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Evaluation of wildlife acoustic surveying as a method to estimate bird habitat quality.

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Department of Ecology
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Abstract

In the world of birds, the sound says it all. The song, the alarm call, the flight call, and the call for a mate, all makes up a soundscape telling their friends and foes of their condition, mate status and tells the predator that its presence is noticed.

In traditional bird monitoring our human ears and eyes are used, with all the pros and cons that comes with the researcher being *in situ*.
But what does the soundscapes of the birds tell us about the habitat quality? If high quality means a habitat with more complex structure, does it mean that the individuals possessing it can spend more time singing for a mate and claim its territory? And less time to call out warning for predators due to the protection the understory and canopy offers? And if so, can we draw the conclusion that their fellow species in open, lower quality habitats, spend more time warning than singing?
By comparing the results of traditional bird spotting in six sites outside Uppsala, Sweden, with the recordings of a SM4 soundscape recorder left on each site for 48 hours, it was possible to not only find which species that inhabited the site but also compare the time each species spent on singing vs the time spent on warning for each site. Part from being an ecological survey, of any behavioural difference between habitats, this project was an evaluation of the quality of the recorder SM4 as well as the software Kaleidoscope Pro from Wildlife acoustic. Findings were that the quality of the recordings were high, and that the software is capable of distinguishing between very small differences of song within species. But that the software still needs more examining to see if the issues, such as cutting phrases into far too short fragments of song, can be adjusted by the settings or if it requires more developing of the software to improve the usability of the software's ability to cluster species. No evidence was found that the quality of the habitat makes the warning more frequent in the open habitats and the singing more consistent in the complex ones.

Key words: soundscape, birds, habitat quality, behaviour, recording, Kaleidoscope Pro, SongMeter4

Sammanfattning

Fåglarnas värld domineras av ljud. Revirhävdande sång, varningsläten, flyktläten och lockrop för en partner, allt vävs samman till den ljudbild som ger vänner och konkurrenter en uppfattning om ens kondition, förhållandestatus och upplyser predatorer om att deras närvaro är upptäckt. Inom traditionell fågelövervakning är det de mänskliga öronen och ögonen som är avgörande, med alla de för- och nackdelar som det innebär att befinna sig *in situ*. Men vad kan ljudbilden fåglarna skapar säga oss om kvaliteten på habitatet? Om hög kvalitet avser ett område med mer komplex struktur, innebär det att dess invånare kan tillbringa mer tid med att sjunga för att locka en partner och hävda ett territorium än att varna för predatorer eftersom undervegetation och trädkronor erbjuder en högre grad av skydd? Och går det i så fall att dra slutsatsen att deras artfränder i mer öppna habitat, av lägre kvalitet, tvingas tillbringa en större del av tiden att varna för faror än att sjunga? Genom att jämföra resultaten från traditionell fågelövervakning i sex provytor utanför Uppsala, Sverige, med inspelningar gjorda av en SM4-inspelare placerad i varje provyta i 48 timmar, var det möjligt att finna vilka arter som bebor området, men också jämföra tiden varje art tillbringar med att sjunga jämfört med att varna eller locka. Förutom att vara en ekologisk undersökning, som jämför beteendeskillnaderna mellan habitatfläckar av olika kvalitet, var detta projekt också en utvärderingsstudie i kvaliteten hos inspelningsutrustningen SongMeter4 (SM4) och mjukvaran Kaleidoscope Pro från Wildlife acoustics. Kvaliteten på ljudinspelningarna visade sig vara hög och mjukvaran har kapacitet att göra åtskillnad mellan små variationer inom samma art. Dock så konstaterades det att det krävs fler och längre studier för att undersöka om problemen, så som att mjukvaran klippte av strofer i väldigt korta fragment när den klustrade, kan åtgärdas med hjälp av inställningarna eller om det kräver vidare utveckling av mjukvaran för att den ska vara användbar i studier av arter. Inga resultat från den ekologiska undersökningen antyder att individer i habitat av lägre kvalitet skulle tillbringa mer tid med att varna för faror jämfört med att sjunga. Eller att individer i habitatfläckar av högre kvalitet skulle spendera mer tid med att sjunga än att locka och varna.

Nyckelord: fåglar, habitatkvalitet, inspelning, soundscape, beteende, Kaleidoscope Pro, SongMeter4

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1 Introduction

1.1 Why keep track of biodiversity?

In a fast-changing world, the ability to see and measure the effect that human activity and environmental change has on nature and its inhabitants is important to save species from extinction caused by fragmentation, isolation, degradation or loss of suitable habitats. In order to establish how habitat changes affect organisms information about the environmental effects on local species is needed. Therefore, environmental monitoring and research of these matters are core areas of ecology and conservation biology.

