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Conservation study on the Pied Flycatcher (*Ficedula hypoleuca*) in the study area "Großer Ahornboden" (Karwendel, Tyrol)

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Abstract

Long-distance migrating birds are experiencing severe population declines and are affected by changes in their breeding and wintering areas, and in their migratory routes. In particular, the Pied Flycatcher (*Ficedula hypoleuca*) has declined by half in the last 25 years, coinciding with a reduced nesting activity due to a lack of suitable breeding structures. Tracking these changes with efficient and scalable methods, is therefore becoming increasingly important for monitoring the status of *F. hypoleuca* and for implementing further conservation efforts. However, comprehensive data on the occurrence of this species in Austria are still incomplete and critical details, such as migration dates, remain unknown.

Therefore, this study investigates the population of *F. hypoleuca* in its key habitat within the Karwendel region (Tyrol), specifically in the “Großer Ahornboden” area (1 120 to 1 210 m a.s.l.). Arrival at the breeding site, distribution over the area and important structures for territory formation were analysed by 10-day interval mapping from April to August 2023, including five rounds of territory mapping. The results were compared with five near-natural habitats, four of them were located around the Großer Ahornboden and one near “Schloss Tratzberg” (620 m a.s.l.). Additionally, the breeding process and breeding success were monitored by regularly checking 43 nest boxes with an endoscopic camera. Point-count mapping was employed to gather information on synoptic appearing bird species and potential nest predators.

Our results revealed a total of 46 territories and two potential territories within the area Großer Ahornboden and an additional one around Schloss Tratzberg. Evidence of breeding was recorded in 41 of these territories. Moreover, individuals of *F. hypoleuca* were observed from 4 May to 22 July and around Schloss Tratzberg from 26 April to 31 May. The nest boxes contained four to seven eggs with an average of 5.6 eggs per clutch and a hatching success rate of 89.5 %. Regarding the detection of syntopic species, *Fringilla coelebs* was the most common species in all areas.

This study highlights the importance of nest boxes for *F. hypoleuca* in the selection of territories and emphasises the value of the sycamore maple (*Acer pseudoplatanus)* trees in the Großer Ahornboden region. Furthermore, our results provide important insights into the population of this species in the Karwendel region and are a first step towards implementing conservation measures in cooperation with the Karwendel Nature Park.

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1 Introduction

The Pied Flycatcher (*F. hypoleuca*) is a small songbird belonging to the order Passeriformes and the family of Muscicapidae. Known for it´s black & white plumage, this species is a long-distance migrant, breeding in forests from south-western Europe to Belarus and wintering in the mountains of north-western Africa (Keller et al., 2020) (Teufelbauer et al., 2024). In Central Europe, *F. hypoleuca* is distributed with a population of 310 000 to 668 000 breeding pairs, occurring in lowland to montane and alpine regions. In Tyrol, 250 to 450 breeding pairs (between 2014 and 2018) have been counted (Lentner et al. 2022), with a high occurrence of 140 to 240 breeding pairs (between 2010 and 2013) in the north-eastern part of the Karwendel region (Oberwalder et al., 2014). A study in the Karwendel Nature Park in 2014 found a high density of *F. hypoleuca* in the Großer Ahornboden region, which is located in Hinterriß (Tyrol) at an altitude of 1 120 m to 1 210 m a.s.l. (Oberwalder et al., 2014). This area contains a high abundance of approximately 2 200 sycamore maples (*A. pseudoplatanus*). *F. hypoleuca* is known as a hole breeding species using nest boxes or pre-existing tree holes of other species for their breeding process, which is an important factor in their habitat choice (Lentner et al., 2022). At present, however a decline of *A. pseudoplatanus*, due to soil wetness, intensive agricultural use and cattle grazing, is observed and the habitat of *F. hypoleuca* is threatened (Tappeiner et al., 2007). Therefore, it is important to investigate the occurrence of *F. hypoleuca* in this area and to gain an understanding of the breeding process.

Distribution & Migration

F. hypoleuca breeds in boreal and temperate zones and on Mediterranean islands. During the 20th century an expansion of the range was observed, due to the migration of cultural landscapes and the availability of nest boxes in some areas (Glutz von Blotzheim & Bauer, 1993). Variations in plumage coloration have revealed clear geographical differences between the populations. These regional differences are probably genetical and lead to the division into five subspecies: *Ficedula h. speculigera, Ficedula h. tomensis*, *Ficedula h. iberiae, Ficedula h. hypoleuca* and *Ficedula h. muscipeta*. The subspecies *F. h. speculigera* known as the “Atlas Flycatcher” is found in Morocco, northern Algeria and Tunisia and winters in western Africa. The subspecies *F. h. tomensis* is found in the taiga of western Siberia from the Ural Mountains to the Yenisey Rivers. This species is also known as *Ficedula h. sibirica* and winters in eastern Africa. Breeding in the Iberian Peninsula and wintering in western Africa is *F. h. iberiae*, which is morphologically similar to *F. h. hypoleuca* and *F. h. speculigera*. *F. h. hypoleuca* has its type locality in the Netherlands and is occurring from the British Isles and western France to western Siberia and from Scandinavia to northern Italy, wintering in western and central Africa (Salvador et al., 2017). The last subspecies, *F. h. muscipeta,* with a type locality in Germany,

is generally considered to be synonymous with *F. h. hypoleuca,* but has a more brownish plumage and is therefore listed as a separate subspecies. Although the distribution of this species overlaps with *F. h. hypoleuca,* it also occurs in Germany and the Netherlands, but mostly in the habitat of riparian forests of the upper Rhyne valley. *F. h. hypoleuca* is more likely to be found in mixed forests in the foothills of the Alps and in the northern Alps, forming a mountain forest population (Glutz von Blotzheim & Bauer, 1993).

