sing from the top of a tree, often choosing one of the tallest trees within their territory, and their singing lasts for several minutes at a time.

Furthermore, data collection did not commence immediately after the first Redwings returned from migration. Instead, it began approximately a week later when many birds had already established territories, and a portion of the passage migrants had departed. This approach ensured that the study area was visited when most of the breeding birds were present. The presence of flocks in the area was documented. In some years, resting migrant flocks were nearly absent, while in others, they remained in the area for an extended period.

When flocks of Redwings sing on migration, it is common to hear several song types at the same time, in contrast to when only territorial birds are vocalising, when typically all birds audible at any spot sing the same type of song. But a very interesting behaviour can sometimes be observed, when there is a loose flock which includes several singing birds. They may all sing similarly and use the true local strophe variant of the area. They may be very local birds just settling into territories, or birds from further away, which are temporarily matching their song to the local territory holders.

## The analysis

The songs were initially classified into distinct song types by analysing the sound spectrograms both visually and audibly. During this process, criteria for identification were developed. The geographical distribution of audibly classified dialects indicates that birds share similar perceptions of song similarity to humans. These classifications were subsequently employed when creating the maps.

Additionally, sound parameters were measured from the spectrograms to facilitate further analysis. The measurements were carried out as follows:

The lengths and frequency ranges of notes, as well as their sequential order, were considered. While this approach excludes certain potentially valuable data, such as frequency modulations, it primarily focuses on note lengths, which can be easily verified, understood, and utilised in the analysis. To ensure consistency, only one strophe from each individual was selected, specifically the recording of the highest quality with minimal background noise. Even in cases where individuals were multi-strophe singers, only one strophe was used.

The length, frequency, and frequency range of each note within a strophe were measured. To compare strophes from different individuals, the differences in the lengths of corresponding notes were counted. Different individuals often possess a varying number of strophe notes, and the challenge lies in identifying corresponding notes across different individuals. However, the presence of an additional note at the beginning or end of a strophe should not significantly affect the strophes' similarity, particularly if these additional notes are brief. Similarly, if a simple song type consists of two similar notes while other birds utilise three similar notes, these two songs would sound quite similar. Therefore, the number of notes should not be heavily weighted. The additional short notes are referred to as "prenotes" in this article, and their measurements were not compared in this analysis.

Furthermore, only the minimum number of notes across all compared strophes was utilised. For instance, the strophe type KEPUP consists of zero to two prenotes and two main notes. When comparing KEPUP strophes to other strophe types, only two notes were considered. On the other hand, the dialect

TALI consistently features three notes, which were used for comparison with any strophe type containing at least three notes. Since no strophe included only one main note, two notes were employed in comparisons across the entire dataset.

## The dialects

A total of 890 recordings were analysed, leading to the recognition of eleven distinct dialects. Among these, four dialects were found to be exclusively distributed within the study area. The distribution of another four dialects was primarily concentrated within the study area, but it likely extends beyond its borders. The remaining three dialects only marginally extend into the study area. The order in which the dialects are listed below roughly corresponds to their sample size, with the largest sample size at the top. To listen to recordings of these songs, please visit https://xeno-canto.org/set/8323.

## Northern Central Park (KEPUP, KEPUX)

This is one of the most widely used dialects, adjacent to another common dialect KEPUE, sounding quite different and with a sharp division between the two. It is probable that the distribution of this dialect extends further north than the study area itself.

This is the only case in this study where a subdialect was recognised with a different code, KEPUX. The strophe type KEPUX was recorded 49 times, while the basic type KEPUP occurred in 142 recordings.

This dialect is consistent and sounds quite simple to the human ear. It begins with none to two very short, strongly modulated prenotes, followed by two or three longer modulated notes. These longer notes initially descend and then ascend, bearing remarkable similarity to one another. Occasionally, the trailing portions of the main notes may appear as separate notes, but they are challenging to distinguish by ear and were consistently not counted as such.

Among the samples of KEPUX, 12 had no prenotes in the recordings, 6 had one, and 29 had two (the remaining recordings were of insufficient quality for assessment in this regard). For KEPUP, 12 had no prenotes, 33 had one, and 92 had two. Prenotes in this dialect are often more subdued than the main notes and may not be audibly discernible from a distance.

This dialect featured the only recorded instance of clear inter-dialectal geographical variation in the study. Birds situated towards the northeast more frequently sang with three main notes, resulting in longer phrases that could sound quite distinct to the human ear. This three-noted subdialect was designated as KEPUX. Many birds displayed a tendency to switch between two and three notes, more than the number of normal dialect switchers. These instances were coded based on the type of strophe they used more frequently or, in cases of shorter recordings, based on the strophe with the best audio quality. Some birds occasionally transitioned from three notes to four-noted phrases, although the strophe with four notes was the main strophe type only twice. Additionally, one bird demonstrated the ability to alternate between two, three, and four main notes.

The distribution area of the KEPUP dialect  is centred in the northern part of Central Park. The southern border towards KEPUE remained well defined through all years where the park is intersected by the Helsinki ring road 1. The dialect's distribution extends westward through the Maununneva area, reaching the major highway between Helsinki and Tampere. To some extent, it also spreads to the western side of the highway. Moving further west, the districts of Kaarela and Kannelmäki offer less suitable habitat for Redwings, resulting in a lower number of breeding birds. In this region, the MAKA dialect is replacing the KEPUP dialect.

In the northwest, the distribution area of the KEPUP dialect is bordered by extensive agricultural fields in the Haltiala district. To the east, the Paloheinä and Pakila suburban areas act as boundaries, with somewhat less suitable habitat, especially in the latter. Despite these factors, the singers of the KEPUP dialect occupy these areas. The eastern border of the distribution area is defined by the Tuusula highway. However, the population density around this highway is low due to the presence of open or built-up areas. Further east, the OUKY dialect emerges, but there is no direct contact between these two dialects as they are separated by areas with low population density.

## Southern Central Park (KEPUE)

This is one of the major dialects in the area, and likely

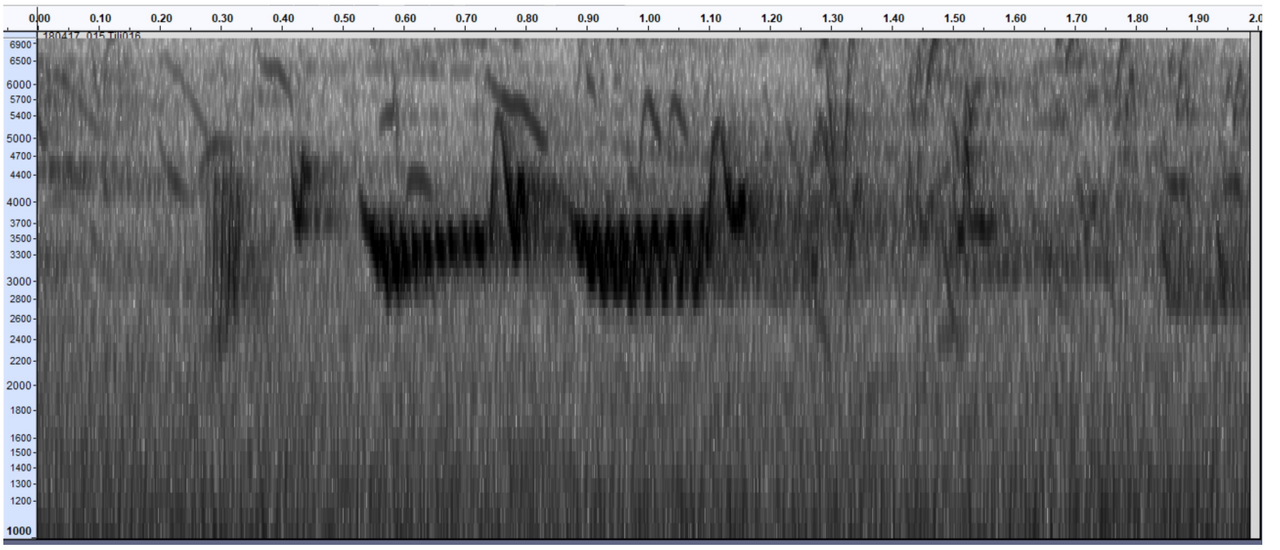


Figure 2. Type KEPUP. Two remarkably similar main notes, both ending in a higher part. Two prenotes which is very typical. The first is somewhat weaker, with a buzzing sound, the second is higher pitched and shorter. Either or both of these notes can be missing, but this is often because of the lack of quality in the sound recordings.

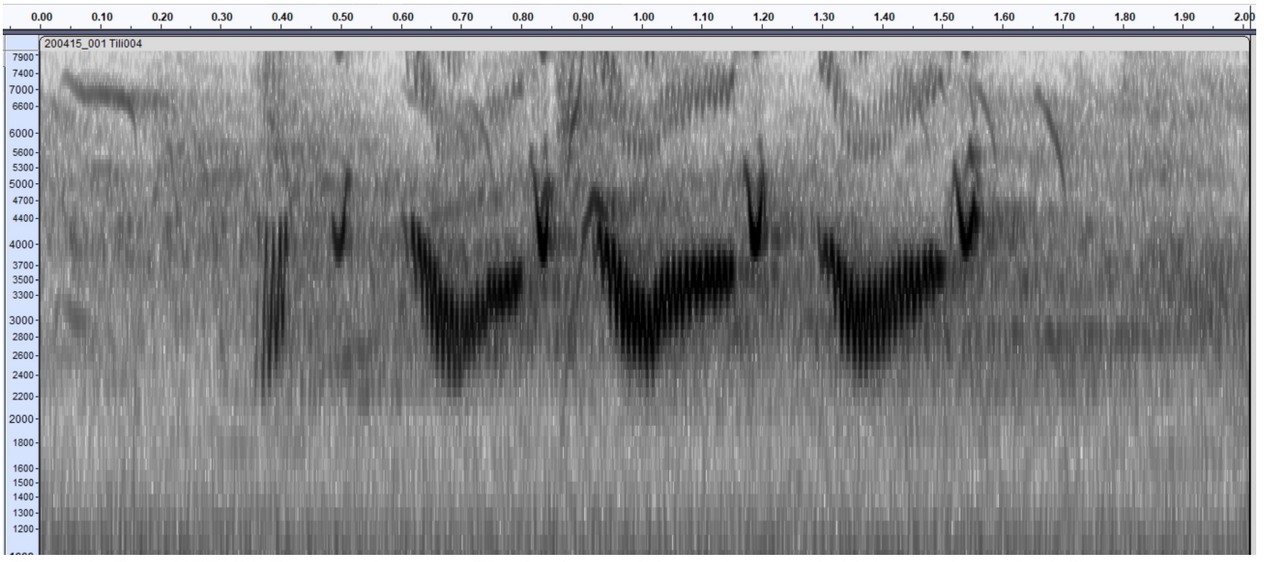


Figure 3. Type KEPUX. Three main notes. The final part of the main notes is higher and may look like a separate note, as in this example, but is not counted as such. The main notes are very similar to each other. Typically, as here, there are two prenotes.

entirely encompassed by the study area. The primary territory covers a relatively small area of approximately 5 km$^2$, but it is nearly completely occupied due to the favorable habitat provided by Central Park. In the southernmost part of Central Park, south of the railroad, there are around 10 territories (based on 17 recordings from the extensively studied year of 2010). Similarly, from the railroad north to ring road I, there are another 10 territories (recorded at 10 different sites in 2014). Additionally, there are a few territories located outside Central Park. Consequently, the total number of males utilising this dialect in any given year is slightly less than 30. Over the course of all the years combined, there were 181 recordings, of which 18 were captured outside the core distribution area.

The dialect primarily consists of strophes comprising a

prenote and four main notes. The first main note is the shortest and exhibits modulation, while the third and fourth notes also display modulation. The second note maintains a consistent pitch. The third note is particularly noteworthy as it is accentuated, with a higher pitch and a descending pattern, making it highly characteristic of this dialect. Variations of the strophe include an additional note at the end, which closely resembles the fourth note but lacks the fourth note itself. Additionally, it is possible to have one prenote, as seen in some other dialects.

## Tali (TALI)

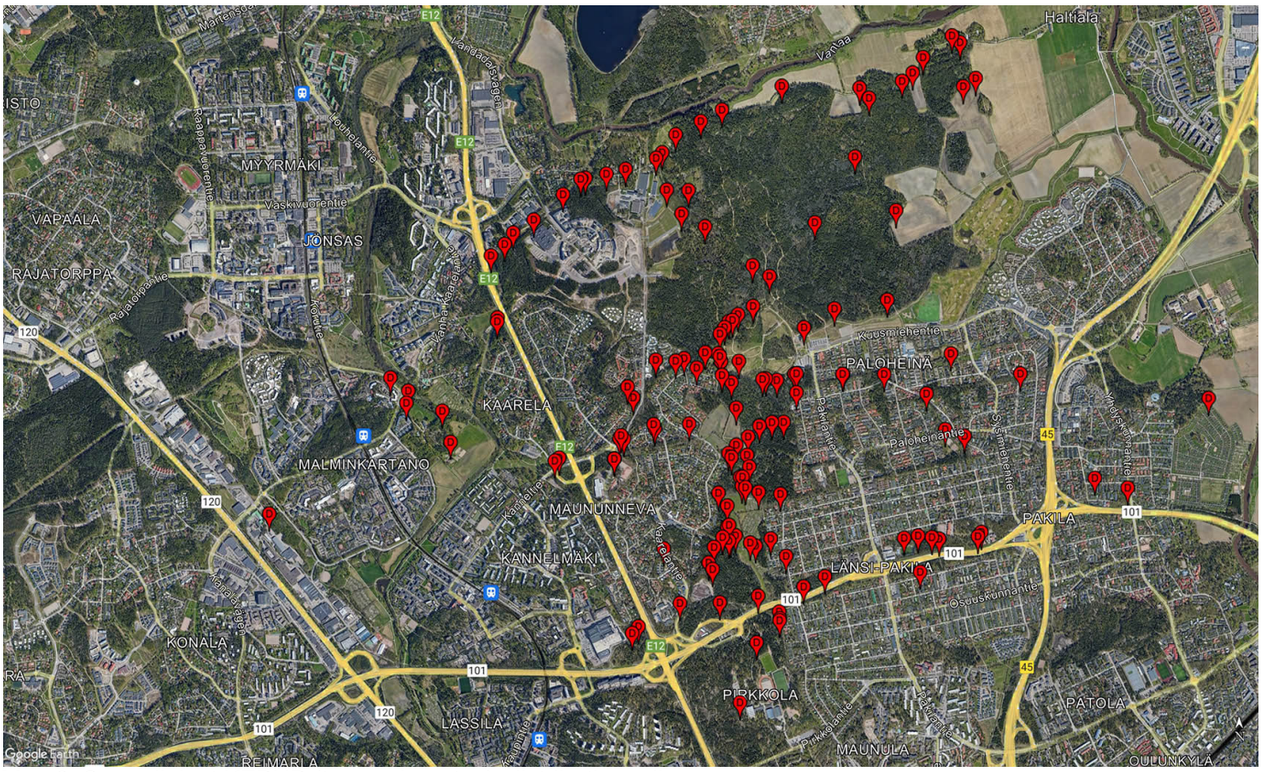
The TALI dialect is likely entirely contained within the study area. Its distribution area spans approximately 4.2 km$^2$, with a total of 78 recordings, 12 of which were captured outside the core area. Typically, the number of males utilising this dialect does not exceed a dozen in any given year.

The TALI dialect displays a consistent pattern with minimal variation. It shares similarities with the KEPUE dialect, as both feature higher accented notes in the middle. TALI consists of three notes, with the first note being modulated, long, and descending, closely followed by the second note, which is higher and maintains a straight pitch. The third note initially starts as non-modulated but transitions into a modulated pattern. There is no variation in the number of notes, and no prenotes were detected within this dialect. However, there is some variation in the shape of the middle note, particularly towards the end where a brief "hiccup" occurs. This shape somewhat resembles the warbling end segment of the Redwing song. The hiccup is audible as a slight irregularity within the song, with its prominence varying. At times, it may appear separate from the second note, but it is not considered a main note within the context of this study.