As a member of the European Union (EU), Sweden is obliged to preserve habitats and assure that species of conservation interest can reproduce and thrive. According to the European union's council directive on the conservation of wild birds (Council Directive 2009/147/EC), Sweden is bound to protect and preserve enough habitat for its wild birds. The measures are applicable for both resident and migratory birds. All preservation measures are to be reported back to the European union together with how well the results respond to the taken actions. This requires regular monitoring and surveying of any changes in the environment, its species and their habitats. Sweden also has its own Environmental goals to consider. A number of these goals relate to biodiversity, and, for example, states that the forest should prosper for both its ecological as well as cultural and recreational value. The wetlands are to be kept for its ecological function and a rich and varied biodiversity are to be kept safe for future generations**.** More precisely it states the importance of genetic variation and a favourable conservation status. It also states that well-functioning ecosystem are important to save and keep, since the services they provide can help preventing climate changes and its effects (Naturvårdsverket, January 16, 2018). Local and

international agreements and goals require that habitats are monitored and changes in habitat quality identified and reported. Therefore, it is important for both local and global conservation of species to find cost-efficient methods for the long-term monitoring of habitats and biodiversity.
To engage a wide range of society when monitoring a landscape and its biodiversity, it is an advantage to use charismatic species. As an organism group birds are well-known, often easily recognized and relatively easy to find. Therefore, birds can be practical indicators for state of the environment (Bibby et al, 1992), especially as land use change has been linked to population declines of birds. As an animal type mainly depending on vocal communication for claiming territories and attracting mates, birds don't have to be seen or trapped to be used as indicators. This opens for the possibility to use remote sound recorders to evaluate the changes in a habitat's bird community as well as changes in species' vocalization behaviour.

1.2 Recording of soundscapes as a monitoring method

In order to make monitoring more efficient and more continuous, the recording of a landscapes sounds has emerged as a method. These soundscapes are basically the acoustic environment with all its content of geophony (wind, rain etc.), biophony (bird song, mammals moving around etc.) and anthrophony (sounds made by humans such as cars, planes etc.). By recording for longer periods of time changes in the soundscape can be noted and connected to environmental changes in, or around, the examined habitat patch. The results can be used as a planning tool, when measuring the impacts of how disturbance and fragmentation causes decline in biodiversity and ecological condition (Fuller et al, 2015). Not having to send researchers out in field for many hours saves resources both timewise and moneywise. The technology used is a recorder constructed to withstand wind and rain that is placed in the area of interest. It is often (always?) used together with a software that efficiently can help analysing hours of sound recordings and, in some cases, cluster these based on the similarity of the sound spectra. An advantage is that the recorders doesn't require a specialist to place them in the investigation area, basically anyone can do the groundwork, leaving the analysing part to the experts. Being able to replay the recordings several times and get them visualized increase the possibility to identify the species correctly (Celis-Murillo, A. et al, 2009).

1.3 How can this method be used?

One important research question that could be investigated using analysis of bird vocalization is “how does a change in habitat quality affect the behaviour and occurrence of species?” Bird vocalization could be used to both establish the species present in contrasting habitats but also to note and record any shifts in vocalization types (such as warning, mating or begging vocalisations) that can be caused by changes in behaviour in contrasting habitats. But this requires that samples must be taken continuously throughout the whole season, something that might be a challenge due to cost of much time spend *in situ*, cost of travelling, data management etc. Collecting data with *in situ* recorders also reduce the risk of disturbing the nesting birds as well as getting false information since their vocalisation behaviour may change, due to either the presence of the researcher or the fact that the singer is absent within the time frame that the researcher is *in situ*. Stuart et al (2012) also comment on the fact that for shy species, non-responsive to playback, a non-intrusive method - such as a recording device, might be the only way to note a species presence.
With a remote sound recorder, such as the SM4, that can record either after a set schedule or continuously throughout the season, the only interruptions would have to be switching the batteries and memory card. When placed in a habitat of interest the recorder can provide researchers with data covering a longer time period than what traditional monitoring normally gives. It is an advantage that the identification might be done by the same researchers over time even though the field personnel might change over a long-time or a large-scale project (Celis-Murillo, A. et al. 2009). The monitoring done by a permanently placed recorder can show whether the species remain year after year. Furthermore, by continuously recording the change in behaviour before or after mating/reproducing it might also give an idea of the success of breeding as well as changes in abundance. This is important since some species and individuals can remain as relics in habitats no longer suitable, giving a false sense of biodiversity although they may no longer find a mate or reproduce (Lindenmayer, D. B, Fischer, J. 2006). A continuous recording will also show the change in song frequency and intensity that occurs during the breeding season and can therefore be used as indicators of whether the nesting attempt has been successful or not.

This of course requires the recordings to be of high enough quality and be accurate enough to recognize not only certain species, but also to distinguish between individuals. The Kaleidoscope Pro audio analysis software is promoted as being able to efficiently cluster many hours of recorded bird song and for being sensitive enough for distinguish between different phrases and variation in calls. The ability to visualize the recordings is useful when trying to find patterns in large series of data (Gage & Axel, 2013).

1.4 What can the soundscape tell us about the habitat?

A habitat is" the subset of physical environmental factors that permit an animal (or plant) to survive and reproduce" (Block and Brennan, 1993 p 36). And the soundscape is "acoustic signals that reflect the dynamics of biological, social, and physical systems of a landscape" (Gage and Axel, 2013). Environmental change in territories, that have formerly been inhabited by certain species, may result in loss of suitable habitat. This reduction in habitat quality or amount can lead to a local decline in abundance of these species and even local extinction. A key consequence of habitat degradation could be a decline in shelter and protection from predators. For example, in boreal forestry in the northern hemisphere, thinning of the understory is a commonly used technique to enhance the growth of trees as well as making future clear cutting easier. But this removal of small trees can lower the habitat quality and even diminish niche diversity for birds who prefer habitats with well-developed understory for nesting (Norris and Harper, 2004, Eggers, S., Low, M., 2013). What to the human eye may appear to be only a small change, such as the removing of understory, may have the effect that birds with certain habitat preferences no longer find this habitat suitable for breeding.