The long-distance migrant follows different routes during migration to and from its breeding sites, showing a looping, counter-clockwise migration (Glutz von Blotzheim & Bauer, 1993). It begins in the winter quarter, south of the Sahara, ranging from Guinea to the Central African Republic. Before and after the crossing of the Sahara, which takes at least eight days, short stopovers have been observed, one before and one after the crossing. Arriving, in the northern part of Africa, different routes were observed depending on the breeding sites, but mostly they are entering Europe via Italy or Greece and fly the shortest route to their breeding site. During the summer/autumn migration one to three stopovers were observed. However, during this migration the route changes and many individuals of *F. hypoleuca* from all over Europe can be found on the Iberian Peninsula. The spring migration usually lasts 14 days, with varying departure dates, but not the duration and the order of females departing and arriving after males. However, the summer/autumn migration does not follow such a strict time schedule and earlier departures of non-breeding males and females with brood loss have been observed. Migration to the wintering area has an average duration of 47.5 days, with arrival between mid-September and early October (Adamík et al., 2023). A well-timed spring migration increases the chance of survival and reproduction of long-distance migrants. However, their migration behaviour may be negatively affected by climate change and facing harsh weather conditions during migration, resulting in high costs and fatigue (Ouwehand & Both, 2017).

Field identification, sounds & vocal behaviour

The size of *F. hypoleuca* is about 13 cm with a weight ranging during the breeding phase and the migration from 11 to 18.3 g. The wingspan is about 21.5 to 24 cm with an average wing length of 80.8 mm for males and 80.4 mm for females. Plumage colouration varies between populations but can be described as grey-brown to black in males and dark brown in females. The underside and throat are bright white in both sexes and there are white patches on the base of the beak and on the secondaries of the wings. There is also a small white stripe, on wing primaries that does not reach the wing margin, distinguishing it from *Ficedula albicollis*. Males have a similar colouration to females during their first winter and summer. The average life span is less than 3.3 years (Bauer et al., 2012).

When the birds are slightly excited, they make sounds like >>zrrt<<, similar to *Troglodytes troglodytes*. During flight and when resting on trees sounds like >>tck tck tck<< or, when more agitated >>zrrrrrt<< can be heard frequently. Their warning call is disyllabic with >>ilü ilü ilü<<, but the second syllable is often unheard. It is also mentioned that regional dialects of warning calls are possible. Their song consists of verses with pure, descending tones. The first part of the verse contains >>tzri<< or >>tvü<<, followed by descending disyllabic elements such as >>dliü-tvi<< or >>didle<< and a final phrase with melodic elements like >>dlü-dlü<<. However, individual variations in the song are common and each male has several verse types. Overall, the duration of the singing activity is short and mostly ends with the onset of the breeding phase (Bergmann et al., 2008) (Bauer et al., 2012).

Diet and foraging behaviour

F. hypoleuca is a diurnal bird, although they do migrate at night. They mostly rest under the closed canopy in the shade of less leafy branches, wherever they also hunt from. Diet is either caught in flight or, during cold and rainy weather, collected directly from the ground or tree branches. The diet mainly consists of flying arthropods and larvae and less commonly berries. Caterpillars and other larvae are caught on the head if possible and thrown onto a hard surface, while soft larvae get swallowed immediately. The birds focus on a hide-hunter strategy, sitting on tree branches, waiting for prey and attacking with a typical nose dive. Food for nestlings is collected within a 50 m radius of their territory, while foraging flights over 100 m are rare (Glutz von Blotzheim & Bauer, 1993). However, due to climate change, a change in diet is possible, which may affect productivity, as loss of caterpillar food has been found to reduce the productivity of this bird species (Goodenough et al. 2009).

Habitat & Breeding biology

The availability of tree holes or nest boxes is the most important habitat selection criteria for *F. hypoleuca*. The food supply is only a limiting factor if there is a high density of birds. Other important habitat structures are tree branches for perching during song, foraging and collecting nesting material (Goodenough et al. 2009). Typical habitats are light, old, deciduous and mixed forests with sparse undergrowth e.g., lowland forests, oak forests and others. If nest boxes are available also parks, cemeteries, gardens and orchards get colonised. *F. hypoleuca* avoids warm climates and therefore occurs in higher regions ranging from 500 m to 1 600 m a.s.l. (Lentner et al., 2022).

Sexual maturity is reached in the first year of life. Males are mostly monogamous, but polygyny has been observed in a few cases. Older males arrive first at the breeding site, followed by younger males and then by females. Upon arrival at the breeding site, males first inspect the area for possible territories until the females arrive and the mating begins immediately

afterwards (Bauer et al., 2012). However, how females select males for mating has been strongly discussed and it has been suggested that they select randomly, due to the short time span of the entire breeding process (Dale & Slagsvold, 1990). During the mating, females begin to build the nests by gathering material from the surroundings, while males sometimes assist. The construction takes four to five days, while a reusage of old nests is rare. The first egg laying in Central Europe begins in mid-May with a clutch size of four to eight eggs and one egg laid per day. The eggs are oval shaped and bale blue in colour, with an average size of 16.6 x 12.7 mm and weighting of 1.65 g. The females incubate the eggs for 13 to 17 days and the juveniles hatch within one to two days. The nestling period is approximately 13 to 17 days long, if there is no disturbance. The juveniles are almost unable to fly, when they have to leave the nest and usually hide among bushes. The breeding season usually ends in July or in some cases in early August (Bauer et al., 2012).