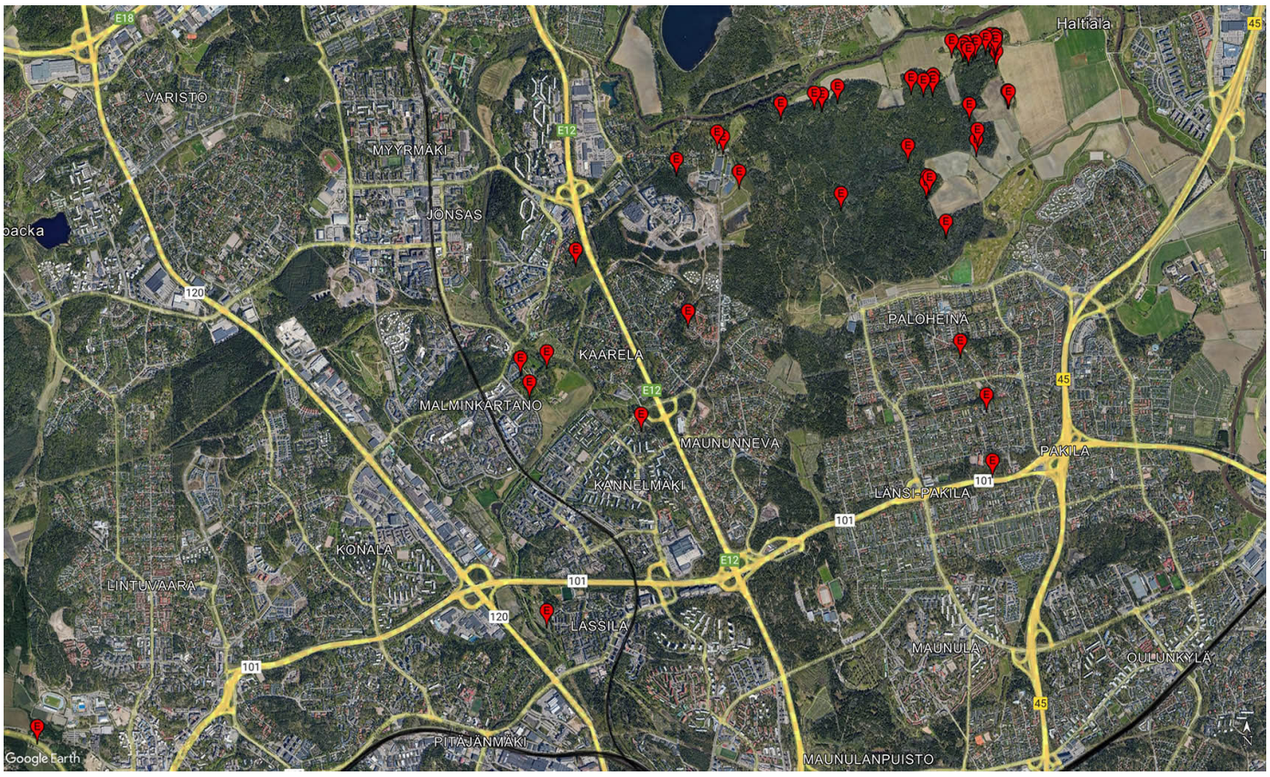
## Oulunkylä (OUKY)

The eastern areas boast a widespread and clearly defined dialect OUKY that extends beyond the boundaries of the study area. A total of 70 recordings capturing this dialect type were collected.

The type sounds simple with a slow and mournful tone. It consists of three prominently modulated



Map 2. Song dialect KEPUP (two main notes), distribution, all years.




Map 3. Song dialect KEPUX (three, or sometimes four main notes), distribution, all years. Overlaps partly with the two-noted variant but is more northerly and especially north-easterly. Almost totally absent around Maununneva, where the two-noted KEPUP is common.

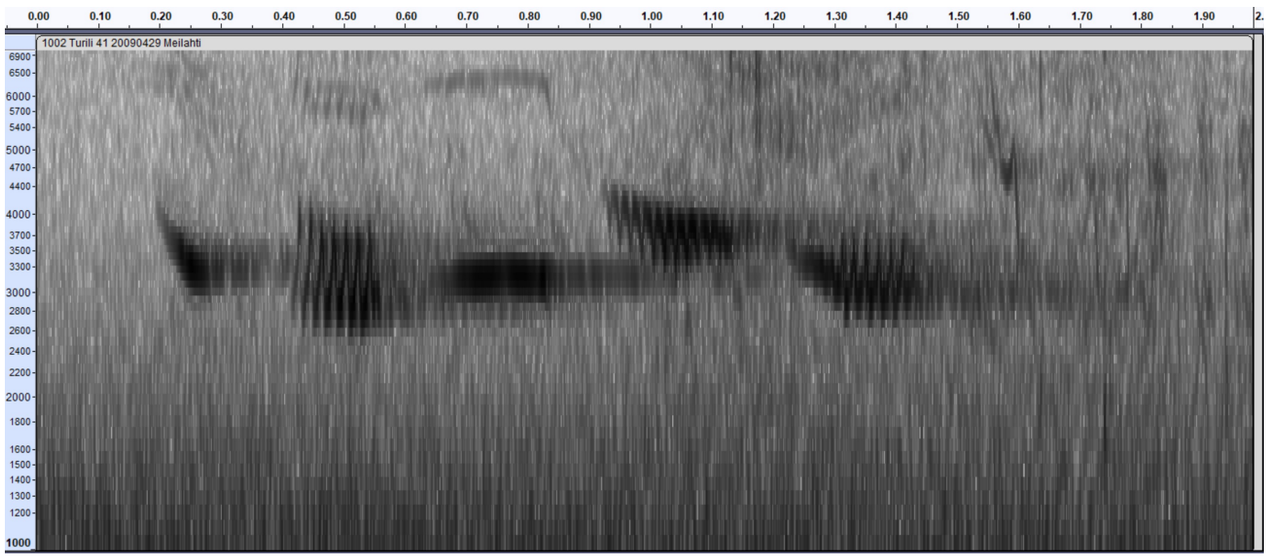



Figure 4. The KEPUE dialect song. The first note here is a prenote, which in this song type is strongly descending. The first main note is strongly modulated, followed by a characteristic pair of one straight clear note and a higher, strongly ascending modulated note. Followed by a similar but lower note.

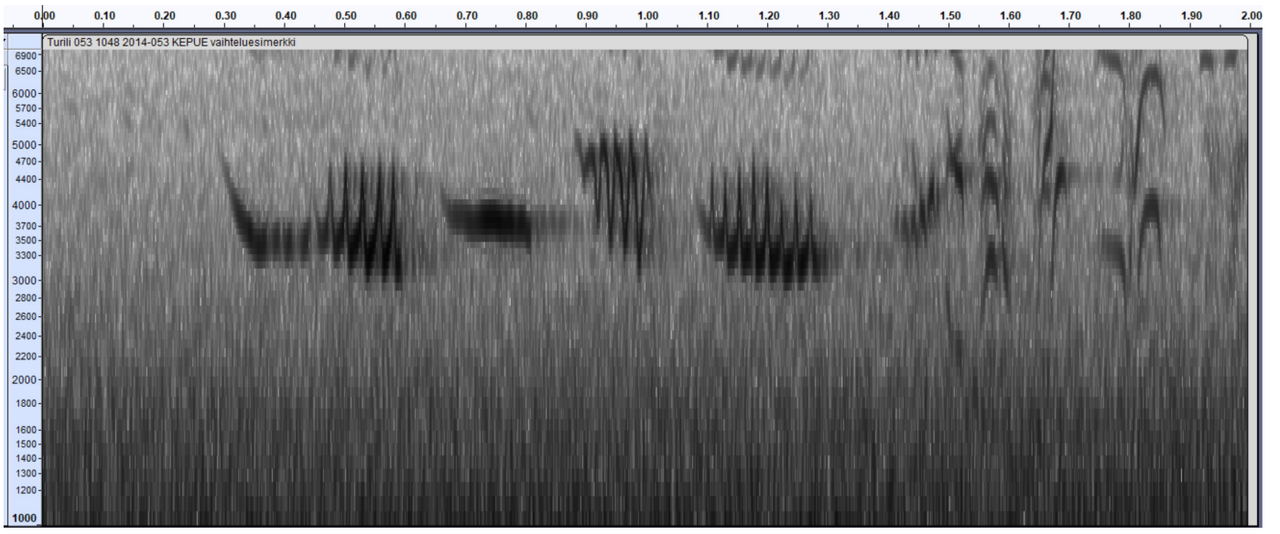



Figure 5. Dialect KEPUE, an example of normal variation. The prenote is strong and the third main note is clearly shorter than the average, but otherwise typical. Strong twittering after the fourth main note.

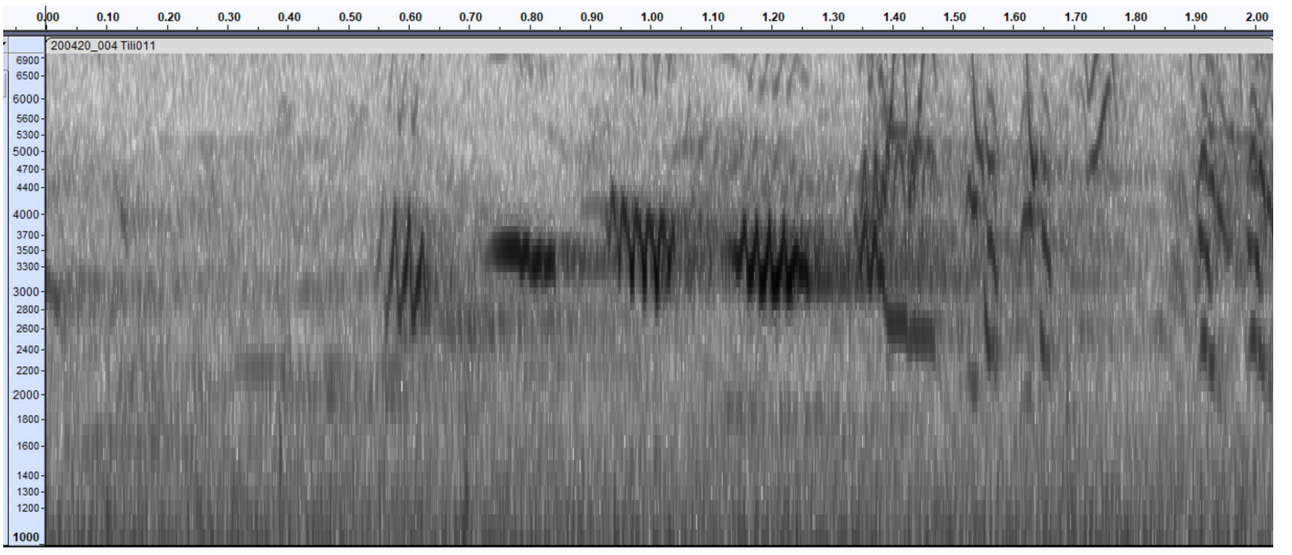


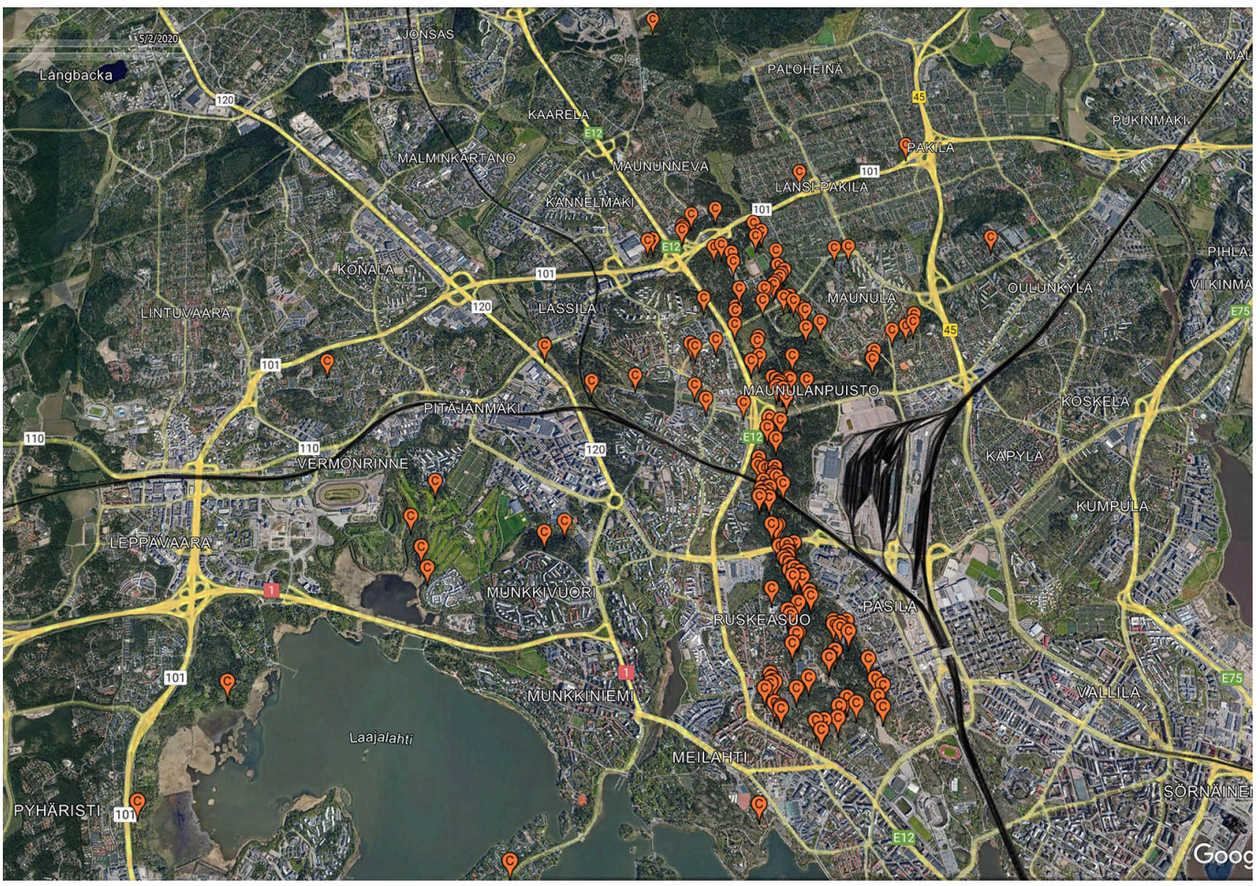

Figure 6. Dialect KEPUE, variation. Without prenotes. The first note is short. To human ears this does not sound very different compared to the previous ones, but when measuring the length of notes, the difference is significant. This kind of individual variation makes it more difficult to find any temporal or geographical trends.

notes. The first note is often short and occasionally challenging to discern, followed by a longer descending note, and culminating in an even longer stressed note that transitions from descending to ascending. The ascending segment at the end is highly characteristic and contributes to the pronounced impression of emphasis. Additionally, the gradual elongation of the notes throughout the strophe is easily perceivable.

On occasion, there may be additional notes at the beginning of the strophe. The dialect remains identifiable due to the distinctive long final note that distinguishes it from other types.

## Karakallio (KAKA)

The coverage of the KAKA dialect area is reasonably comprehensive, although the northern part is likely situated outside the study area. In total, 97 recordings were collected.



Map 4. Distribution of dialect KEPUE, all years.

The dialect, for the most part, displays consistency and a well-defined structure. However, it bears resemblance to the neighbouring MAKA dialect. It conveys a sawing impression with alternating longer and lower-pitched notes alongside shorter and higher-pitched ones. These note pairs typically occur in at least two sets, followed by a longer final note, resulting in a typical arrangement of five notes: three long and two short. The overall shape of the note pairs remains consistent, but individual notes become more strongly modulated after the initial pair. Additionally, on occasion, a very short prenote can be detected. Other variations within this dialect include instances of one or three note pairs instead of the usual two, resulting in three, four, or seven notes in total, excluding the prenote.

## Malminkartano (MAKA)

The northern portion of the MAKA dialect's distribution is likely situated outside the study area. A total of 39 recordings were collected to capture this dialect.

The MAKA dialect bears some resemblance to the neighbouring KAKA dialect, as it also features a sawing pattern characterised by alternating shorter, higher-pitched notes and longer, lower-pitched notes. However, in the case of MAKA, the longer notes exhibit a strong descending pattern, including the final note, which imparts a more mournful quality. Typically, there are two or three sets of these shorter and longer note pairs. At the beginning of the strophe, there may be an additional thick and short note, while at the end, there might be an extra long note. This additional long note is pitched similarly to the higher and shorter notes.

## Konala (KONAL)

Defining the KONAL dialect in relation to the adjacent HAGA proves somewhat difficult. These two dialects were separated as independent entities because, as a combined dialect, they would exhibit much greater variation than the other dialects.