Bird species with open nests especially rely on the protection the understory can provide. Therefore, effects on the soundscapes are expected to be clearly linked to changes in the habitat, either due to the change leads to loss of species or that the remaining species change their behaviour. For example, a behavioural change can be that instead of spending most of their time singing to attract a mate and to claim a territory, more, or most, time is instead spent on warning. Species that have been shown to be affected by changes in the forest understory include the Siberian jay (*Perisoreus infaustus*) that shows a clear decline in breeding success both from partial thinning and partial clear cutting (Griesser et al, 2007). Loss of protection from the understory increases the threat from avian predators, predators that poses the greatest threat are the ones who uses both acoustic as visuals cues to locate the nest of their preys (Eggers et al, 2005). Thus, forest thinning and its expected changes to bird communities and species behaviour provides a suitable study system from investigating how soundscape can reveal impacts of habitat change on biodiversity.

1.5 What was the purpose of this study?

This pilot study had three purposes: 1) To investigate the capability of remote audio recorders (Song Meter 4) from Wildlife acoustics and its software (Kaleidoscope Pro) that is promoted as being able to efficiently batch analyse many hours of recording into similar clusters for easy species identification. 2) To compare the number of species caught by the remote recorder and batch analyses of the vocalizations with manual auditory and visual counting. The intention was to investigate if the recorders can catch more, or other, species than traditional point surveys since the gathering of information can be done for a long time and for full days in a row, but with a minimum of disturbance.
3) To investigate if soundscape data can be used for behavioural studies by investigating if the data reflects the community composition and if species behaviour differ between simple and complex understory forest patches.

The expectations were high about the software's capability to cluster species and thus where the analysing part expected to be rather quick, since the species already noted in the patches are common ones, usually easy to recognize if they were to be sorted into song cluster based on species. The ecological hypothesis was that in a habitat of higher quality birds will spend more time singing since the well-built understory provides more protection, whereas they will spend more time calling in habitats of low quality with more exposure to predators.

2 Methods

2.1 Choosing plots and placing of recorders

To be able to compare the method recording of soundscapes with traditional methods one of the criteria was to survey plots where data was already collected by visual and auditory monitoring. And to get as clear result as possible the plots were chosen from the far ends of a scale reaching from very high to very low, where a high-quality habitat was a plot with its understory intact and a low-quality habitat had had its understory removed. All plots were chosen for being in the same type of matrix, consisting of clear cuts. The plots were recorded in pairs where each pair consisted of one high quality and one low quality plot. Soundscapes were recorded continuously for 48 hours before the recorders were moved to another pair of plots.
The plots measured 50 meters in radius and the recorders were placed in the middle of the plots (to minimize bias from birds singing in trees in the matrix). The recorders, Wildlife acoustics SM4, were fastened to the trees, using bungee cords, 1,8 m above root level among the branches of spruces (to make them less visible to passers-by and curious animals and to minimize the recording of geophony such as wind and rain). The recordings were made from May 5th to May 11th, 2019 in sites some ten kilometres from Uppsala, Sweden.

2.2 How the Kaleidoscope Pro works

The software cluster the sounds using a complicated set of algorithms. Before clustering parameters such as length of detection, inter syllable gap as well as how far from the cluster centre a sound is allowed to be to be filed into the same cluster, can all be set after your own preference. It will then use the most frequent sound of the area as a reference and place it as the first cluster in the row. The following clusters are then listed after how close they are to this base cluster. When doing a simple cluster analysis “by the book” you are to listen to the three first in each cluster since they are the ones considered to be of the highest quality. If they are clustered accurately it is possible to label the ones of the highest quality in each cluster with the recognized species and then run the data again. The program will then use the clusters that are labelled as a specific species as a reference in order to create an even more accurate list of clusters. This can be done several times to refine the software’s ability to distinguish between species.

2.3 The clustering and naming of its species

Since this project’s main purpose was to test the technique and the software’s ability to cluster and recognize species. The aim was to determine if it was a method worth trying at larger scale and for investigations of both biodiversity and behavioural studies. It was therefore decided to keep things simple; The settings used were the ones recommended as a starter point from Wildlife acoustics. That is that the pauses between vocalization (inter syllable gap) was set to 0,35 seconds, the frequency to between 250 and 10 000 Hz and the length of detection between 0,1 and 7,5 seconds.
The 145 clusters the software created were not named in the software itself, but in a for this purpose created Excel file where it also was noted which plot, what cluster, which species that was being recognized in the first three files of the cluster, any issues (for example if anthrophony such as passing planes or geophony such as wind or rain made it hard or impossible to identify the species). It was also noted which species the software appeared to have singled out as the species it used as a cluster species, if that species was singing or calling and a column for comments if anything particular was being noted in the files (table 1).

Table 1: *Example from the excel file showing plot, cluster number, type of sound and which species each cluster contained. As well as any issues with the cluster and which species that the software had chosen to cluster.*

Plot	**Cluster**	**Type of sound**	**One/ same species**	**Species recognized in cluster**	**Issues**	**Does the cluster identify a species?**	**Which species?**
37	.000	Call	Yes	Chaffinch		Yes	Chaffinch
4	.003	Song	No	Chaffinch, Red robin	Different species	No	
111	.124	Song	Yes	Thrush, Chaffinch, Great tit	Biophony (bird chorus)	No	

By running the metadata created by the Kaleidoscope Pro through Access, it was possible to combine all the metadata/csv-files from the Kaleidoscope Pro with data written in excel when listening through the clusters. For this evaluation the decision was made to only categorize the sound as song or call. No attempt was made to distinguish between warning calls and calls for a mate this time. Instead it was investigated the total time the birds spent singing compared to calling in the different habitats. Comparisons were made to see how the songs and calls were spread out during the day as well as when the different species were singing. The different species abundance between the plots were examined and compared to data collected by traditional methods.