The area Großer Ahornboden

The protected area Großer Ahornboden located in Hinterriß (Tyrol, Austria) is a unique area containing around 2 200 *A. pseudoplatanus* trees that are up to 300-600 years old (Lentner et al., 2022). This important habitat has probably developed over centuries of flooding by the Rißbach river, which has created a sandy and barren soil that is a perfect nutrient provider for maple trees. During this time, *A. pseudoplatanus* trees were able to develop, because the cattle of the farmers were no longer at the Eng Alp for fear of being roped during the thirty-year war. In 1960, the first buses began using the road, that crosses the area to the Eng Alp, and since then, tourism in the area has grown. In 2013, a total of 622 buses, 48 199 cars and 80 motorcycles were counted during the opening of the toll road from May to October. In 2013, however, the number of tourists was much lower than in the years between 1990-2000. This region is not only known for its tourism and agriculture, but also for the important habitat it provides for endangered moss, bat and bird species as well as for *F. hypoleuca* (Kiebacher et al., 2018) (Sonntag & Straubinger, 2019). Although, in recent years a severe decline in canopy vitality and an increased mortality have been observed. Possible reasons for this are the increased soil wetness and the high density of grazing cattle (around 500 cows), which damage tree roots in waterlogged soils, due to the high pressure on the ground. Therefore, it is important to adjust the use of this area and to protect the old habitat (Tappeiner et al., 2007).

In this study we investigate the occurrence of *F. hypoleuca* in the study area Großer Ahornboden. Further, it is analysed how successful the breeding process is in the nest boxes, attached to *A. pseudoplatanus* trees. Further, behavioural information on migration, egg-laying, feeding and hatching will be collected. This information will be compared with near-natural habitats in order to investigate territoriality. During this study we aimed to gain a better

understanding of the population of *F. hypoleuca* in the study area Großer Ahornboden, in order to improve the conservation management. Our observations highlight the importance of the area for *F. hypoleuca* and the high breeding success due to the availability of nest boxes.

2 Material & Methods

2.1 Study locations

A main study area and five additional observation areas were defined in order to implement different methods for studying *F. hypoleuca*. The main study area (Figure 1) and four additional areas (A 1-4) were located in the Großer Ahornboden area (1300 m.a.s.l.) around the Eng Alp in Hinterriß (N 47°23´47.1´´, E 11°33´28.1´´). This area was chosen because of the high number of breeding pairs of *F. hypoleuca* observed during an evaluation for the book “Atlas der Brutvögel Tirols” (Lentner et al., 2022). In total, the main study site covered an area of 105 ha (Figure 2), consisting mainly of sycamore maple (*A. pseudoplatanus*) on an alpine pasture used by grazing animals, especially cows, and surrounded by a spruce forest. The main area is divided into two parts, due to a large part without trees and a crossing street, where we estimated, that this area will not be used by the birds. The four additional sites (A 1-4) in the Großer Ahornboden area were selected by identifying areas of potential habitat for the birds. Two of the plots (A 1&2) bordered the main area to the north and two to the south/west (A 3&4). The vegetation of all four additional plots included *A. pseudoplatanus* on an alpine meadow with a lower density compared to the main plot. The most south-western additional area contained only a few specimens of *A. pseudoplatanus* and was composed of a more mixed forest with *Picea sp*., *Fagus sp*. and *Pinus mugo*. The total size of the four additional plots was 65 ha.

Figure 1 Photo of the main study area in May 2023. © Sandra Schallhart

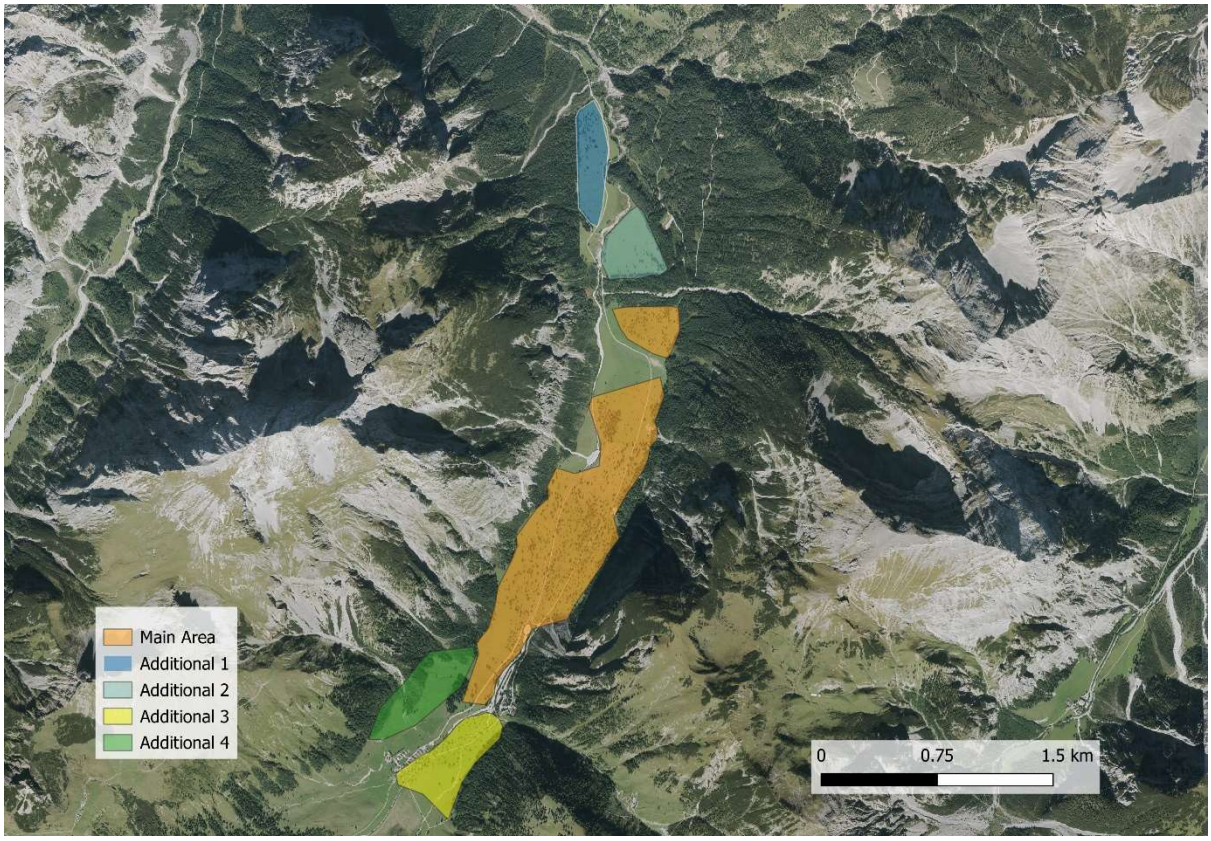

Figure 2 Study areas at Großer Ahornboden (Hinterriß, Tyrol): Showing the main area in orange and the four additional areas 1-4.