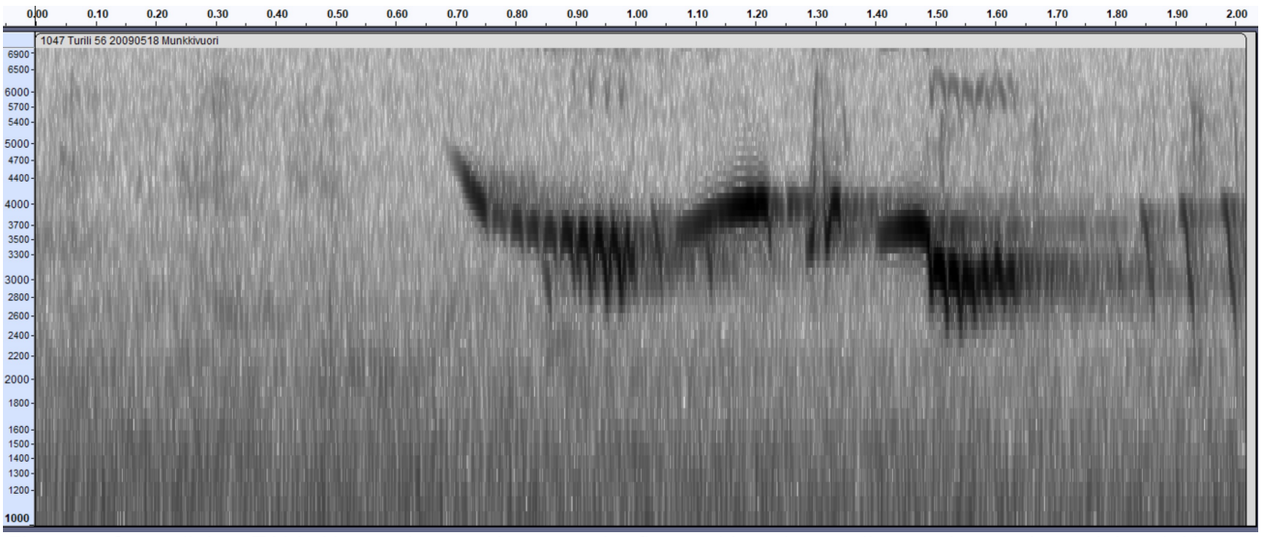
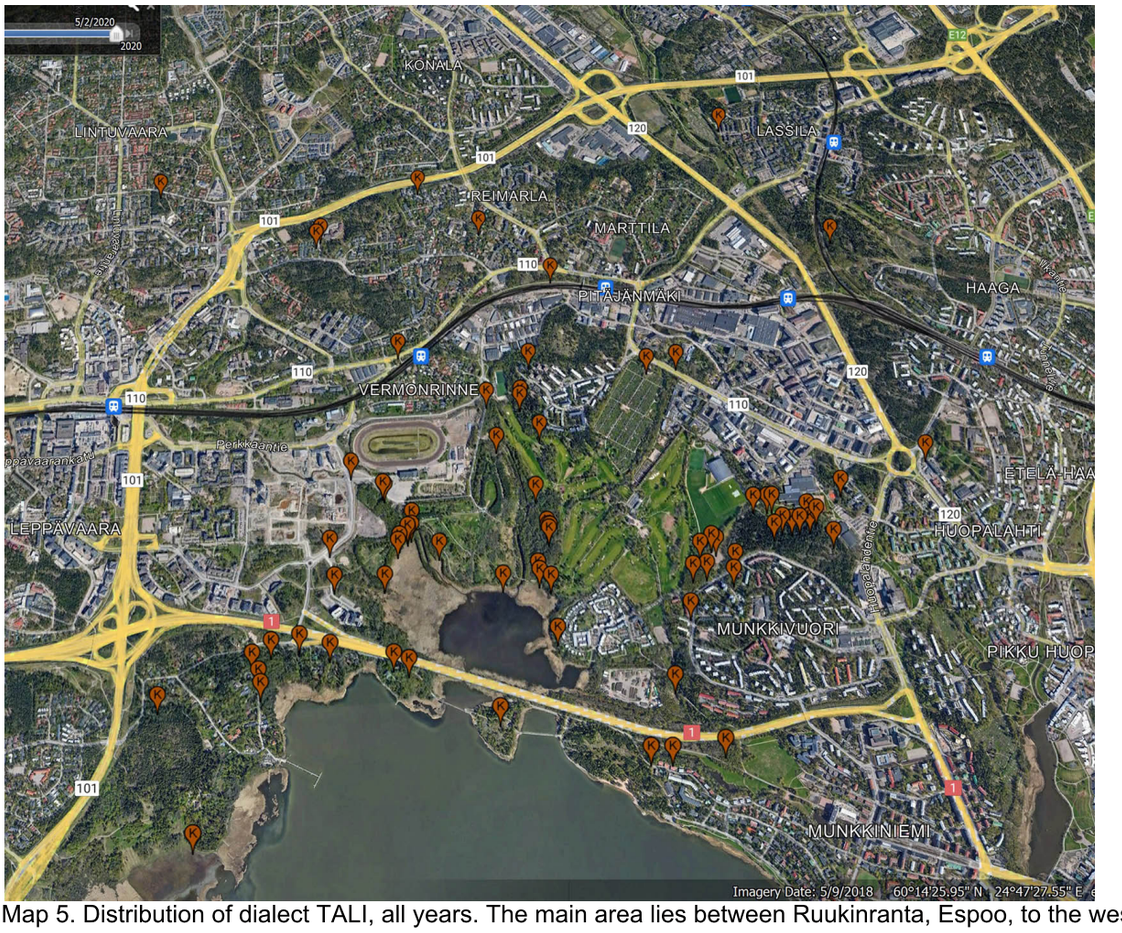



Figure 7. Song dialect TALI. Always three main notes, the first and last descending, and strongly modulated. Never any prenotes. There may be an inserted middle note between the second and third main note, as in the spectrogram above. This note has a clearly different form compared to the main notes and in this article is considered as a part of the final chatter. TALI is the only dialect described in this study where there is this kind of variation.




Map 5. Distribution of dialect TALI, all years. The main area lies between Ruukinranta, Espoo, to the west and Tali, Helsinki to the east, and includes a lot of good habitat for the species. This dialect is separated from the others by less good habitat, with the only exception being towards the south-west along the shore of Laajalahti bay.

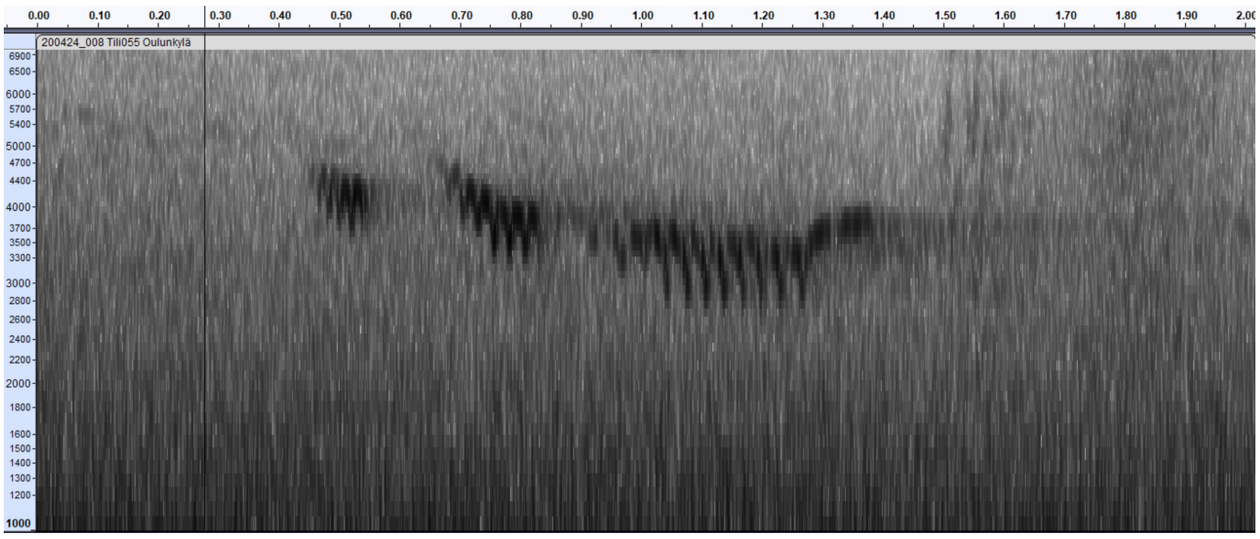
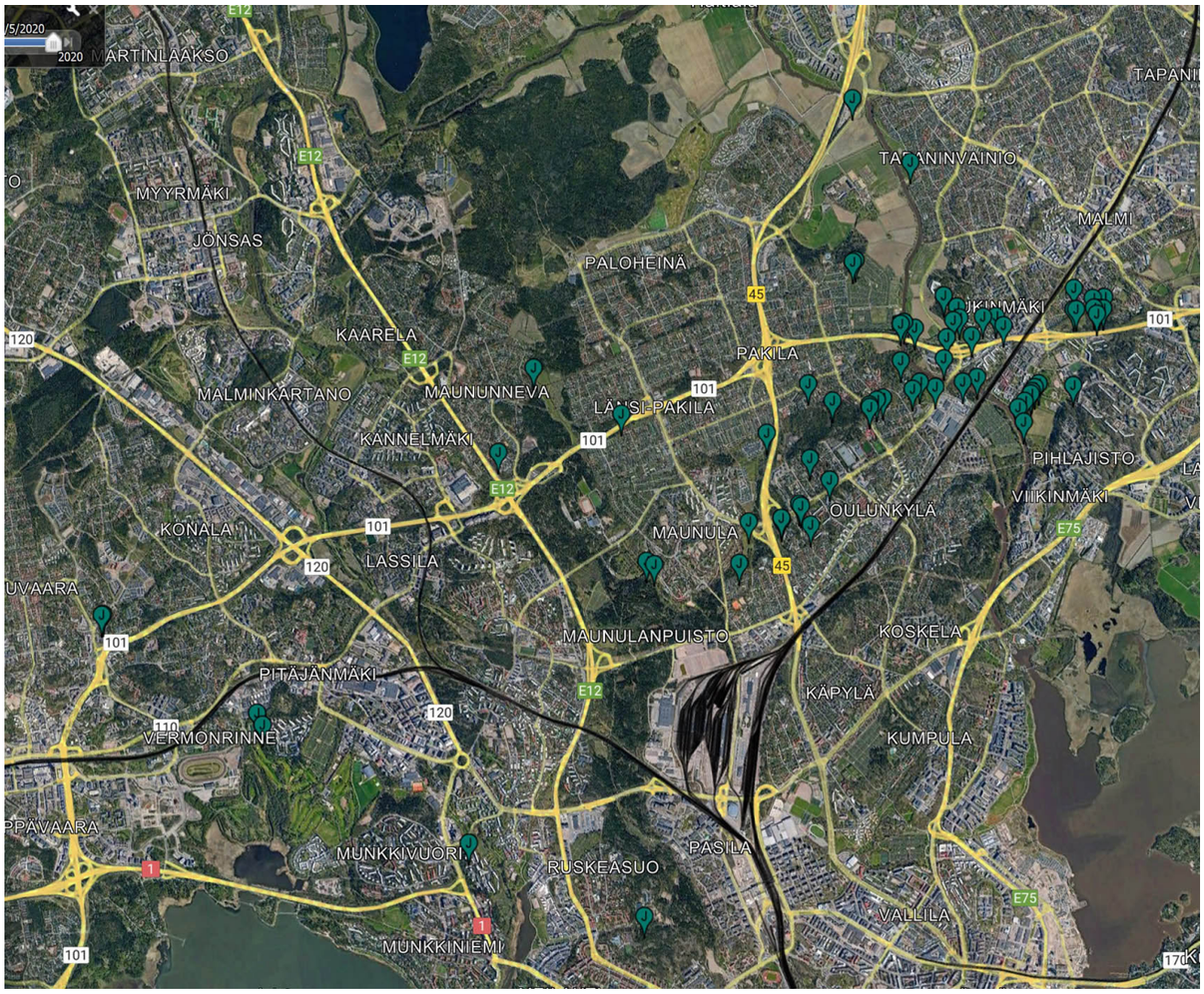



Figure 8. Dialect type OUKY. Most commonly three strongly modulated descending notes which grow longer. The last note has an almost straight tail pointing upwards.




Map 6. Distribution of the OUKY dialect. The distribution continues towards the southeast to the outside of the study area, and probably also towards the north to Malmi. Inside the study area, it is replaced abruptly by KEPUE in the south-west, south of Maunula.

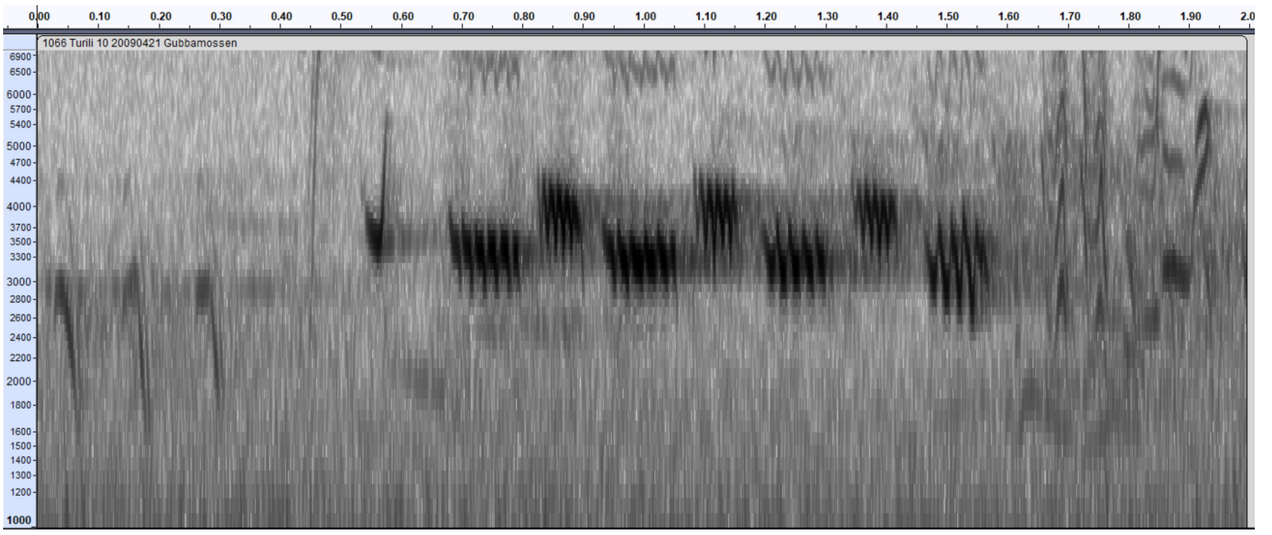
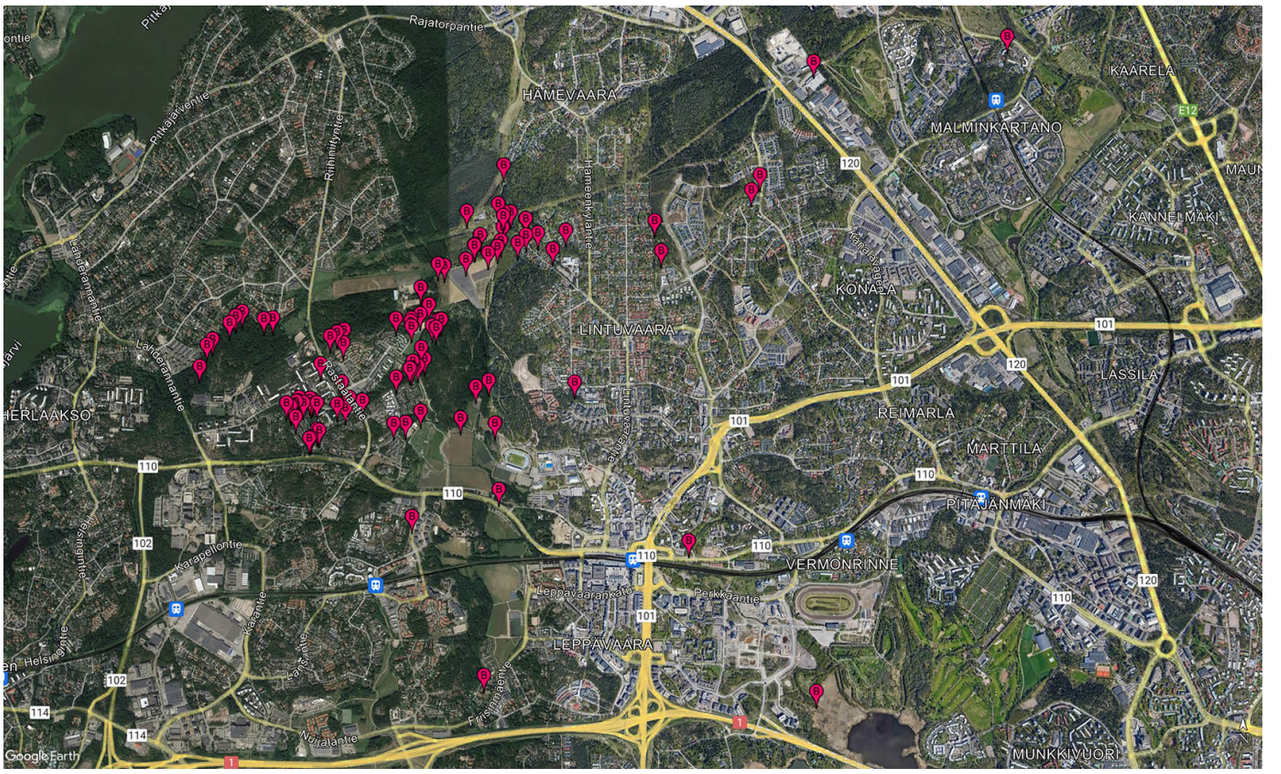



Figure 9. Song dialect KAKA. The prenotes of this song dialect are V-shaped with a high right fork. Alternating buzzing notes with the higher ones slightly shorter. The last note is lower and slightly different.