Since the software creates copies of some sounds, mainly because it might reach the left and right microphone with some time difference, the duplicates were removed by identifying those with the identical duration, time and date.

3 Results

3.1 Evaluation of the software

When in total 288 hours of recording, from in total six plots - that is three plots in either end of the quality scale reaching from open to complex habitat - with 48 hours of recordings each, was run through the Kaleidoscope Pro software it clustered the information into 145 different cluster within 30 minutes. When first listening through the clusters there were a lot of confusion since the program is supposed to cluster the files with the most similarities together and this is supposed to be both heard in the fragments in each file and also be visualized by a sonogram shown as the recordings are played. The top clusters where clearly calls where each file contained only very short fragments (less than 0.5 seconds). But even in these short fragments it could be heard and seen a variation within the same cluster, which at first was diagnosed as a faulty clustering from the program. These apparently “faulty” clustering was a frequently returning issue throughout the whole batch. Another issue was that even when the files contained song it was still divided into very short fragments which made it very hard to recognize the species. In the end it was clear that an expert ornithologist was needed to name the birds correctly. It was then realized that what at first sight had appeared as faulty clustered fragments was in fact correct but that the Kaleidoscope Pro most likely had clustered different fragments of a sequence from the same individual.

When the hours of recording were examined, and compared between open or complex habitats, no significant differences could be found in time spent singing and calling (figure 1).

The calls are spread out more evenly during the day in both habitat types, whereas the song is more clearly connected to time of the day (figure 2).

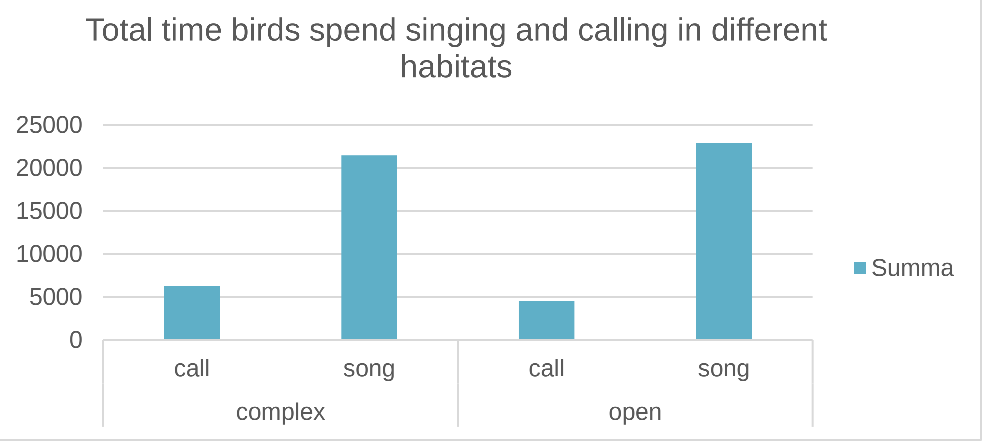

Figure 1: When divided into the two types of habitats in boreal forest - open, with the understory removed and complex, with a more intact understory - this diagram shows that the total duration of recorded bird songs and calls in seconds (y-axis). When clustering all species together like this, the total duration of sounds is very similar between the habitats.

The result shows how the software can visualize how the songs and calls are spread out during the day (figure 2). For example, it appears to be a small difference in how the dawn chorus starts (more abruptly in open environments). Also, there are no clear peaks when predators might be expected to be active.