The fifth study site (TZ) (Figure 3&4), which was also an additional area was located in Jenbach near the castle “Schloss Tratzberg” (N 47°23´5´´, E 11°44´35´´). It was chosen because a frequent number of breeding areas from *F. hypoleuca* had been observed in previous territory mappings. This study site covered an altitude of 620 m.a.s.l. with mixed forests and grasslands and an area of 73 ha. On 12 April all areas were visited to locate the main study location and the five additional ones.

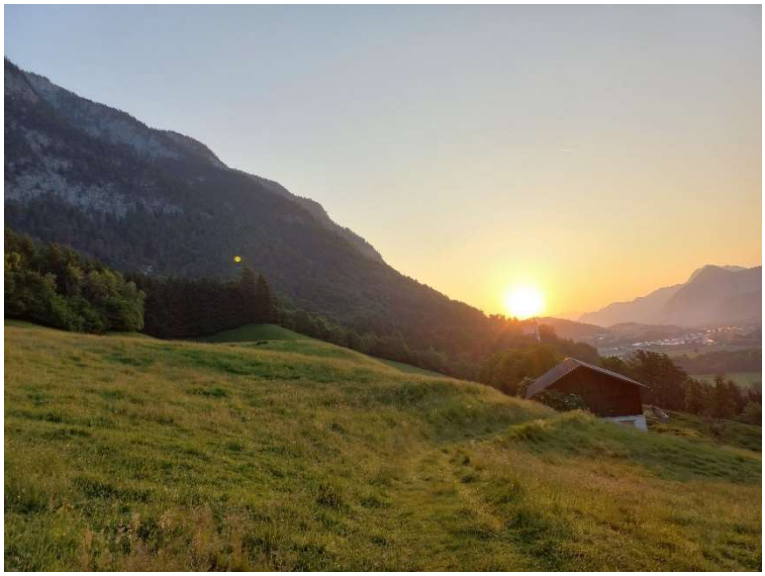

Figure 3 Photo of the additional study area TZ around Schloss Tratzberg. © Sandra Schallhart

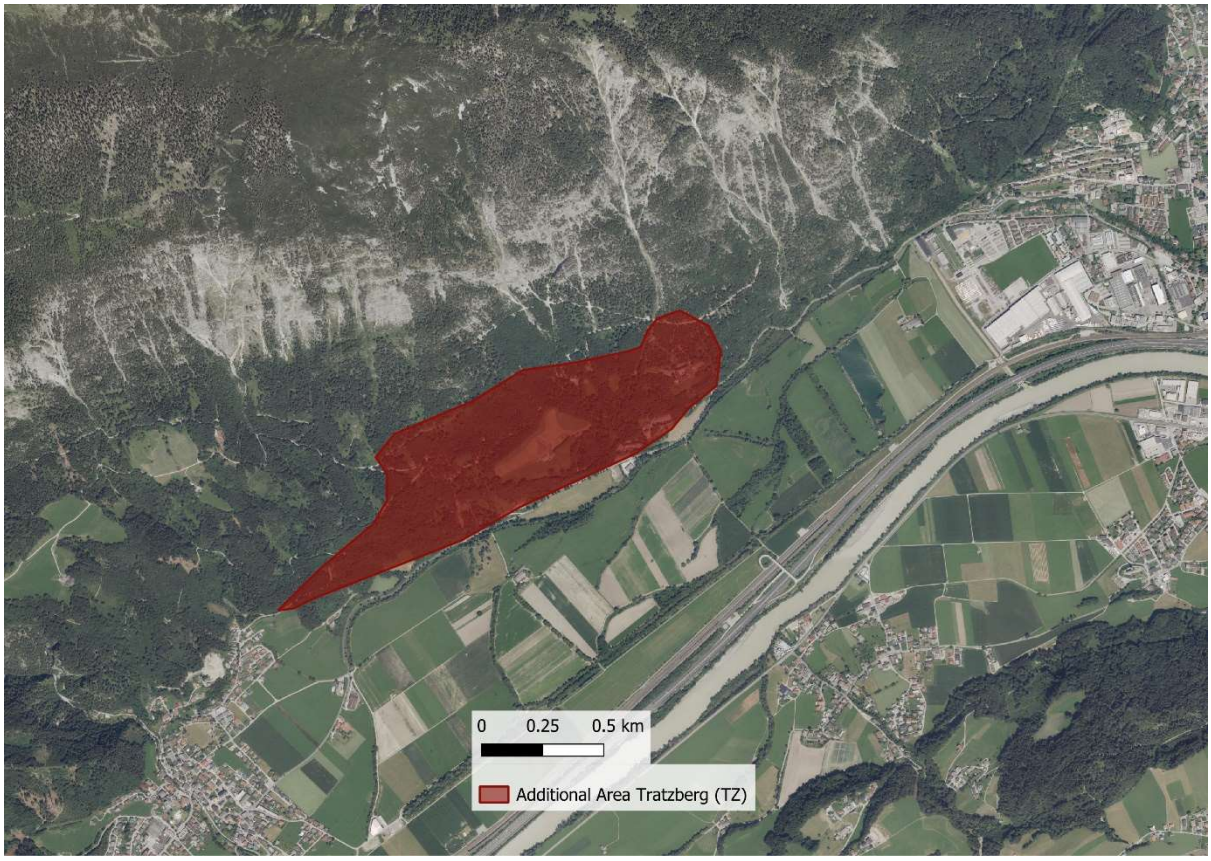

Figure 4 Additional area TZ around Schloss Tratzberg (Jenbach, Tyrol)

2.2 Field methods

The first activity in the field was to map the arrival time of *F. hypoleuca*, which had not yet been determined for Tyrol. This activity started on 21 April and included only the main area in the Großer Ahornboden and the additional area next to Schloss Tratzberg. The plots were visited and walked in a loop at intervals of ten days, with all routes tracked by the GPSMAP 60 CSx device. If no sign of *F. hypoleuca* was observed, acoustic sounds (2x warning sound, 2x singing sound) were played with a high resolution speaker (JBL Clip) at a distance of 400 m. The use of acoutstic sounds was agreed with the department “Abteilung für Umweltschutz, Land Tirol”. This task was repeated until the start of the territory mapping and resumed after the territory mapping was completed to observe the departure of the birds. Observation of the birds during this and all other activities was done with binoculars from Swarovski Optik (NL Pure 10x42) (Figure 5).