Map 7. Distribution of dialect KAKA (B). In the west there is a border with very different sounding VIHER. The less good habitat in Lintuvaara separates KAKA in the east from the area of the somewhat similar sounding MAKA. The distribution of this dialect includes a lot of good breeding habitat for the species.

The KONAL dialect is likely entirely encompassed within the study area, occupying a relatively small region of just 2.7 km$^2$. A total of 43 recordings were collected, with nine of them obtained from locations outside the core area. It is probable that in any given year, fewer than ten males use this dialect.

There are four rapid notes. Initially, there is a slightly modulated downward note, often accompanied by a higher layer. This is followed by an unmodulated descending note of higher pitch, succeeded by a lower and longer modulated descending note. The strophe concludes with a higher modulated straight note. The prolonged, high, and straight final note is particularly distinctive. There is some variation observed in the first note, which occasionally splits in the middle, thereby influencing the vocal impression. Only once was the first note split to the extent that it needed to be counted as two separate notes. Apart from this variation, no prenotes were detected. Additionally, there was a single instance where the last note split, with the latter portion being lower. This divergence significantly impacted the overall impression perceived by the human ear.

The four-noted variation of HAGA appears visually and audibly similar to KONAL. Nevertheless, the differentiation between these two dialects is based on the characteristics of the first note. HAGA features a curved up-down note, while the KONAL note tends to be more or less straight, often accompanied by a second layer on top.

## Haaga (HAGA)

The HAGA dialect is probably completely included in the study area, occupying a relatively small distribution area of just 3 km$^2$. A total of 45 recordings were obtained, with six recordings collected from locations outside this area. It is possible that in any given year, fewer than ten males utilise this dialect.

The HAGA dialect consists of three distinct notes. The first note is characterised by strong modulation and a curved up-down pattern. This is followed by a very short unmodulated and descending note, and the strophe concludes with the longest note. The final note starts with an ascending segment, transitions into a descending segment, and is only  modulated in the middle.

Variations were observed with added notes at the end of the strophe. The characteristics of the first note play a crucial role in shaping the overall impression of the song, and makes the strophe sound similar to either the HAGA or KONAL type, but the four-noted HAGA type sounds somewhat like a combination of the two dialects, which it very well may originally be.

## Laajalahti (LAAJA)

The majority of the LAAJA dialect's distribution likely extends beyond the boundaries of the study area. A total of 24 recordings were obtained for this dialect.

The LAAJA dialect stands out prominently in comparison to the other dialects examined. It is characterised by a rapid and gradual descent, featuring a series of short, curved notes arranged in subgroups of three. With approximately five subgroups, the LAAJA dialect can encompass up to 21 distinct notes in total.

## Viherlaakso (VIHER)

VIHER is the westernmost dialect, with its primary distribution area extending beyond the boundaries of the study area. Only 16 recordings were obtained for this particular dialect.

The VIHER dialect exhibits some variations in its main notes, contributing to its less well-defined nature, which is further emphasized by the limited amount of available data. Typically, the strophes consist of two or three intricate notes closely following the initial note pattern, which is characterised by a sequence of downward-upward-downward movements. Additionally, the second note tends to be a downward-straight pattern. In some instances, a short prenote may also be present.

Throughout the study period, the VIHER dialect appeared to undergo certain developments, with longer strophes consisting of 1+3 notes transitioning to strophes containing 0/1+2 notes. These changes suggest a potential evolution or variation within the dialect over time. Unfortunately, the sample size is too small for further analysis.

## Meilahti (MELA)

MELA is a relatively small dialect that was not

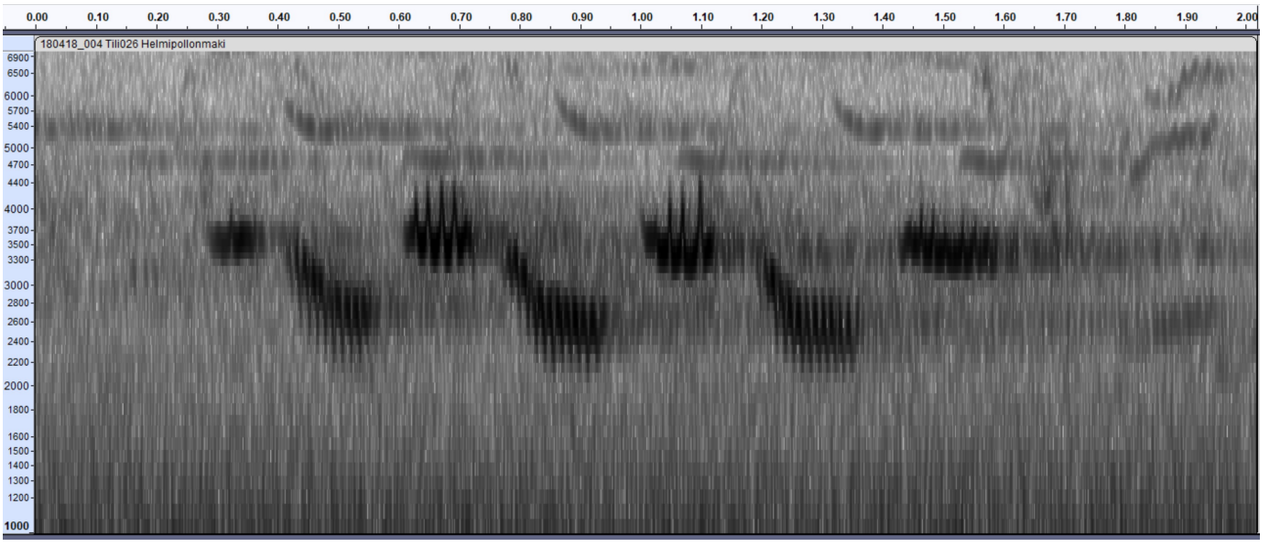
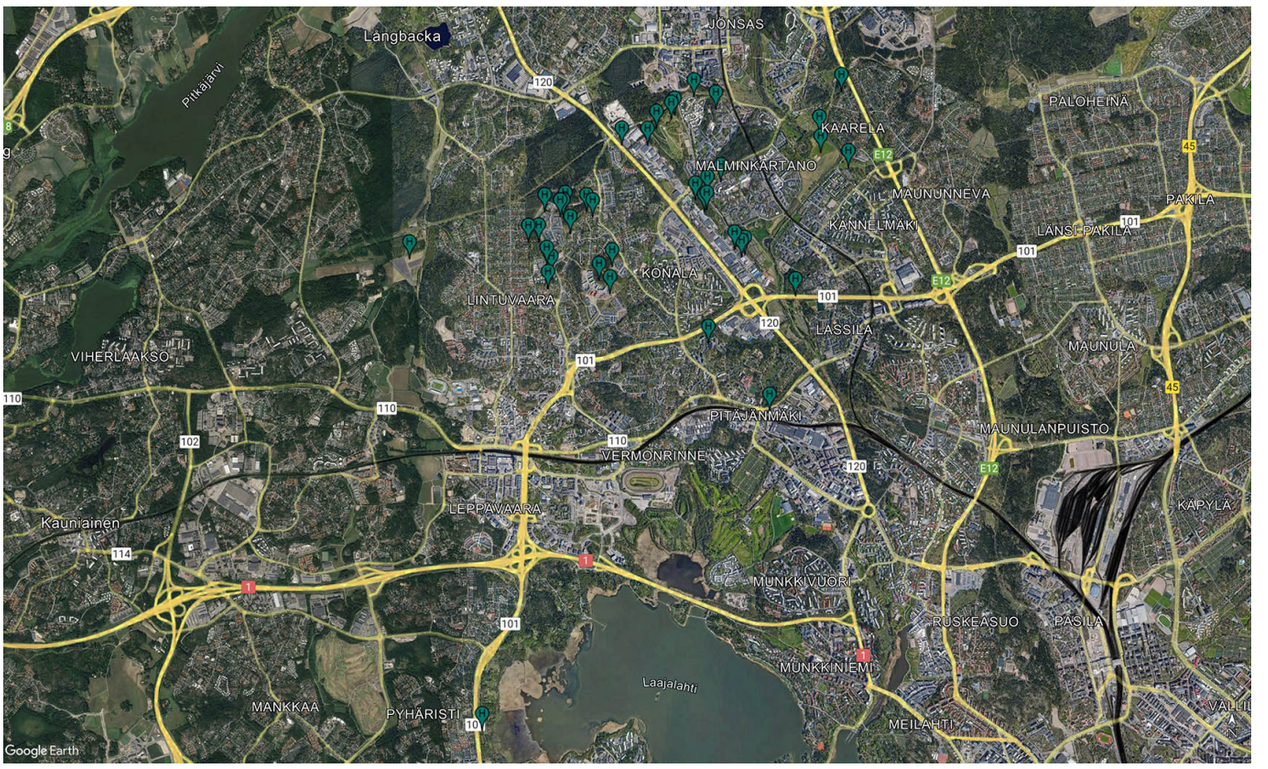



Figure 10. Song dialect MAKA. Resembles KAKA with alternating longer, lower, and shorter higher notes, and in this case one prenote. The difference is that the long notes are strongly descending, making the song sound mournful to the human ear.




Map 8. Song dialect MAKA (H) distribution. The area is rather large, and may continue northwards outside of the study area, but the good habitat is patchy and the number of individuals is not that high.

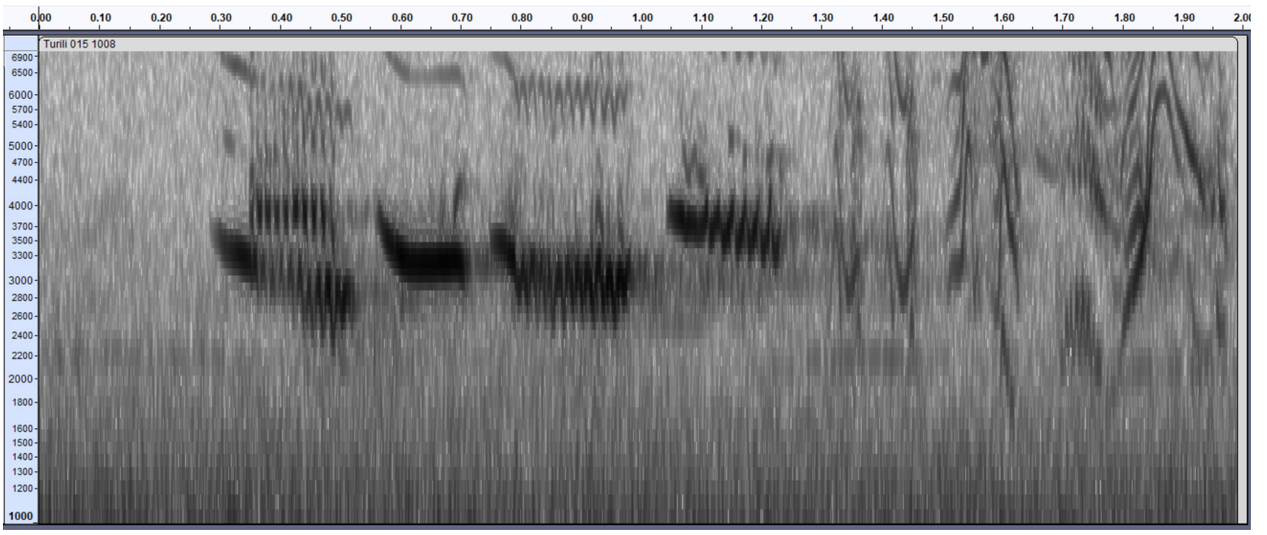
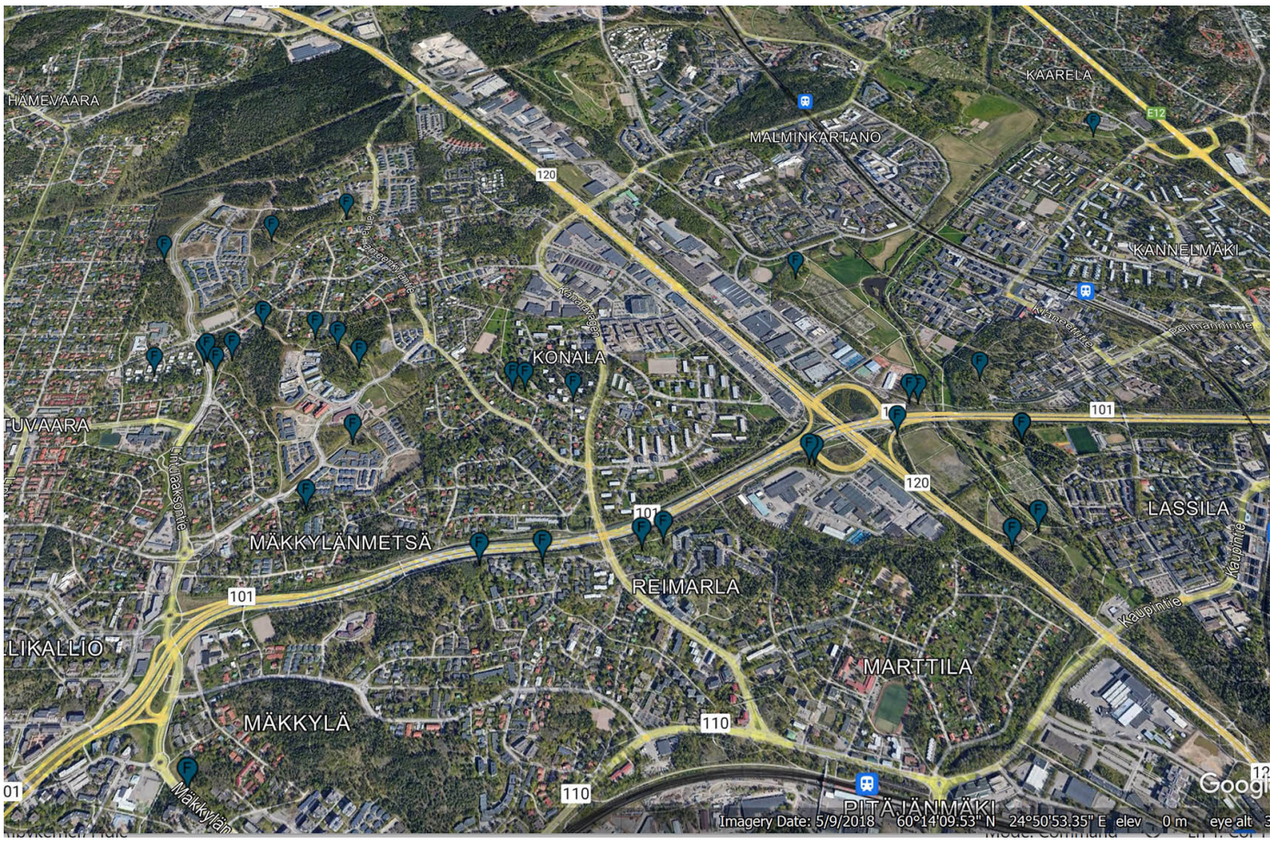



Figure 11. Song dialect KONAL. Four notes with the first often having a second layer just on top. The second note is shorter, strong, unmodulated, and downward inflected, and the fourth main note is longer and comparatively straight.




Map 9. Song dialect KONAL (F) distribution.