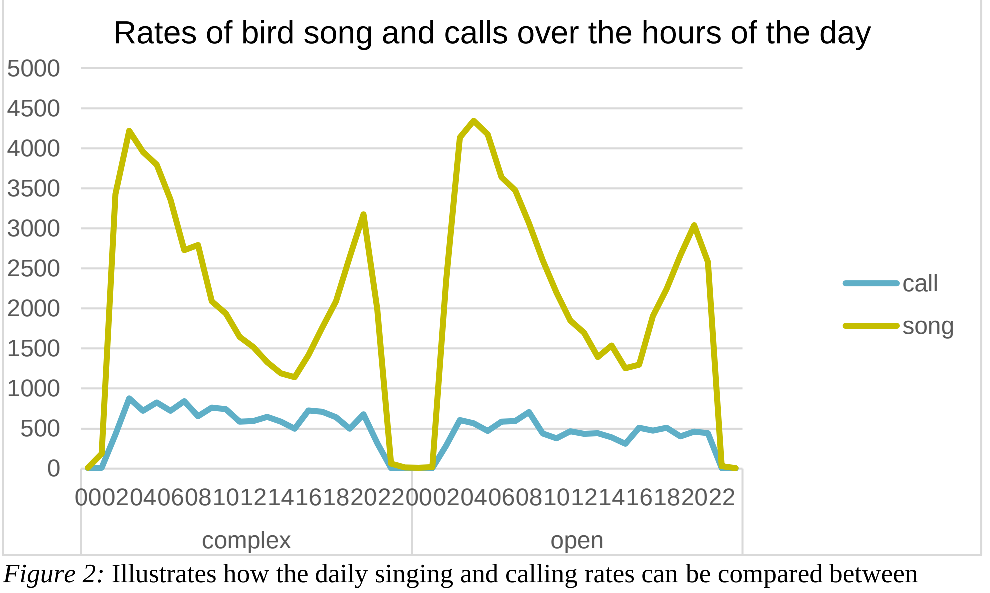

Figure 2: Illustrates how the daily singing and calling rates can be compared between habitat types, in this case in boreal forest. Where the complex habitats have a slightly slower start of dawn chorus. With time of vocalisation in seconds (y-axis) compared to time of the day (x-axis). Here, no clear differences were observed between simple and complex habitats. There was a tendency toward higher level of calls in complex habitats. It is clear that the singing rate varies to larger extent, but that calling is more evenly spread out during the day.

Since the SM4 provides the information of what time a song or call is recorded it's possible to investigate when the singing and calling of all, or a certain species of interest, is more, or less, intense. As can be seen in figure 3, that shows the vocalisation pattern of the most commonly recorded species in the plots, some species are mainly recorded during morning and/or evening, whereas others are active and singing throughout the day.
The recordings can also be used to investigate how the vocalisation time differs between plots. In figure 4 it's for example clear that the durations of Red robin vocalisation differ a lot between the plots but shows no clear pattern between habitat types.

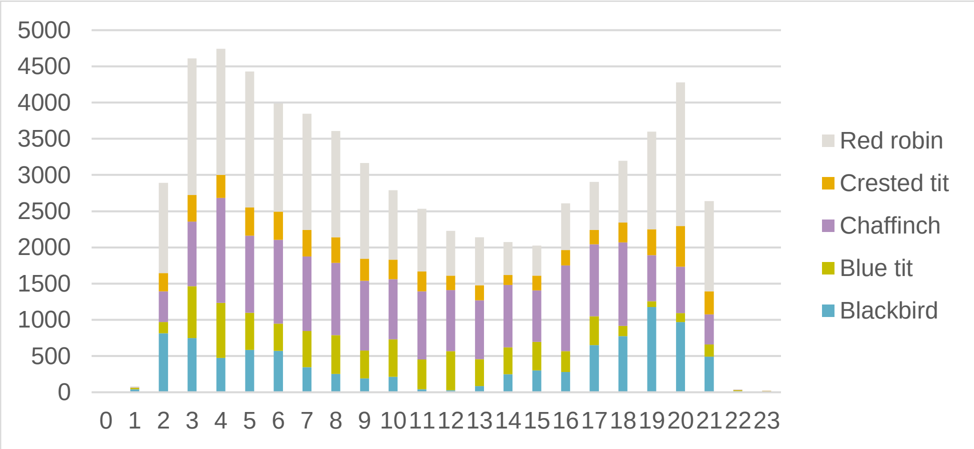

Figure 3: The number of vocalisations (y-axis) recorded by the SM4 of the most common bird species and how they vary in number of notions over the hours of the day (x-axis).

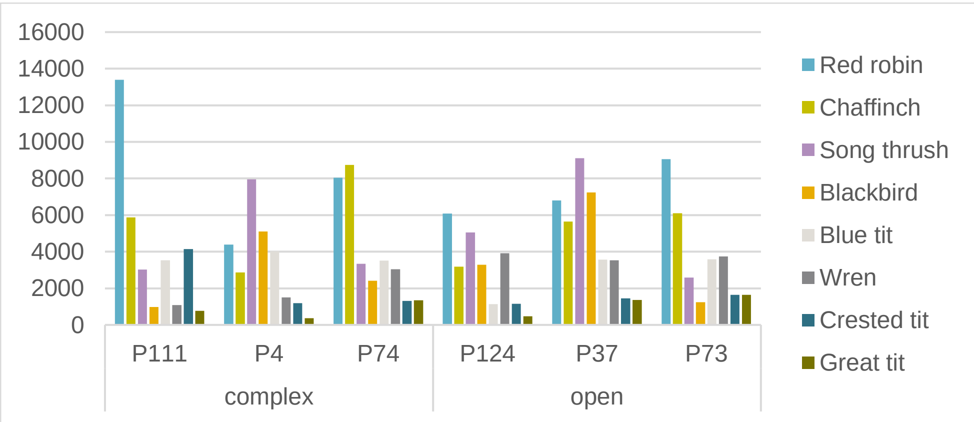

Figure 4: A selection of bird species from the "raw" data from SM4 recordings showing how the duration of vocalization in seconds (y-axis) can differ between habitats (x-axis). The plots names on the x-axis are divided in type of habitat: open, with understory removed, or complex, with understory intact, all in boreal forest.