Figure 5 Photo of the field equipment (without GPS device and speaker): Map of the territory, binoculars (Swarovski Optik NL Pure 10x42 and endoscopic camera (Depstech 1200P). © Sandra Schallhart

In order to determine the territorial behaviour of *F. hypoleuca* in all study areas, territory mapping was started when the first male singing activity occurred, which was on 20 May. For this purpose, the plots were walked through in loops, with a distance of 50 m between each

loop, and all territorial behaviour e.g. singing, nesting etc., was recorded on an orthophoto of the area. A total of five replications were carried out starting at dawn unless there was no heavy rain. One replication consisted of three days: main area, A 1-4 and TZ. Also during this field work, if no specimens of *F. hypoleuca* could be found over a longer period of time acoustic sounds were used. During the territory mapping a second method was used to get an overview of the synoptic species occurring in the study areas. This was done by a point-count mapping every 15 minutes during the territory mapping. At these time points a period of five minutes of standing without noise was included to be the least disturbing. This was followed by five minutes of counting, during which all bird species that could be seen or heard were recorded. All point-counts were recorded with a phone recorder to be replayed afterwards for species identification. Additional analyses of various parameters were carried out, including vegetation and predators, in a 50 m radius.

Including the information of the 10-day interval mappings and the territory mappings a definition of the bird´s life stages (phase 1-5) was made to compare the use of different sites at each stage. This classification is based on observing the bird´s behaviour in the field and comparing it with literature and other observations. According to (Bauer et al., 2012) these stages would be defined as follows: The arrival of *F. hypoleuca* starts mid/end of April until May and the males arrive > 7 days before the females. The males then fly around the area searching for possible breeding sites. When the female arrives, she begins nest building immediately or up to 14 days later. The first egg is laid from the third decade of April to early May and hatches 14 to 15 days later. The nestling period is 13 to 17 days, after which the juvenile birds fly out. In Central Europe the breeding season ends in July and the migration starts immediately afterwards (Bauer et al., 2012).

To gain a better understanding of the breeding behaviour of *F. hypoleuca* data on the breeding process in nest boxes was collected. Therefore, 43 pre-installed concrete nest boxes (diameter 10.6 cm, height: 24 cm), set up by the Karwendel Nature Park in 2012 were emptied of old nesting material before the arrival of the first birds on 15 March. All nest boxes were placed at different heights and orientations on trees of *A. pseudoplatanus* trees in the main area, except for one nest box, which was located in A 4. All these parameters were noted for further evaluations. At 10-day intervals these boxes were checked with an endoscopic camera (Depstech 1200P) for breeding activity until the fledglings left the nest and took their first flight. The breeding data were then compared with weather information from the GeoSphere Austria.

2.3 Data analysis & Territory classification

Territories were determined by plotting all territorial behaviour signs on paper maps. Territorial signs and subsequent territories were defined according to (Südbeck et al., 2012) and therefore a territory was defined if at least two independent territorial signs (e.g. singing) during two of the five mappings were found in one location. If nesting signs (e.g. eggs, juveniles, bird with food or nesting material etc.) were found, this area was immediately defined as an individual territory. Further, potential territories were defined, where only on one date a bird showed territorial behaviour and on a second day non-territorial behaviour for example warning sounds, was detected. Territories were enclosed from each other mostly through the detection of simultaneously singing birds. Once the territories were defined, they were transferred to the program QGIS 3.30.1, were further analysis and the creation of maps was performed. Further graphs and tables were produced using Microsoft Excel and statistical calculations (e.g. Pearson linear correlation) were performed using the programme PAST 4.13. In order to collect information about the solar radiation in the area and to be able to use template maps in the field, additional maps were created online with tirisMAPS.

3 Results

3.1 Appearance of *Ficedula hypoleuca*

A total of 34 days of fieldwork were conducted, including two days at the beginning to define the boundaries of the study areas and to remove old material from the nest boxes (Table 1). The dates before and after the appearance of the birds in the area and the inclusion of the additional area around Schloss Tratzberg, were chosen to collect information on the arrival and the departure times in the breeding area. The arrival of the first birds was detected between 19 and 24 April 2023 in the area TZ and between 27 April and 4 May 2023 in the main area. The five territory mappings (according to Lentner et al., 2022) were started on 20 May with a 10-day rhythm, depending on the weather situation. Not all areas could be surveyed in one day, therefore one territory mapping round included three days. In some detections, individuals were only recognised by singing and could not be observed with binoculars due to the high density of leaves in the tree canopy, therefore the sex of some birds is not identified (Figure 6).

Table 1 Overview of the field days showing presence (x)/ absence of Ficedula hypoleuca and the counted birds in total. The life stages 1-6 were divided by observations in the area and classified as described in the section Material & Methods. Territory mappings (TM) are shown in grey.