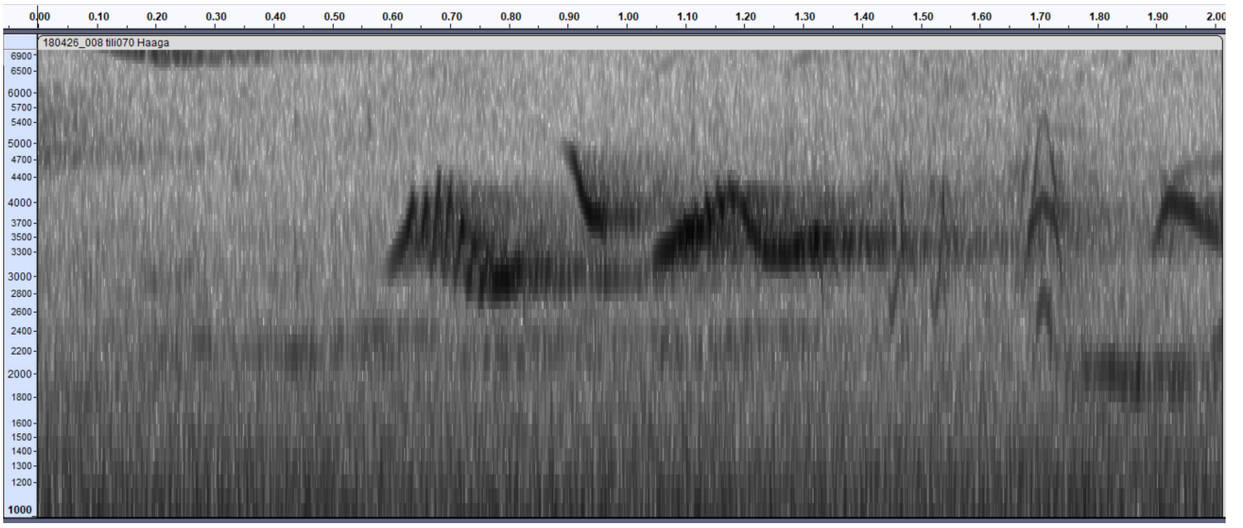
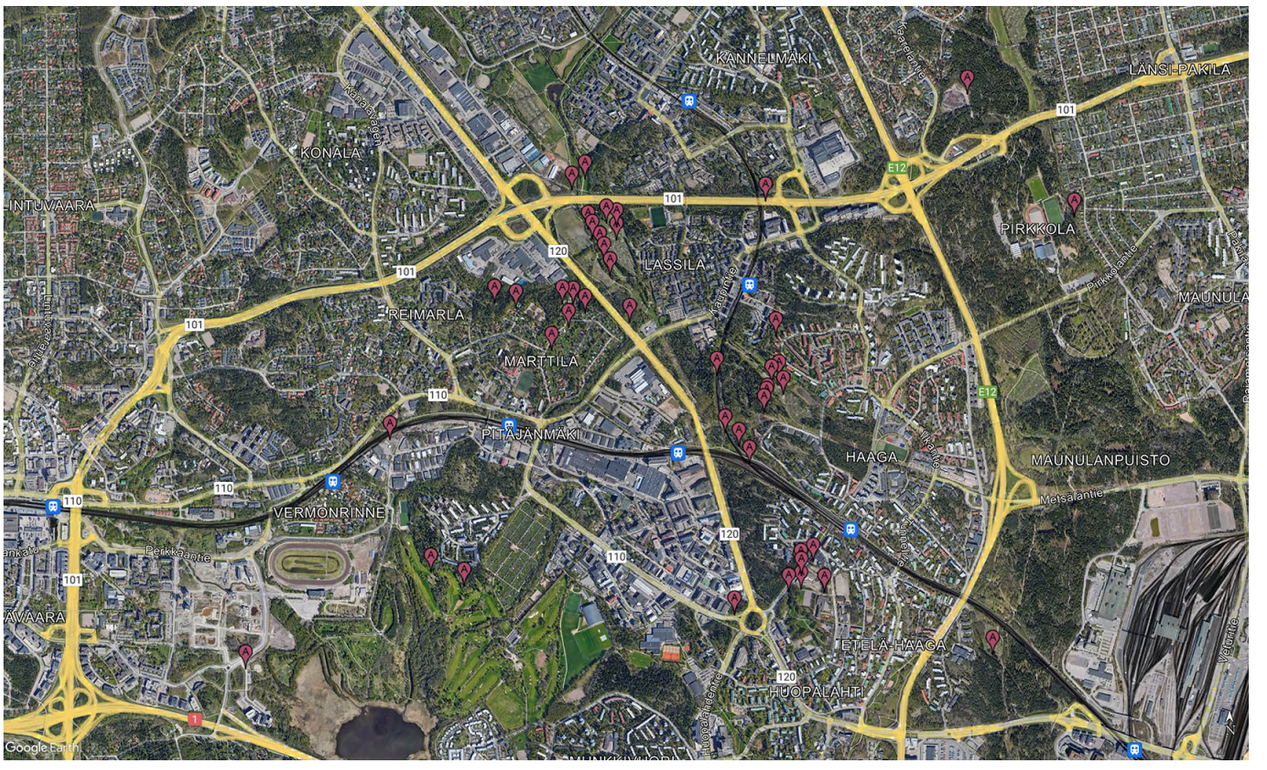



Figure 12. Song dialect HAGA. Typical song.




Map 10. Song dialect HAGA (A) distribution lies almost wholly to the south ring road 1. This road marks the border between that and KONAL the same way as between the dialects KEPUE and KEPUP about just one kilometre to the east, but is much less striking because of the sparse population of birds just there. The area has some good habitat but is patchy.

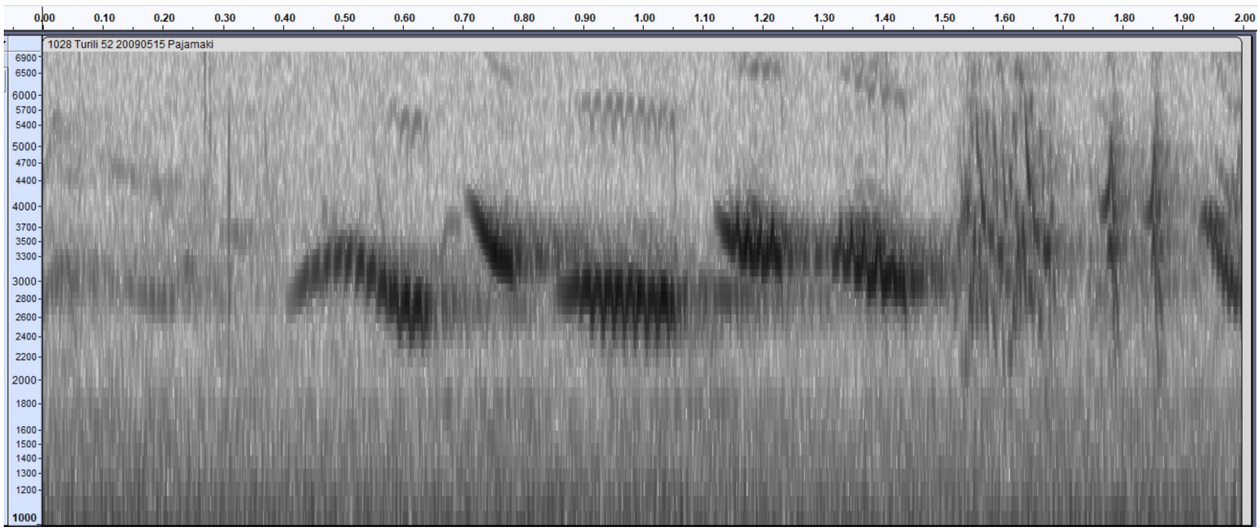



Figure 13. Song dialect HAGA. Five notes – two additional notes at the end. These notes make the song sound quite similar to KONAL. Also, the third note in this recording is different from the typical third HAGA note.

recorded after 2013. It is situated adjacent to KEPUE, primarily towards the southwest, with a portion of its distribution potentially extending beyond the study area. Only 15 recordings of this dialect were obtained, and some of these recordings may represent repeated observations of the same individual on different days.

The MELA dialect consistently consists of three notes, similar to the TALI dialect, and shares several similarities with TALI overall. However, MELA distinguishes itself by featuring a modulated second note, with certain parts appearing almost separated, and lacking a straight segment at the beginning of the third note.

## Unique songs

A total of 89 songs (10% of the recordings) could not be classified into any of the established dialect types. These songs exhibited significant variability and were dispersed throughout the entire study area. Based on Map 1, it appears that these unclassified songs were more likely to occur in regions with patchy species distribution, rather than in the core areas dominated by the well-defined KAKA, KEPUE, KEPUP, and OUKY dialects.

Some of these unique strophes exhibited notable deviations from the normal dialects observed in the area. For instance, there were instances of fast-rising trills, a common type of Redwing song found in other regions (the only fast trill in the studied area was the descending LAAJA dialect). Additionally, certain songs seemed to combine elements from multiple established dialects, although this assessment is subjective and could potentially be coincidental.

It is worth noting that some Redwing singers belonging to known dialects were found in "wrong" areas, where the majority of Redwings were using a different dialect. This suggests that some of these unique singers might actually belong to neighbouring dialects located outside the study area. However, no definitive cases were identified, and no dialects without a distinct core area were discovered during the study.

## Dialect distributions

Two distinctive features characterise these song dialects. Firstly, they are confined to remarkably small distribution areas, typically spanning only 3-5 $km^2$ when fully encompassed within a study area. For instance, Central Park S (KEPUE) represented one of the primary dialects examined in this study, yet the number of individuals utilising it in any given year remained in the low dozens. However, it is more probable for these miniature dialects to be entirely encompassed within a study area, so the average may be larger. Bjerke & Bjerke (1981) discovered considerably larger dialect areas. Despite their limited range, dialects display remarkable consistency both in their structure and areal distribution across different years. Evidently, a significant factor contributing to this

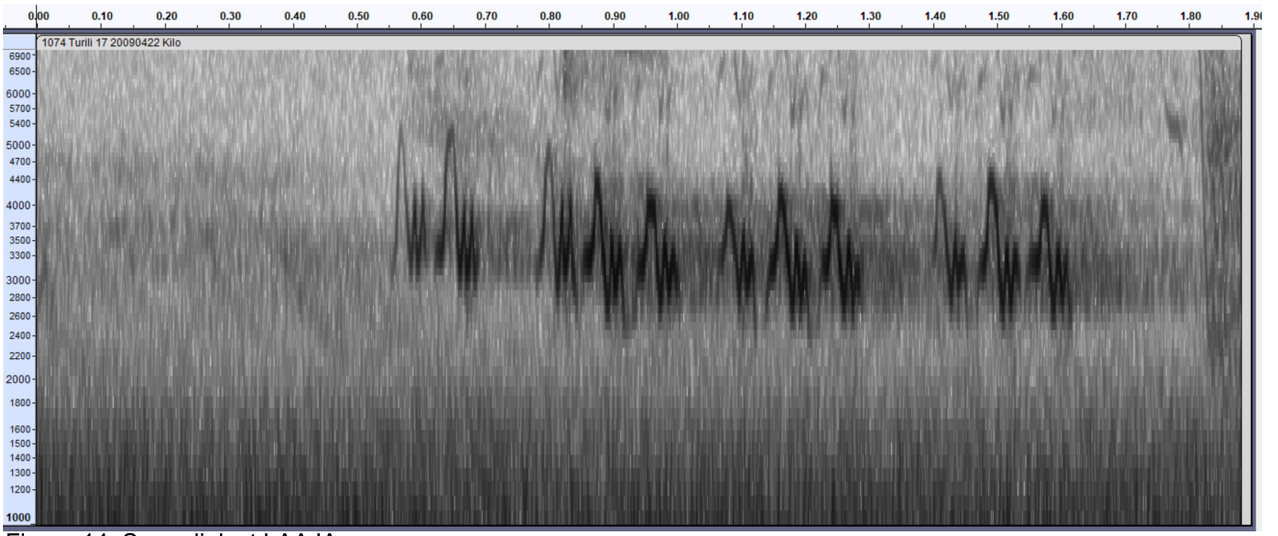
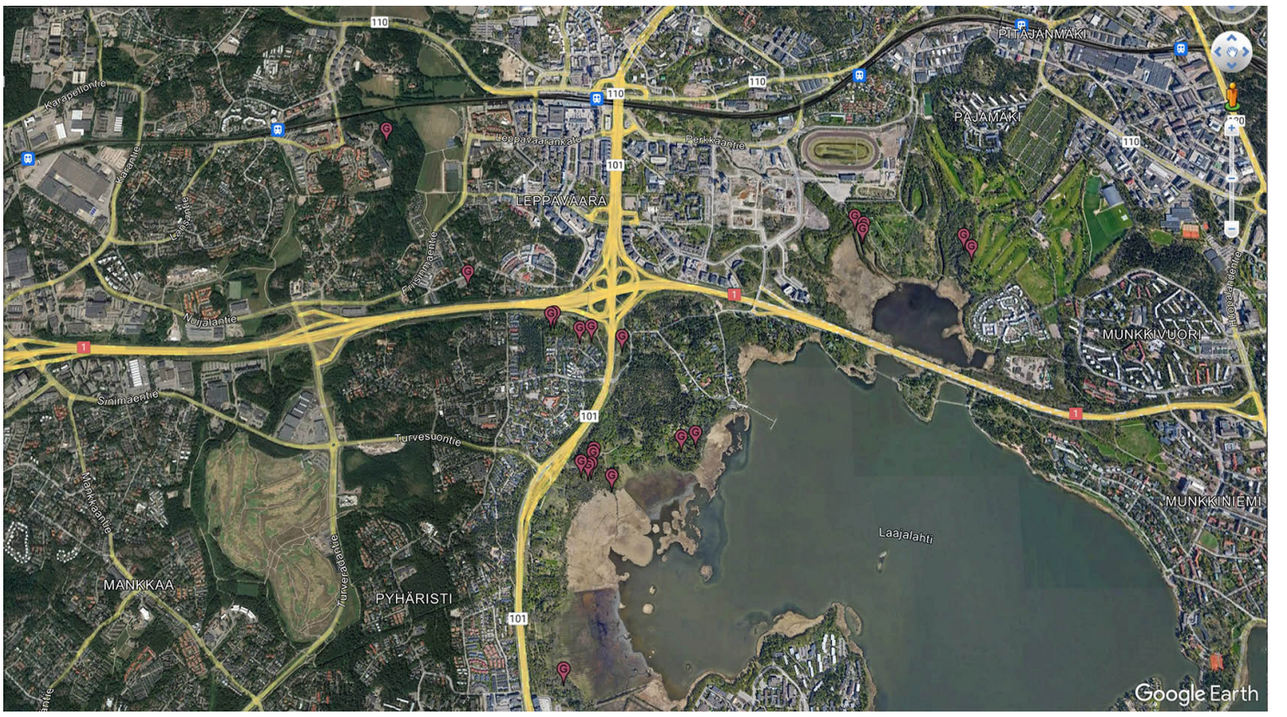



Figure 14. Song dialect LAAJA.




Map 11. Song dialect LAAJA (G) distribution. Continues more towards the southwest to the outside of the study area. The border with TALI towards the northeast is in a small corridor of good habitat.

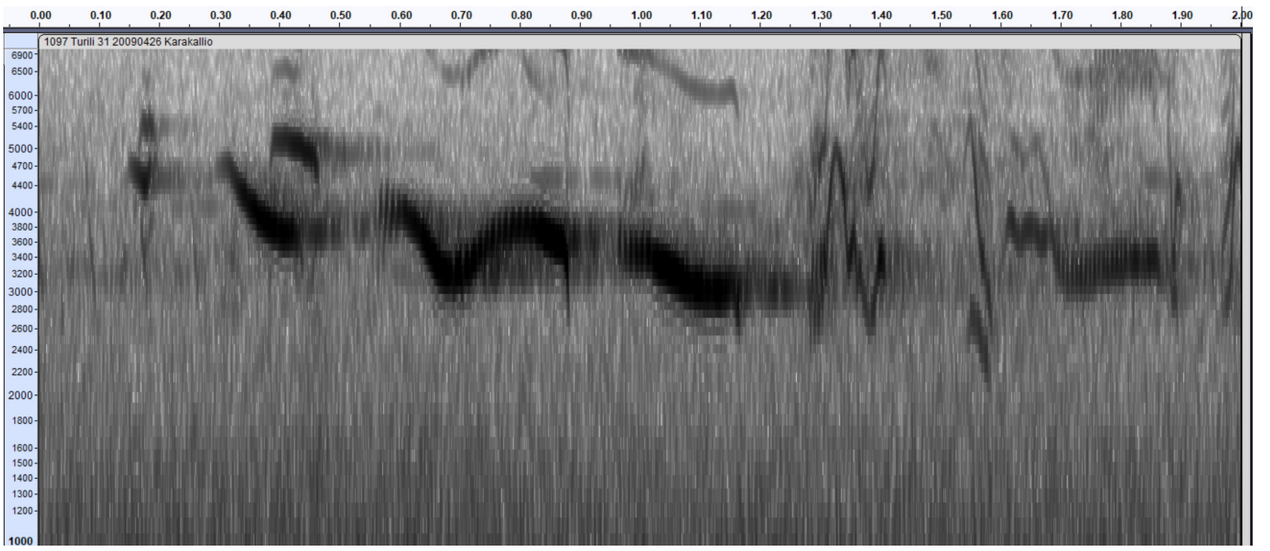



Figure 15. Song dialect VIHER.


Map 12. Song dialect VIHER (L) distribution. It continues towards the west, outside of the study area.