3.2 Issues with the software

- From the files recorded by the SM4 recorder, Kaleidoscope Pro created almost 70 000 clusters. Out of these almost 20 000 clusters were not possible to use for identification. Which means that a little less than 50 000 clusters were useful for identification of bird species (figure 5).
- That silent files were clustered together with ones with considerable length (figure 6). Some as number one or two in a cluster containing song.
- The files in the clusters were sometimes organized so that there could be two good ones of one species, one with another species, and then one or several good ones with the first species again (figure 6).
- Based on the comment above and the fact that it sometimes was very unclear which species it was sorting from; it was hard to name the clusters since there was no way to know what the program used as reference.
- Although the song or call sounds the same in the cluster, the sonogram could differ quite a lot. This causes confusion when the software is said to create sonograms showing what can be heard and that it would even be possible to identify from them.
- In some clusters the "voice" may sound very much alike, but the phrase heard differ between the files (figure 6).
- Many files contained only a short call, some of them were clustered together, but some were listed very far apart – although they were the same species. This could of course be a sign of the software being able to distinguish between individuals which would be a very useful ability for future research – but since this can't be known for sure without further testing it remains as an issue.
- Attempts were made to name the species "manually", but this caused the issue that once a species was named, it was not possible to change the name if it was later realized that the naming was faulty. This because the program then changed all the clusters named with that species – not only the faulty one.
- Due to the sensitivity of the software it picks out short fragment from at longer phrase and cluster them based on this fragments similarity to the one it has placed in top as the most frequent sound (figure 6). In simple clustering setting this not only means that a lot of information get lost further down in the cluster. But also that a lot of species might not be recognized since short fragments of their song

are too similar to others, meaning a short fragment may not be enough to tell them apart.

- The software had problems distinguishing between species when many birds were singing simultaneously, such as during the dawn chorus (figure 6).

Figure 5: From the files recorded by the SM4 the software, Kaleidoscope Pro created almost 70 000 clusters (y-axis). Out of these a little less than 50 000 were possible to use for identifying species.

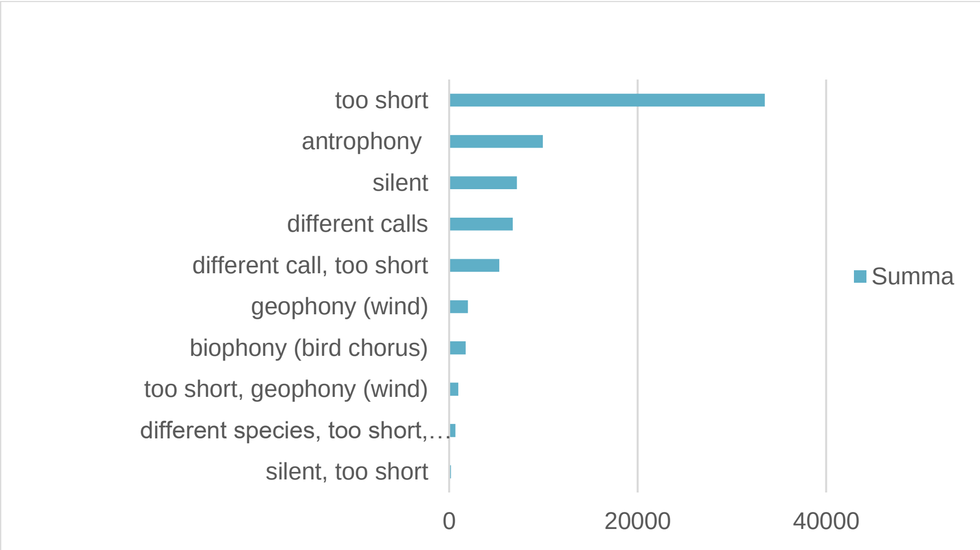

Figure 6: The clustering done by Kaleidoscope Pro from the SM4 recordings of bird song and the issues that complicated species identification. The total number of each issue (x-axis), where being too short is by far the most recurring issue, followed by anthrophony, silent and calls that can be distinguished as different species by ear, but not separated by software. Some combinations such as a cluster both contained different calls and were too short to identify or too short clips and geophony were also reoccurring.

3.3 Comparing with manual monitoring

To be able to evaluate how many species that can be detected using the recording of soundscape, it was compared with the number of birds noted during manual monitoring done during the second half of April. Chaffinch was by far the most noted species, closely followed by Blue tit (table 2 and figure 7). As seen in table 2 (below) Jay only has visually notions, larger woodpecker is noted visually two out of three times and great tit has a 50/50 distribution in visual and auditable notions respectively. This means that even though the auditory notions are dominating, visual counts to 1/5 of the total number of notions when doing monitoring.

Table 2: *Sum of notifications of birds done by traditional surveying during April 2019. Total surveying time was 30 minutes, divided into 5 minutes spent watching and listening for birds x 6 plots. The habitat was boreal forest some ten kilometres from Uppsala, Sweden.*

Species	**Numbers of auditory notions**	**Numbers of visual notions**
Chaffinch	11	
Redwing	1	
Blue tit	10	2
Song thrush	2	
Gold crest	1	
Dunnock	3	
Jay		5
Larger woodpecker	1	2
Red robin	4	
Coal tit	2	
Great tit	2	2
Wren	1	
Crested tit	1	