Date	Location	*Ficedula hypoleuca*	Male	Female	Not identified	Life stage
19.04.2023	Tratzberg		0	0	0	1
21.04.2023	Ahornboden		0	0	0	1
26.04.2023	Tratzberg	x	3	1	0	1
27.04.2023	Ahornboden		0	0	0	1
04.05.2023	Ahornboden	x	39	22	0	1
05.05.2023	Tratzberg	x	2	0	0	2
09.05.2023	Ahornboden	x	41	24	2	2
13.05.2023	Ahornboden	x	41	36	4	2
20.05.2023	Ahornboden	x	3	1	3	3/TM
21.05.2023	Ahornboden	x	40	35	5	3/TM
22.05.2023	Tratzberg	x	0	1	1	3/TM
29.05.2023	Ahornboden	x	33	34	7	3/TM
30.05.2023	Ahornboden	x	0	0	4	3/TM
31.05.2023	Tratzberg	x	0	0	2	3/TM
08.06.2023	Tratzberg		0	0	0	3/TM
10.06.2023	Ahornboden	x	30	33	8	4/TM
11.06.2023	Ahornboden	x	0	0	5	4/TM
18.06.2023	Tratzberg		0	0	0	4/TM
19.06.2023	Ahornboden	x	32	33	6	4/TM
21.06.2023	Ahornboden	x	1	2	1	4/TM

Date	Location	*Ficedula hypoleuca*	Male	Female	Not identified	Life stage
30.06.2023	Tratzberg		0	0	0	5/TM
01.07.2023	Ahornboden	x	2	3	2	5/TM
02.07.2023	Ahornboden	x	17	13	10	5/TM
11.07.2023	Ahornboden	x	1	2	0	5
12.07.2023	Tratzberg		0	0	0	5
21.07.2023	Tratzberg		0	0	0	5
22.07.2023	Ahornboden	x	1	2	0	5
04.08.2023	Tratzberg		0	0	0	5
05.08.2023	Ahornboden		0	0	0	5
12.08.2023	Ahornboden		0	0	0	5
17.08.2023	Tratzberg		0	0	0	5
24.08.2023	Tratzberg		0	0	0	5

Figure 6 Pictures of a male individual of Ficedula hypoleuca (left) and a female individual (right). © Sandra Schallhart

The number of *F. hypoleuca* after the arrival was stable until the departure of the first birds and ranged mostly between 70 and 80 individuals (Figure 3). The highest number of birds counted in one day, was in the main area on 21 May with a total of 87 individuals. The number of detected males and females was mostly equal, except during the arrival timepoint of the birds, where the males were disproportional due to the late arrival of the females. The departure of *F. hypoleuca* in the main area started on 2 July and the last birds were observed on 22 July 2023.

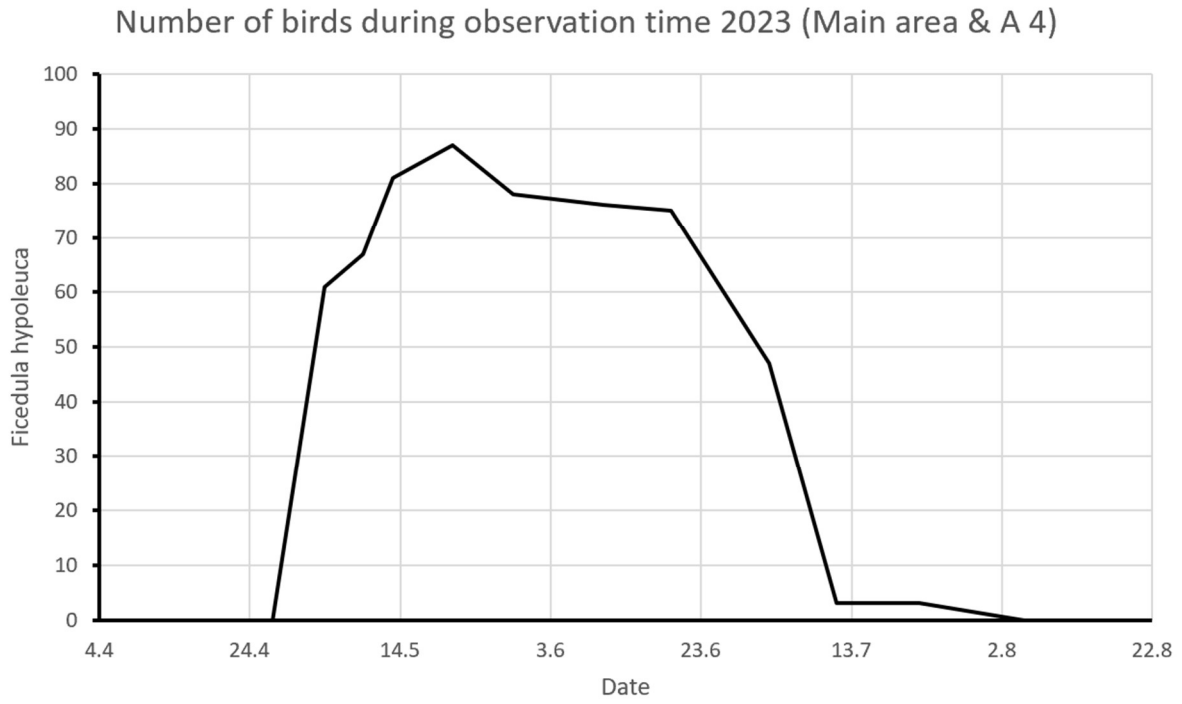

Figure 7 Numbers of Ficedula hypoleuca individuals, which were present on the current date in the main area and the additional area 4.

3.2 Territory mapping and distribution in the study areas

Territories

Overall, 42 territories and two potential territories were recorded in the main area (Figure 8). In A 4 four territories were detected. No territories were counted in any of the other additional areas in Großer Ahornboden. For 39 territories in the main area the determination of a territory was based on evidence of breeding. This evidence mostly consisted of birds bringing in nest material into nest boxes and occupying nest boxes with eggs. Breeding behaviour was also observed for the two southern territories in A 4. For the other two territories in A 4 no breeding signs were observed, but two times simultaneous singing males were detected on two different observation days. There was no evidence of breeding in any of the potential territories and only once simultaneous singing males were detected, but several times singing *F. hypoleuca*

could be heard. The distribution of the territories was mostly spread over the whole area, where sycamore maple trees grow and only a few were located near the transition to the closed forest.