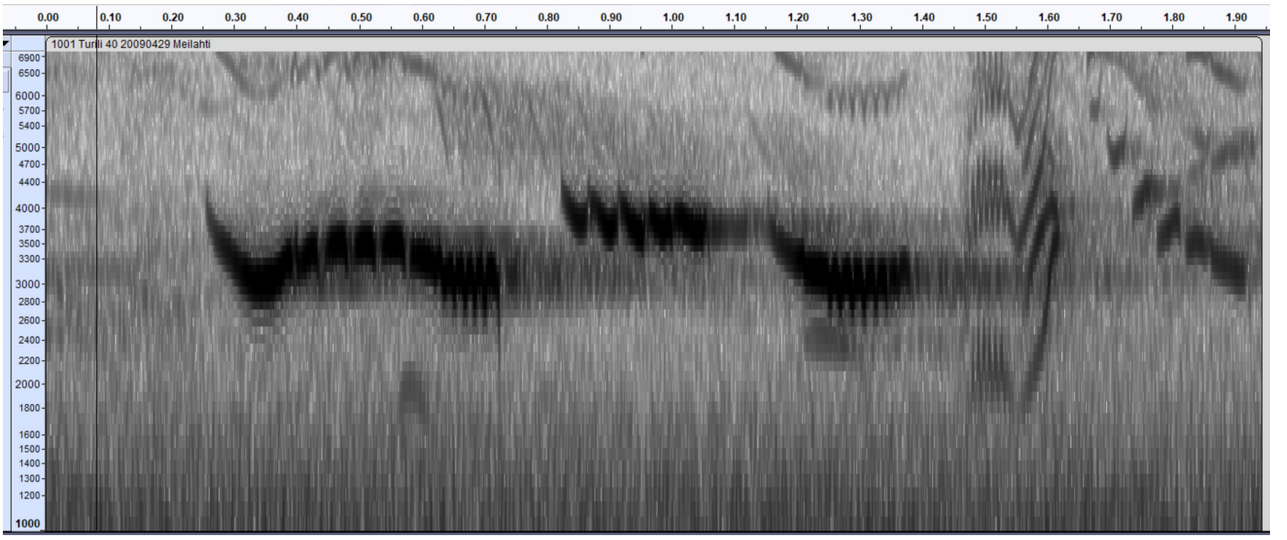



Figure 16. Song dialect MELA


Map 13. Dialect MELA (I) distribution. The few obtained recordings are from the southernmost tip of Central Park. There are small patches of suitable habitat towards the southwest outside the study area, but otherwise towards the south and southeast the urban areas are tightly built.

consistency is the presence of returning males that employ the same song. Since not all males can survive throughout the winter, there must be some immigrants who adopt the songs of the preceding residents as part of their cultural repertoire.

For the formation and persistence of song dialects, it is crucial that neighbouring males engage in song matching. Without the ability to hear each other's songs, there can be no matching, implying that some form of contact is necessary between males, at least part of the time. However, the boundaries of dialect areas are not solely determined by geographical factors. Frequently, neighbouring males can hear each other across dialect borders, raising the question of why they choose to use one dialect over another. An intriguing example of a dialect boundary is found at the Helsinki ring road 1, which cuts through Central Park. This road, one of the busiest in Finland, generates significant anthropogenic noise. Despite similar habitats on both sides, it would be tempting to attribute the presence of a dialect boundary to the traffic noise. However, this is not the case for many other instances in the study area. Busy roads leading from Helsinki to Vihti, Tampere, and Tuusula do not create clear boundaries, although the species is not a common breeder in those areas. The KEPUP dialect in northern Central Park is bordered to the west by the Tampere highway, coinciding with less favorable habitats beyond Central Park. Interestingly, Redwings do not appear to be greatly affected by noise, often singing happily for hours near busy morning traffic.

Apart from noise considerations, areas with fewer birds contribute to the separation of different dialects, particularly in densely built-up regions such as Lintuvaara, Leppävaara, Konala, Pitäjänmäki, Haaga, and Kannelmäki. Relatively few dialect borders intersect with suitable habitats (e.g., VIHER-KAKA, TALI-LAAJA, KEPUE-KEPUP), and these boundaries consistently persisted throughout the study years.

There is a lot of variation inside any dialect – in fact, songs of every individual are somewhat different if studied closely enough, and the adjacent strophes of a single individual vary also. Still, the dialects themselves remain remarkably consistent and easily distinguishable. Adjacent dialects often display significant differences, as seen in the contrast between LAAJA and TALI, or KEPUE and KEPUP. However, geographical variations exist within KEPUP, and two pairs of adjacent dialects, KAKA vs. MAKA and HAGA vs. KONAL, bear such resemblance that it may not be coincidental. A few intermediate individuals were recorded between these latter pairs, although their numbers were limited.

## Song switchers

Among the recorded individuals, 41 individuals (4.6%) were found to use two distinct song types. Because of the song recordings were not long, it is possible that some cases of double dialect singers were missed. However, in the known instances, both song types were relatively frequent and easily identifiable, even within shorter recordings. In many cases, one song type exhibited clear dominance, while in others, the dialects were more evenly used.

Out of the song switchers, 20 individuals (49%) displayed at least one strophe of a unique song type, and three birds had both types unique. This percentage is significantly higher than the proportion of unique singers within the entire population.

Of the 21 cases where both dialect types were known, 19 individuals utilised adjacent dialects. In the two cases where non-adjacent dialects were observed, one combination involved TALI-KONAL, and the other featured KEPUP-TALI. Among the combinations of adjacent dialects, the most common pairing was HAGA-TALI, recorded five times. Remarkably, the HAGA dialect frequently appeared in combinations, occurring 16 times among the dialect switchers, which is notable considering its small size.

## Temporal changes in dialect distribution

In previous studies (Bjerke & Bjerke 1981 and Espmark et al. 1989), the observed dialects exhibited remarkable consistency across different years, and the same is true here. Minimal changes were noted, indicating a high level of stability. The only notable exception was the absence of the MELA dialect after 2013. Even prior to its disappearance, the MELA dialect held a marginal presence, and it is plausible that it continued to exist outside the scope of the study area during subsequent years.

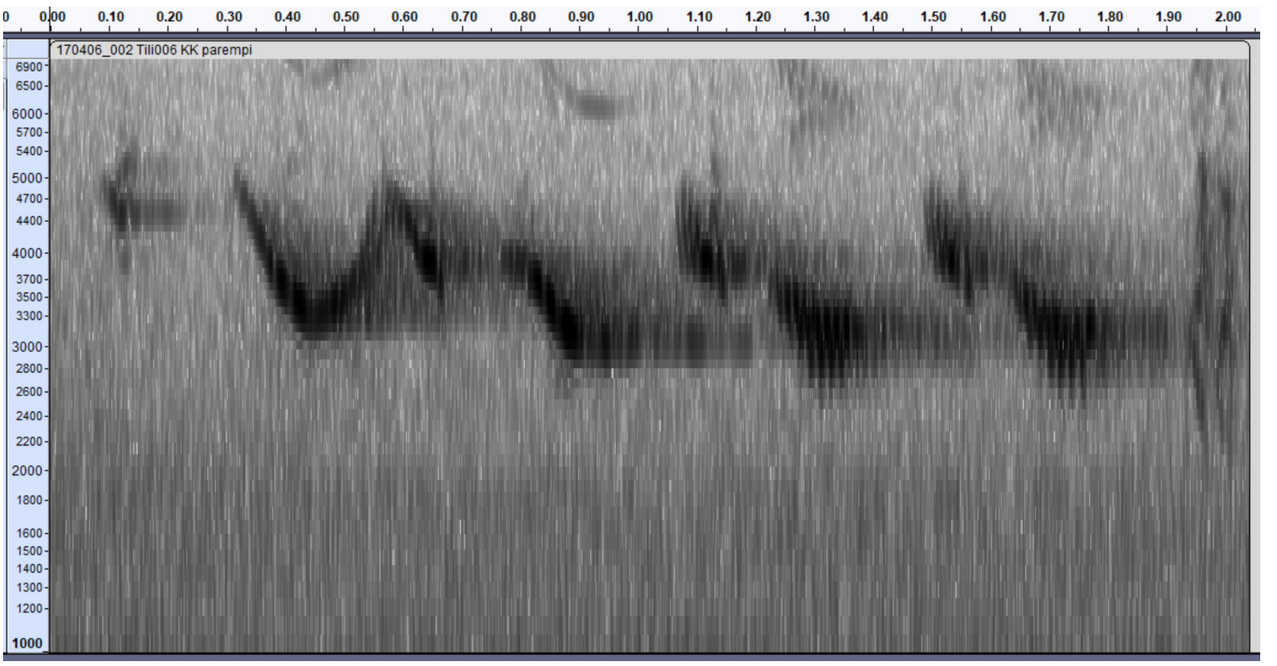



Figure 17. A rare case of an apparently mixed strophe. The prenote and two main notes following it resemble VIHER and the last four notes KAKA. These two are adjacent dialects and this recording is from where these two meet.

## Discrimination of the songs

The songs were initially categorised into groups based on a combination of auditory analysis and examination of spectrograms, as described earlier. Subsequently, a linear discriminant analysis was conducted to determine whether the dialects could be distinguished using measurements extracted from the sound spectrograms. Linear discriminant analysis is a commonly employed statistical method that aims to find linear functions that optimally classify groups of observations. Typically, the analysis involves utilising pre-classified observations to identify the functions, which are then used to assign the most probable labels to other observations. In the following section, we explore whether the dialects can be separated using this alternative approach, distinct from the method employed for the initial identifications.

For each note, three variables were considered: length, highest frequency, and lowest frequency. Comparisons were made between corresponding notes within the strophe. Hence, when using two notes, six variables were available. Additionally, the interval between subsequent notes was taken into account. Consequently, with two notes, a total of seven variables were used, which increased to 11 with three notes and 15 with four notes.

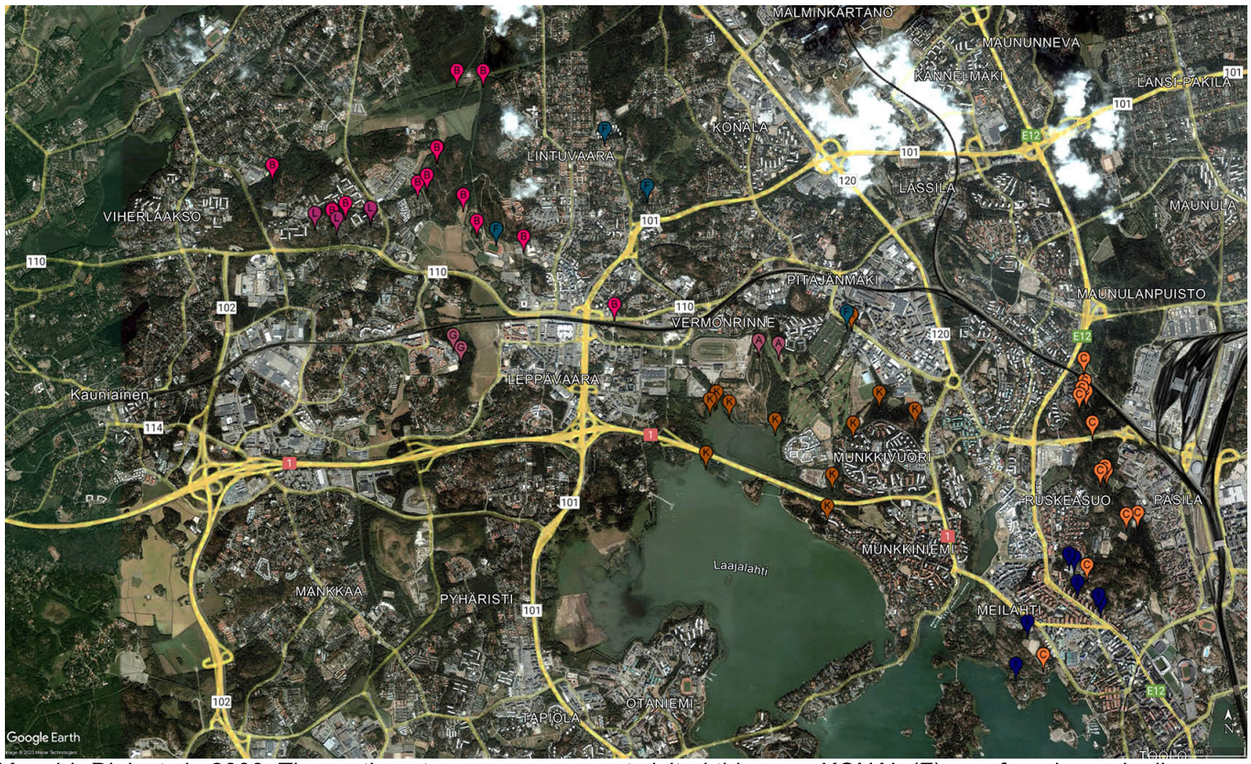
In Phase 1, focusing on two-note comparisons, the unique strophes and the marginal dialects VIHER, LAAJA, and MELA were excluded, see Figure 18.

The dialects KEPUP, OUKY, KEPUE, and TALI were distinctly separated from each other. On the other hand, KAKA, MAKA, HAGA, and KONAL exhibited a greater degree of overlap. Since all of these dialects consist of strophes with at least three notes, it is possible to proceed with incorporating additional variables for a more comprehensive analysis. See Figure 19.

When examining the dialects KAKA, MAKA, HAGA, and KONAL using three-note analyses, it becomes evident that they are distinguishable, albeit with some degree of overlap. Notably, the groups KAKA-MAKA and KONAL-HAGA exhibit distinct characteristics when compared to each other. The similarities of the songs are commented on in the dialect descriptions. The similarity is probably not coincidental, because they are adjacent distributionally.

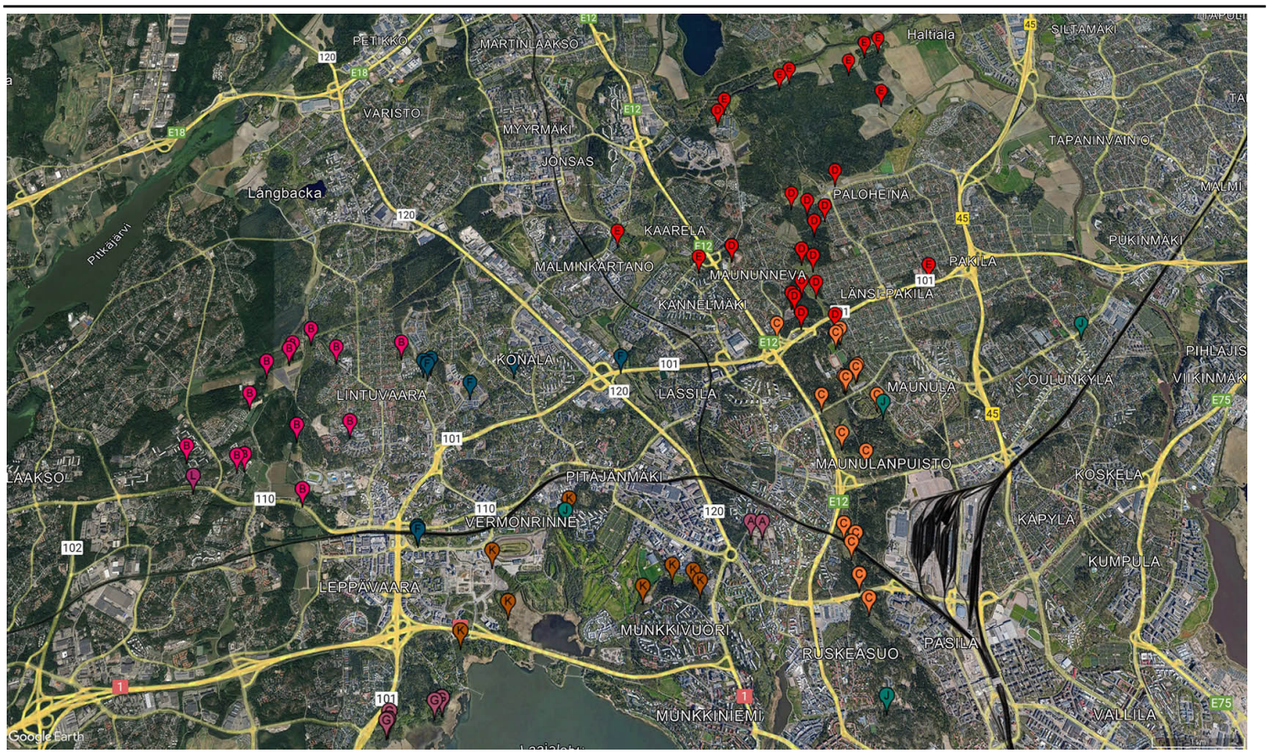
## Temporal changes in the songs

Changes in dialects and their distribution has been observed in several studies of birds in general