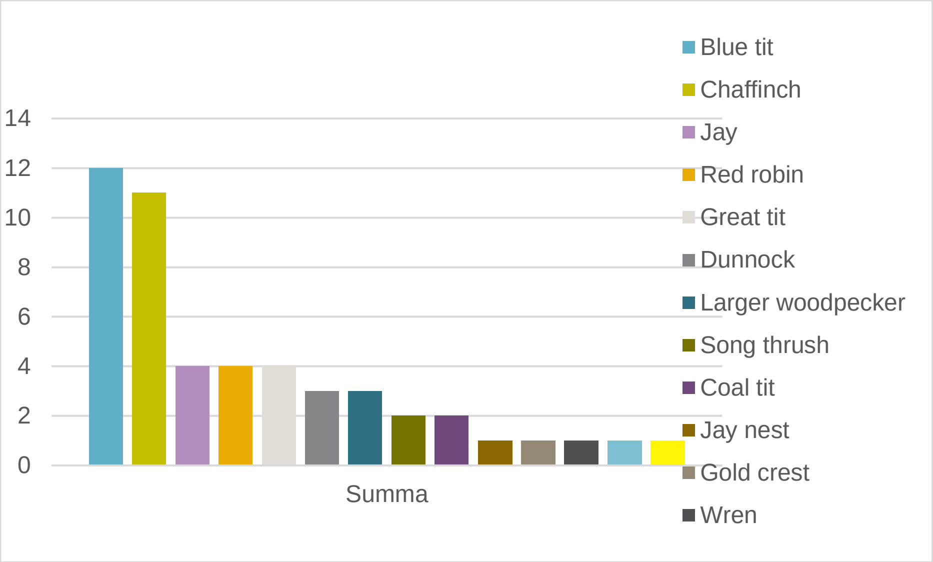

Figure 7: The total number of notions from the traditional survey of birds, both auditory and visual, with number of individuals of each species on the y-axis and the bird species on the x-axis.

4 Discussion

4.1 Overall

The hypothesis when starting this project, was that there would be a clear difference between habitats in the two ends of the scale “complex” and “open” and that the birds would spend more time singing in the complex habitats. This due to that complex habitats offers more protection and therefore would require less time to be spent on warning. When looking at figure 1 it’s notable that the difference between call and song is not in line with the hypothesis. Of course, the result can be false because (in this study) no distinction has been made between warning calls and calling the mate. Of course it’s also possible that the birds in the complex environment might have to call both for mates and threats more since there’s always a chance that the neighbours not have detected a threat, whereas in an open environment it’s enough of a warning signal to simply be quiet when a predator is closing in. And even though the potential mate might hear the song, maybe it needs more guidance to the right spot in a complex environment – simply because the sound of the calls doesn’t reach as far as in a less complex one? The fact that calls and songs have different reach in open and complex environments must be taken into account. As well as the reach of some species is further than that of others, which means it makes it possible to catch the sound of their calls from further away than the decided plot radius, whereas others can be missed even though they are within the decided area due to their quieter calls. The sum of duration (figure 1 and 2) means that a species that make a lot of calling can match a species that sings longer strophes at the time, but less frequent. The Robin is the most – or at least one of the most – vocal species whether the habitat is complex or open, whereas the Blackbird differs between plots but shows no pattern when it comes to habitat type.

The software's ability to tell which species that are dominant in singing at certain times during the day can be useful for future single species studies and/or behaviour studies.

The figures (1-4) above showing multi-species vocalization activity are illustrative but are of limited use when used for just one season, in only a few plots. The full benefit of these techniques may become more obvious with repeated years of data and with larger sample size in the different habitat quality types. Questions that can be asked, using this technology for a long-time study, is for example how the distribution of multi-species vocalizations change over years or in the face of major habitat change? Something the figures does illustrate is the evenness of the vocalizations in plots as well as if one species seems much more dominant than another. Which would make it possible to examine the changes of community structure over whole seasons or even between seasons over years.

The fact that the recordings of the different species were put in different clusters showed that the software had found enough differences between calls and song fragments to say that it probably can distinguish between voices. At least the fact that many of the clusters containing the same species as top examples are separated into different clusters that are not placed immediately after one another gives a hint about that. If the software is able to distinguish between voices, it might be able to distinguish between individuals. Which would make it useful for future studies regarding behavior.

By comparing the two methods it's possible to see that, even though many species are overlapping, the visual monitoring add some species that are not found by the SM4 – or at least not noted as a unique species by the Kaleidoscope Pro (table 2). Similar results was found by Celis-Murillo, A. et al (2009) that stated that the two methods might have a similar results in number of species, but that they might detect different species. The same authors also concluded that soundscape recording might be better to detect the presence of rare species, since their rareness might risk them to be misidentified when only heard infrequently out in the field. A conclusion that was drawn also by Stuart et al (2012). Although this was a small study the fact remains that 1/5 of the notions is done only or partly visually (figure 6).

Of course the reasons that a species is not picked up by the recorder can be as simple as the birds are not resident at the plot, but only happen to be present when noted by the observer, that it has been chased off by a more dominant species, or – as is most likely with the species in this case: that they have already nested and started brooding and therefore do not sing anymore. But it can also mean that the software is not yet able to distinguish between these species calls and the ones found in the charts above. Instead the software has incorrectly clustered them together with the more frequently singing species but considering the song or calls as a less good quality one of the species it has chosen to cluster. The software might therefore have placed it too far down the number of files in the cluster to be heard when listening according to the recommendation from the software developer (listening to the three first files of each cluster). As noted under “Issues with software” the software has difficulties singling out different species during the dawn and sunset chorus. This suggest that it might be of better use in less intense seasons, when calls are less frequent, e.g. winter. Another issue with the technology is that there - according to the software – are no calls of Robins in the plots. Since Robins were resident, this could point out one of the main issues with this software: the fact that it tends to divide/chop the phrases up into very short fragments. This is a problem, not only for an unexperienced bird researcher, and even for a more experienced ornithologist, but also because it heightens the risk of the software clustering many different species into the same cluster because it finds similarities in short fragments of different phrases. Instead of using the whole phrase as a reference for clustering it uses a single syllable which for many species might be very much alike. A problem like this must be solved for the software to make relevant and trustable clusters to be used for biodiversity studies. Hopefully this can be solved by adjusting the parameters to get longer strophes before clustering and by teaching the software different species by naming only the best examples of files and clusters. In this evaluation project only the simple classifier was used, since the time frame didn’t allow deeper understanding and evaluation of how much the software can be taught to improve identification of vocalisations. It was discussed as an alternative approach that three files could be picked either randomly or from the middle of each cluster to examine if they would be of the same species as the three top matched ones. Naturally the files can be sorted not only after the top match but also after duration, meaning that only the sound fragments of considerable length could have been picked out and listened to. With more available time it would have been interesting to compare this to the approach recommended in the software’s manual to know if it might be a good alternative.