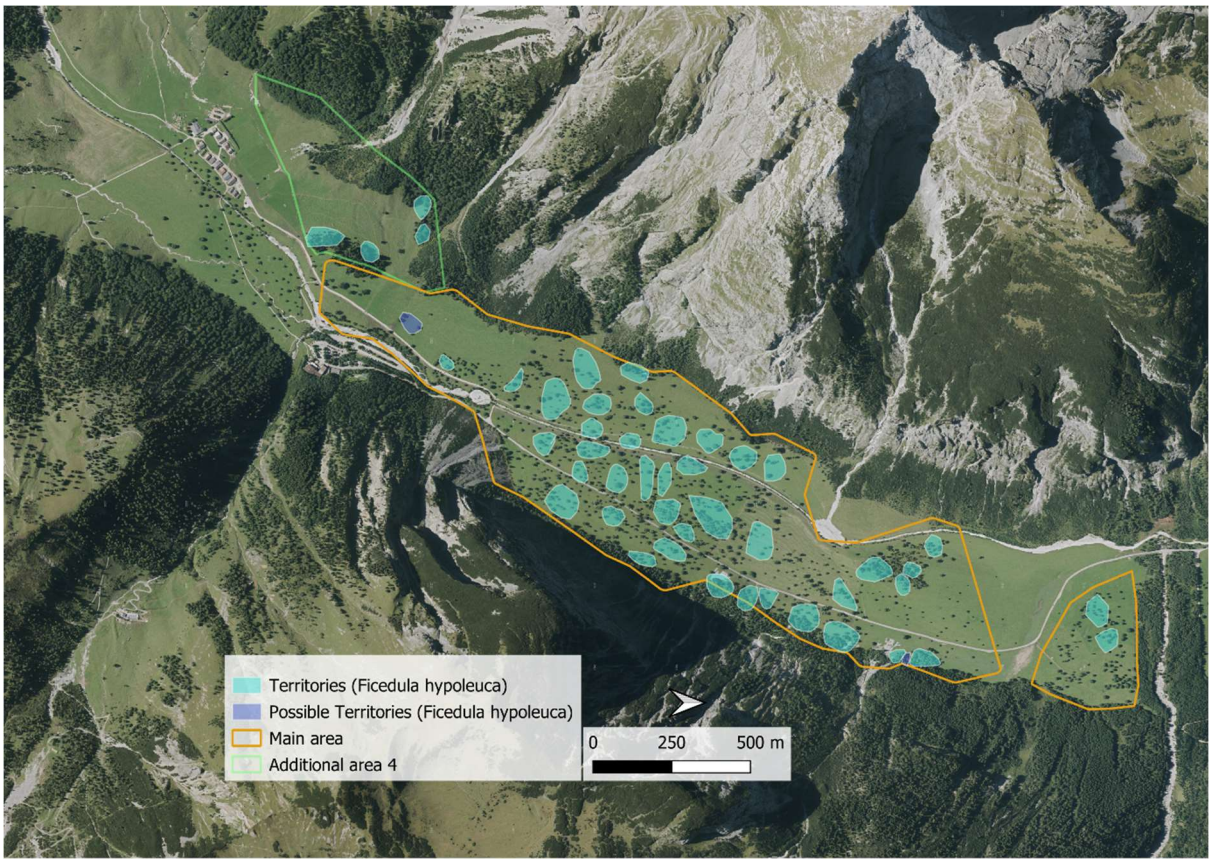

Figure 8 Displaying the territories (light blue) and the possible territories (dark blue) of Ficedula hypoleuca in the main area and the additional area 4. The lines mark the boundaries of the areas.

In the additional area TZ only one territory was recorded (Figure 9), which was located in a part of the forest, where mostly *P. sylvestris* was dominant and nearby a large area with open grassland. For this territory there was no evidence of breeding behaviour observed, but three times a singing male and also an alerting female were detected. However, in this area on 31 May *F. hypoleuca* was observed for the last time during the observation period.