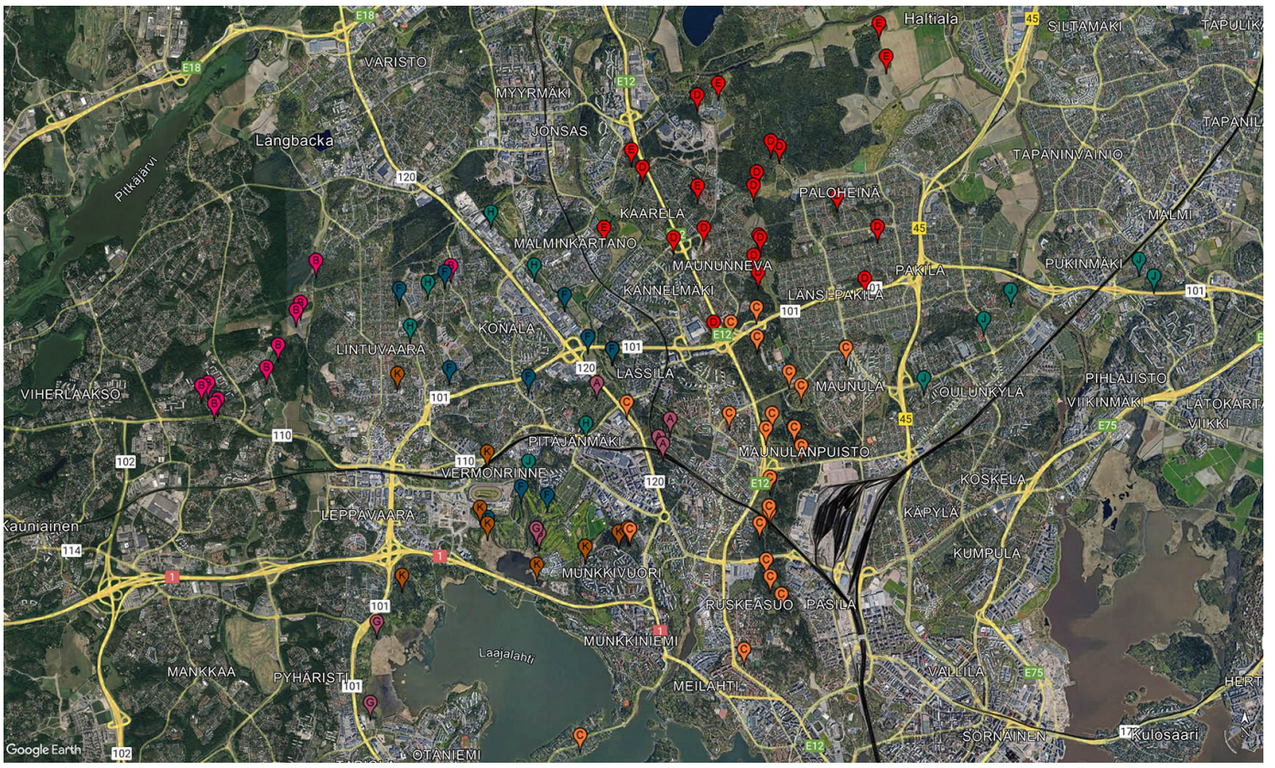



Map 14. Dialects in 2009. The northeastern areas were not visited this year. KONAL (F) was found marginally, as well as HAGA (A). VIHER (L) is already present in the same area as in the last years of the study.

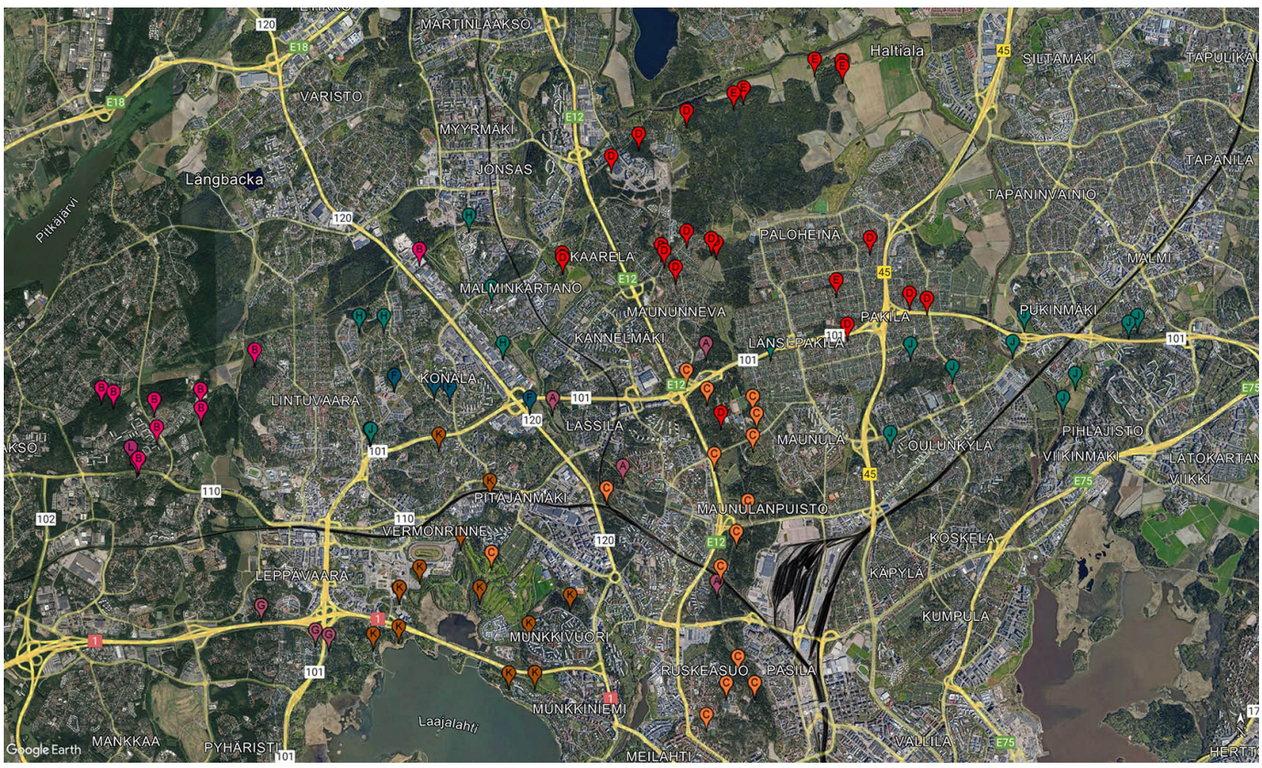

Map 15. Dialects in 2010. For The following three years only the southern core area of KEPUE (C) was visited. Only KEPUE (C) and MELA (I) were found there.



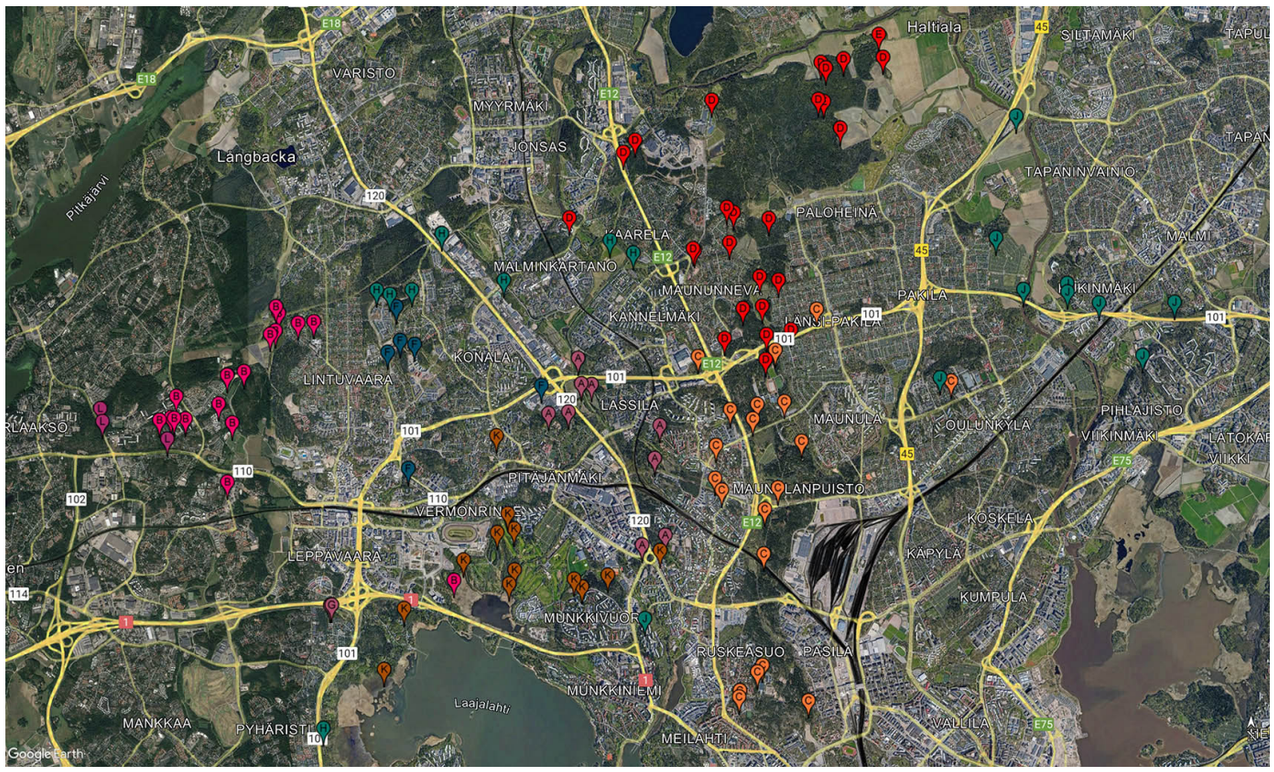

Map 16. Dialects in 2014. The northeastern areas were visited for the first time; the three-noted variant of KEPUP (D), KEPUX (E) is already present. Compared to 2009, no real changes, other than that MELA (I) has disappeared. OUKY (J) appears, but still only marginally. Also LAAJA (G) heard for the first time.



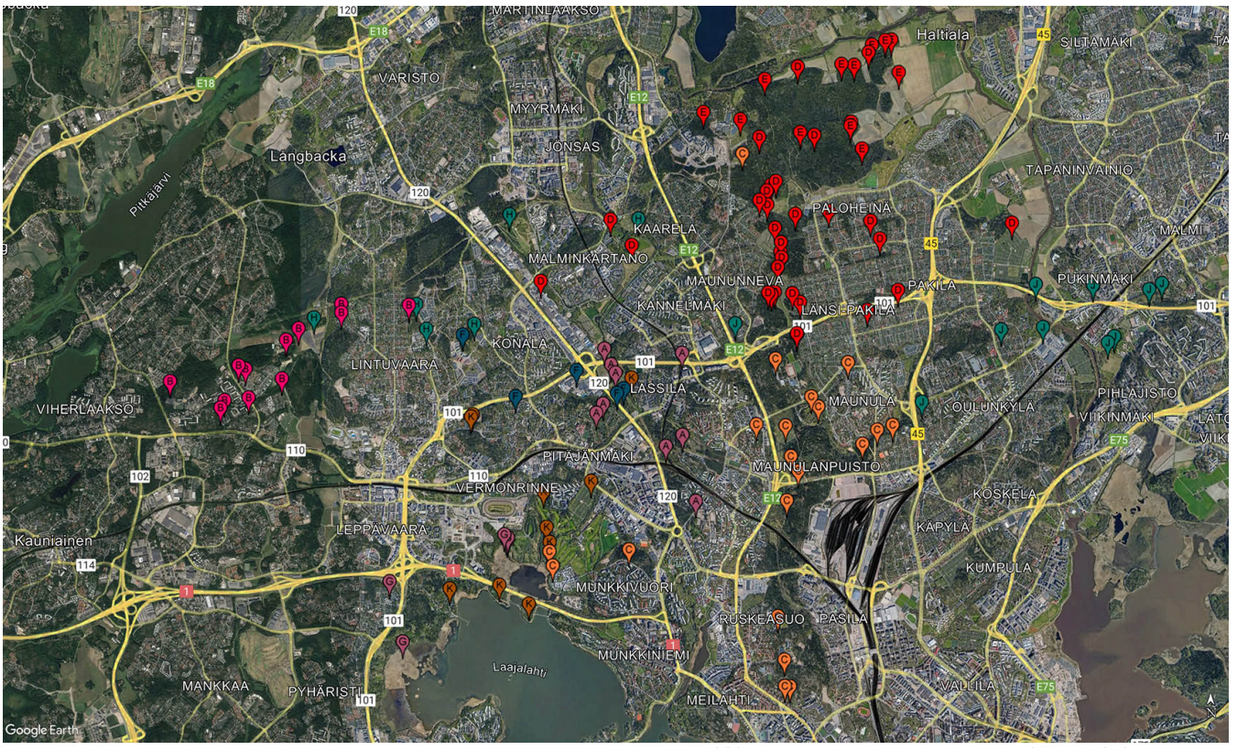

Map 17. Dialects in 2015. OYKY (J) core areas are visited for the first time. MAKA (H) heard the first time, but its areas were not well visited before, so no indications of any change.



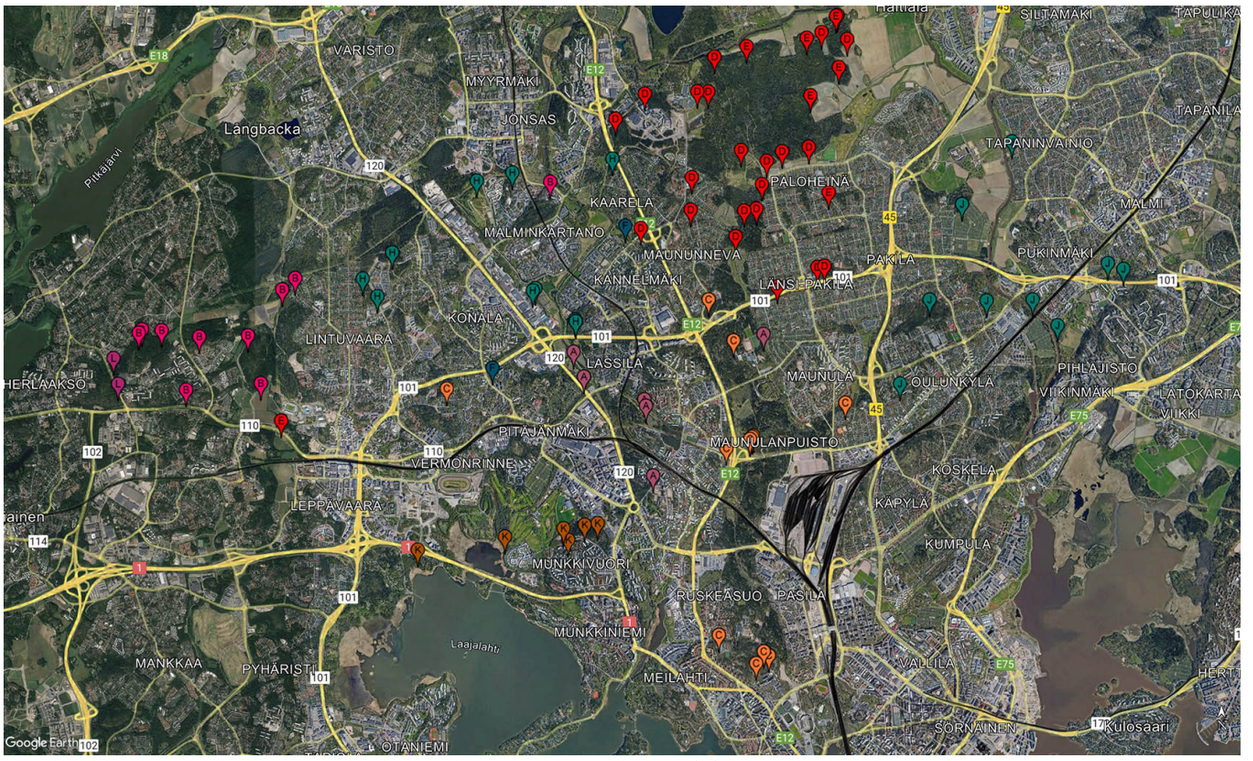
Map 18. Dialects in 2016.