Some attempts were made to change the distance between sounds to see if this could solve the problem with files being too short to recognize the species. No clear result came out of this, but one option is to change the FFT settings in the menu after the clustering is done. Depending on how many MB or GB it’s set to it can play whole sessions of the recording with the cluster names showing above the sonogram. Adjustments must be made manually while listening to be able to read the cluster names however, since they are very tightly crammed together. This is a great function to get the overall picture of the soundscape and to make it easier to identify a species. Unfortunately, no function making it possible to skip from the whole session to the file at hand was found. Instead the cluster of interest must be searched after by adjusting the FFT settings to find one example of this cluster – which may not be the exact file last listened to. A very time-consuming task, which ruled this out as an option for this evaluation. If a function that makes it possible to skip from the file listened to, to the exact place and cluster in the whole recording can be found (or developed) this would make the software a lot more usable.

When comparing the methods, it could be worth to keep in mind that the data in table 1 was collected during April, and that the recordings were all done during the month of May. This can mean that the bird's behaviour might have changed during these weeks and the result can therefore seem to be in favour of the traditional monitoring. But it does show that the methods might work well as a complement to one another. The data in table 1 can for example provide us with the information that there are jays resident in one of the plots. For one visual encounter there's even a nest with eggs in them. The presence of jays is lacking on the recordings, which means that without the personal monitoring the biodiversity measure might be incomplete.

4.2 Methodical conclusion

The recorders have the capacity to provide researchers with a lot of information which later can be analysed. But more evaluation is required before it is possible to determine how well this software can be trained to distinguish and recognize species and individuals before it is possible to say of how much use it can be for getting reliable results in biodiversity, abundance and behavioural studies. However, in this field huge leaps forwards are most likely occurring within both software and hardware, making it more and more useful in the future.
The difficulties in creating a software that is reliable in recognising species, due to within species variation, have been mentioned by other ecologists (Stuart et al, 2012; Towsey, 2014; Gasc et al, 2016) that all concludes that human identification still is necessary.
When looking at table 2 it suggests that with all the advantages the recorder might give, it might still need to be supplemented with visual survey – if the goal of the survey is to catch all species. If the goal is instead to survey changes in biodiversity over time a recorder such as SM4 will be fully capable to provide researchers with more than enough data to do. It's important to remember which species that are likely to inhabit and nest in the plot and not presume that all species recorded are typical for this habitat.

4.3 Ecological conclusion

There is no indication that birds in more open habitat spend more time warning and less time singing due to more exposure to predators and less protection from understory. Instead there's a tendency towards the birds in more complex habitats being more prone to warning. If this should prove to be a trend showing in other areas as well, it could be worth examining if this is due to that birds in more open habitats go quiet as a warning signal instead of call and thus risk the attention of an approaching predator. Whereas the birds in complex habitats can take the risk of warning their neighbours since their calls will be less detectable in the denser understory. In complex habitats there's also a chance that the neighbours haven't noticed the threat due to the more well-built understory and warning calls are therefore more necessary.

4.4 For the future

Should future evaluation of the software show that it has the ability to efficiently distinguish between different types of calls (call for a mate, warning etc.) it would be possible to study behaviour based on the soundscape as well as (for example) note how much stress, and therefore lack of resource it takes to create the fault bars (Möller et al, 2009). The vast knowledge and experiences in the ornithologist community can help developing this relatively new survey method and advances in the technology can in turn improve ornithology and conservation of avian species (Gasc et al, 2016).
The fact that the software can provide the researchers with information on when a species is most dominant in its singing is something that can be useful to know for future single species studies and/or behaviour studies. If the recorder can be set up in the same plot year after year the collected information can be used to examine behaviour changes of inhabitants during pre-breeding season as well as in seasons with less intensive vocalisations. Surveying birds with permanently placed recorders also makes it possible to notice any change in breeding season, the abundance of species as well as the species diversity and maybe even provide the researchers with information about individuals and whether they are returning to the same site over seasons. This in turn might show how many years a bird of a certain

species is in top condition and able to keep a nesting site in a high-quality habitat.

Biodiversity measures can be followed year by year to see if a species is only remaining as a relic, or if the breeding is still successful, and this kind of monitoring can be useful to follow the abundance, species diversity and evenness of a plot for a longer time. For example, the soundscape method could be useful when monitoring and measuring change over time in areas that are affected by for forestry and urbanization, a so called BACI (Before – After – Control – Impact) study designs. It's not always possible, financially or time wise, to measure the biodiversity and abundance of species for a long time before an impact and after it and at the same time keep regular investigations going in a control area. The recording of soundscapes can be a way to keep track of the changes in both abundance and biodiversity for vocal animals.

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