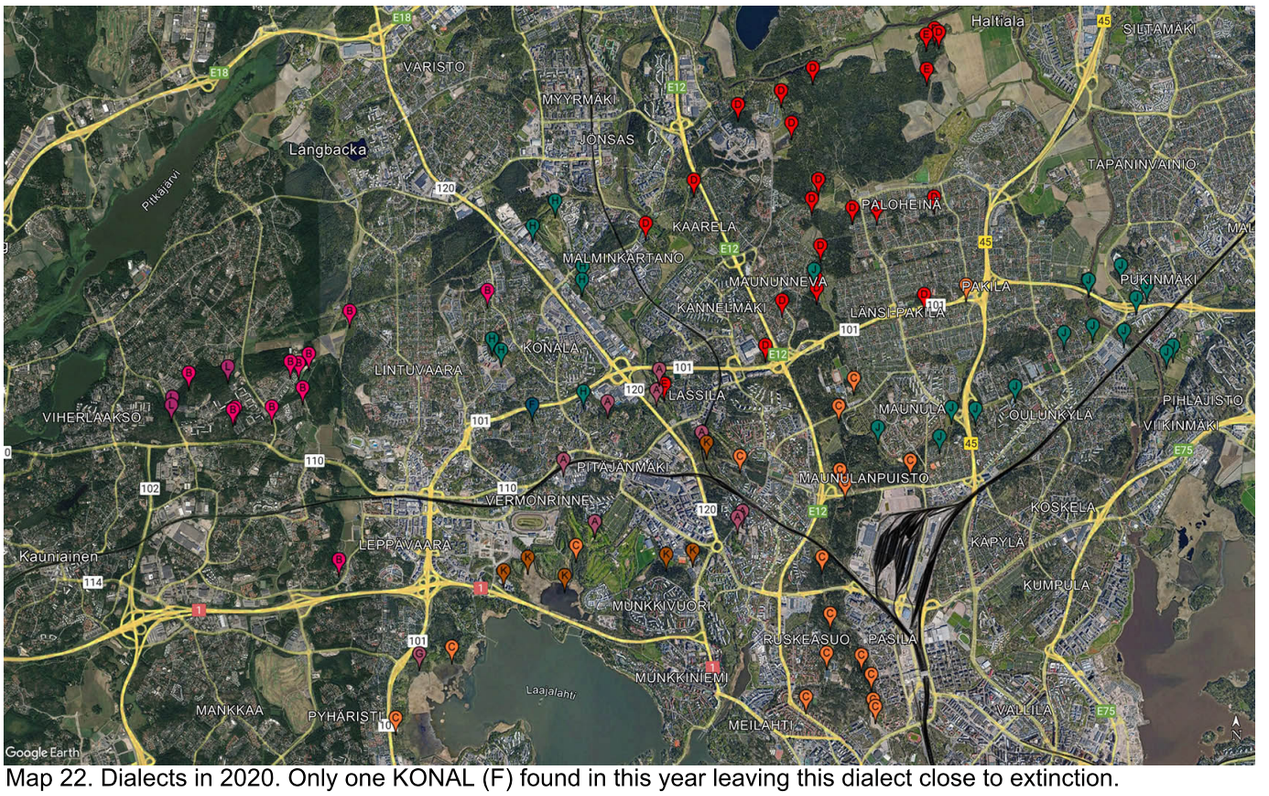
Map 19. Dialects in 2017



Map 20. Dialects in 2018. In this year, there were several KEPUE (C) singers in the core area of TALI (K).



Map 21. Dialects in 2019. The situation in the core area of TALI (K) has returned to normal. Now it starts to look like KONAL (F) has lost foot in the northern parts, to the MAKA (H) dialect, and also construction in the new Painiitty housing development has been completed, leaving less habitat for the species as a whole.



Map 22. Dialects in 2020. Only one KONAL (F) found in this year leaving this dialect close to extinction.

(Catchpole & Slater 2008). In Redwing, the observed changes have been relatively minor (Bjerke & Bjerke 1981). In the current study, spanning a period of 12 years, no significant song development was observed in the field or through listening to the recordings. To investigate more subtle changes, a linear discriminant analysis was conducted specifically on the KEPUE dialect, which was the most closely monitored dialect over the years. The samples were categorised into four groups: A) years 2009-2011, B) 2012-2014, C) 2015-2017, and D) 2018-2020. The KEPUE dialect typically consists of four primary notes. Out of the 176 recorded samples, 150 contained at least this number of notes and were included in the analysis.

The results of the linear discriminant analysis (Figure 20) suggest that the last group (group D) differs somewhat from the other groups. The red dots seem to be concentrated to the lower left area of the graph, especially the horizontal discrimination from the first, blue group is evident. The dissimilarity of group D is further supported by the Mahalanobis distances, which average at 12.2 for group A, 13.0 for group B, 13.7 for group C, and 19.5 for group D.

Any difference is far from obvious when listening to the recordings or looking at the spectrograms. However, the most negative impact in the horizontal function stems from the higher minimum frequencies of second note – the straight one, which on average is 300 hZ higher in group D than in group A. The most positive impact comes from the longer interval between notes two and three, but again the difference is very small. The distinctive characteristics of group A are related to the second note; in this group the second note is the longest, with the longest interval following it. It also has the lowest maximum frequency and lowest minimum frequency. In group D, the third and fourth notes are long and the interval between them is short and the second note is high-pitched.

As a summary – there are indications that some change has occurred but it is masked by individual variation and changes are very subtle and difficult to figure out during this time span of twelve years.

More noticeable changes have occurred in the number of prenotes, as illustrated in Figure 21. While the number of main notes has remained relatively stable, there has been a decrease in the number of prenotes.

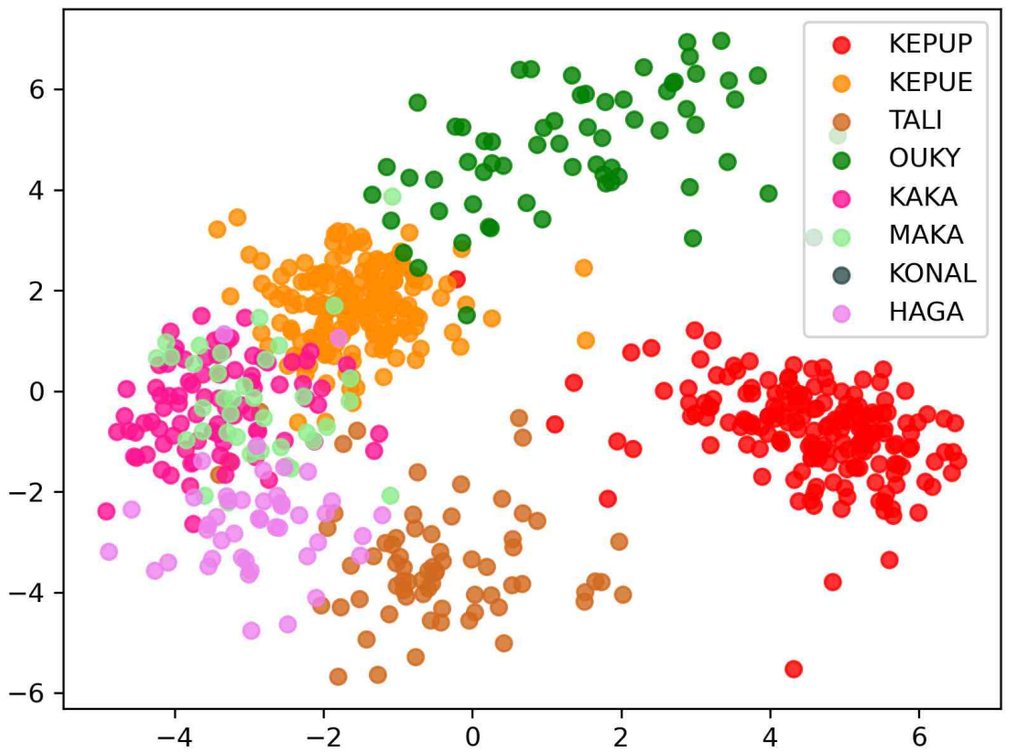



Figure 18. Linear discriminant analysis of all the non-marginal dialects.

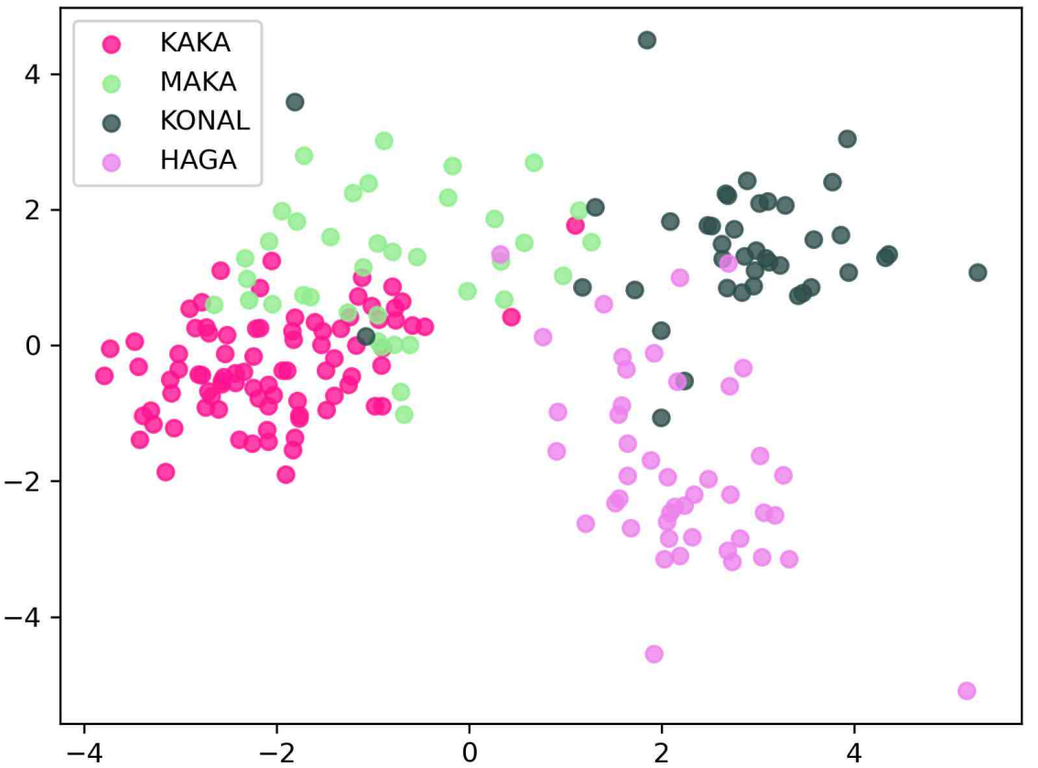



Figure 19. Linear discriminant analysis of the “middle group” of dialects.

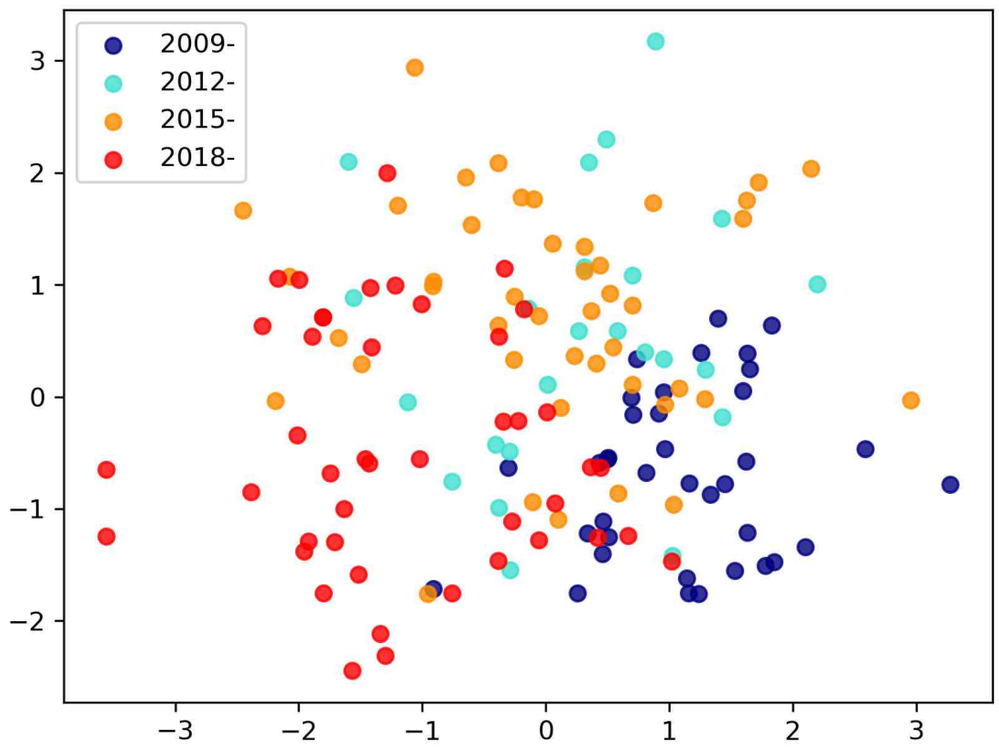



Figure 20. Linear discriminant analysis of the KEPUE dialect through time, with every three years grouped together.

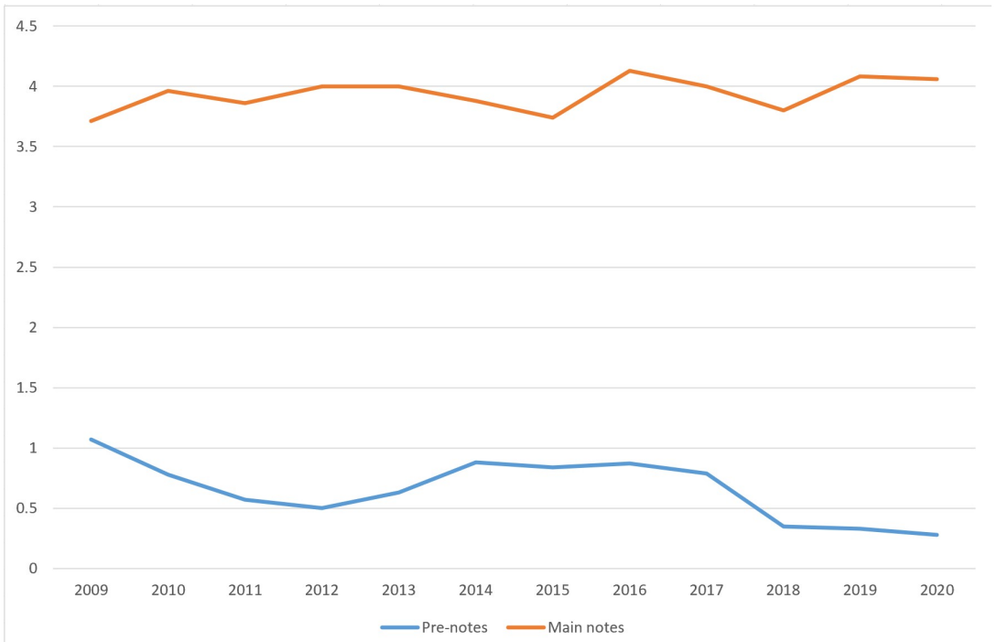



Figure 21. Average number of prenotes and main notes in the KEPUE song through the years.

## Summary

The distributions of song dialects were tiny, 4-10 km$^2$, accommodating only a few dozen territorial males at most. Dialect boundaries exhibited sharp distinctions when intersecting areas of suitable habitat, with adjacent dialects easily discernible to the human ear. However, the majority of boundaries occurred in less favourable habitats with lower bird populations, resulting in fuzzier differentiations. In some cases, adjacent dialects shared similar characteristics, leading to a slightly less distinct demarcation between them, but the boundaries were never indistinct or gradual.

Over the course of twelve years, there were minimal temporal changes observed in the dialects, both in terms of their distribution and sound characteristics. One marginal dialect vanished entirely, while another dialect that was previously completely encompassed within the study area became exceedingly rare in the final two years. Although some minor alterations in songs were detected, they were not readily apparent. Given the small size of the areas and bird populations associated with the dialects, it appears that learning from ancestral sources can only partially explain the phenomenon, with song matching during the spring migration playing a significant role.

Approximately 10% of the birds exhibited strophes that did not belong to any known dialect, and these individuals were widely and evenly distributed, rather than being concentrated in areas with a higher population density of the species. Among all the individuals studied, 4.7% utilised two distinct alternating strophes. While dialect core areas were clearly defined, it is noteworthy that more than 10% of dialect users were recorded in areas where the majority of singers employed a different dialect, indicating some level of dialect overlap or flexibility.

## Software

Audacity 3.2.2 for working with spectrograms including measuring.
ChatGPT
Google Earth Pro 7.3.6.9345 (64-bit)
Google Docs
JupyterLab version 3.4.4 for using Python
Microsoft Excel and Word
Microsoft SQL Server Express for storing, searching and analysing data, with Microsoft SQL Server Management Studio
Notepad++ v. 8.1.2 for some conversions of data during the transfer.
Python 3.9.16
Python libraries NumPy, pandas, SciPy, Matplotlib for linear discriminant analysis.
R Core Team (2022). R: A language and environment for statistical computing. R Foundation for
Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.
Ripley B, Lapsley M (2022). _RODBC: ODBC Database Access_. R package version 1.3-20,
RStudio 2022.07.1 Build 554 © 2009-2022 RStudio, PBC for using R.
Scribus 1.4.8 for publishing.
Wickham H (2022). _stringr: Simple, Consistent Wrappers for Common String Operations_. R package version 1.4.1.
Wickham H, Averick M, Bryan J, Chang W, McGowan LD, François R, Grolemund G, Hayes A, Henry L, Hester J, Kuhn M, Pedersen TL, Miller E, Bache SM, Müller K, Ooms J, Robinson D, Seidel DP, Spinu V, Takahashi K, Vaughan D, Wilke C, Woo K, Yutani H (2019). “Welcome to the tidyverse.” _Journal of Open Source Software_, *4*(43), 1686.

All of the above mentioned software except Word and Excel are free, and many thanks belong to the creators and maintainers.

## Literature

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Podos J & Warren P S 2007: The Evolution of Geographic Variation in Birdsong. Advances in the Study of Behavior 37: 403-458.