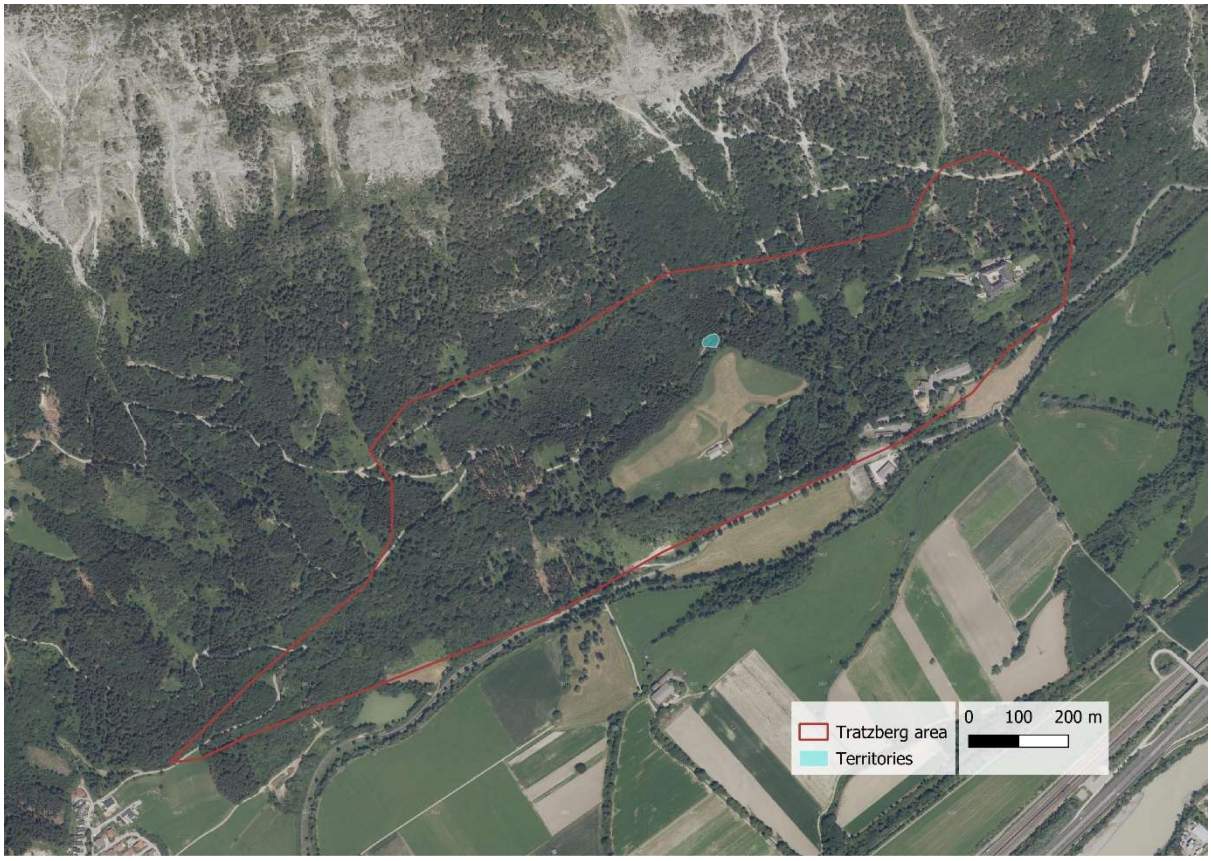

Figure 9 Displaying the territory (light blue) in the additional area around Schloss Tratzberg. The red line marks the boundaries of the area.

Distribution in the study area

To visualise the locations used by *F. hypoleuca* during the different life stages in the main area, maps were created using QGIS. To count how many individuals were in a particular location at a particular time, grids were drawn over the map and numbered (Figure 10). These maps were also used to visualise the change in location from one life stage to another, and therefore, to understand, which habitat type is important for *F. hypoleuca*. The same procedure was followed for all additional habitats, presented in the chapter 3.4. The area at Großer Ahornboden could be divided into 161 grid cells, of 200 m^2 each. During the appearance of *F. hypoleuca* in the breeding area, 66 of the 161 grid cells were occupied, with the density of occupation varying (Figure 11). The highest number of overall detected individuals was in A 147. The change of the densities between the different life stages is shown later in this chapter.

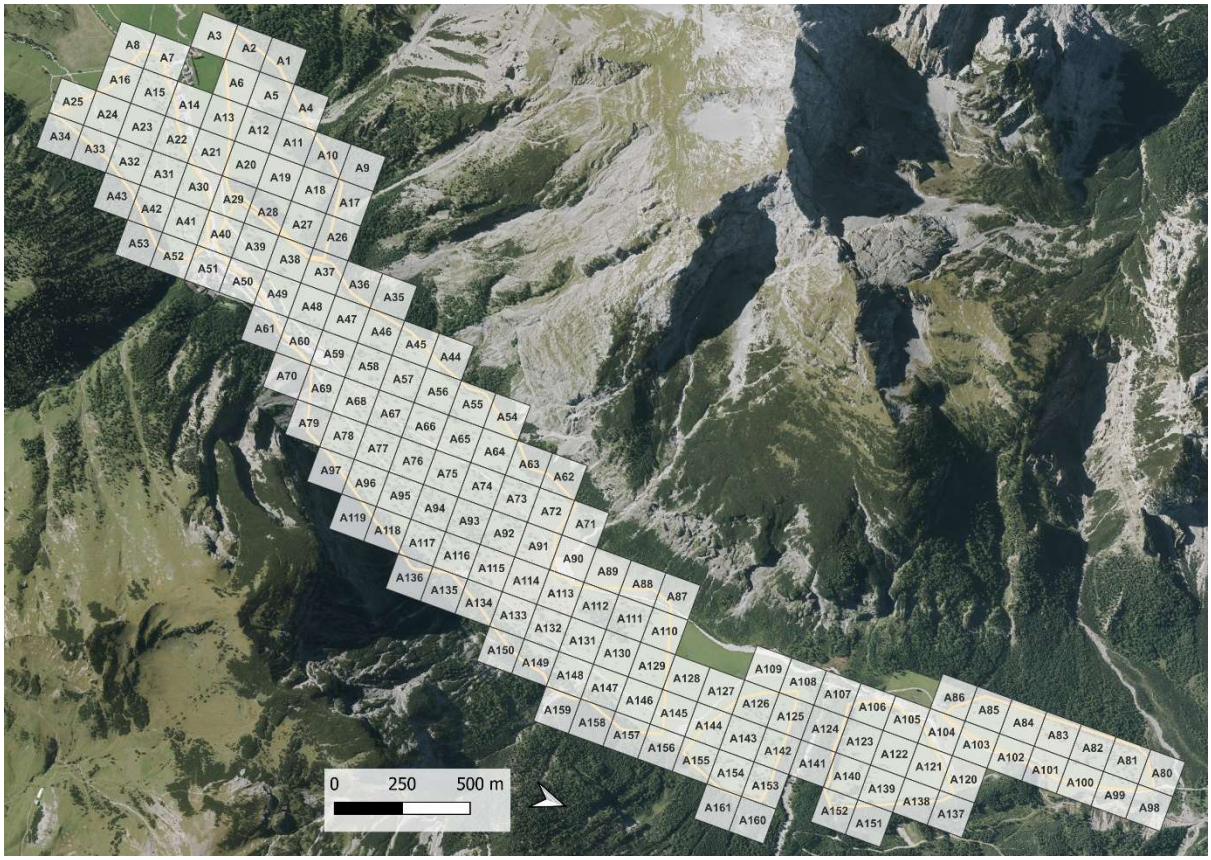

Figure 10 Showing the area Großer Ahornboden with an overlaying grid layer, where each grid has an own number. One grid has an area of 200 m².

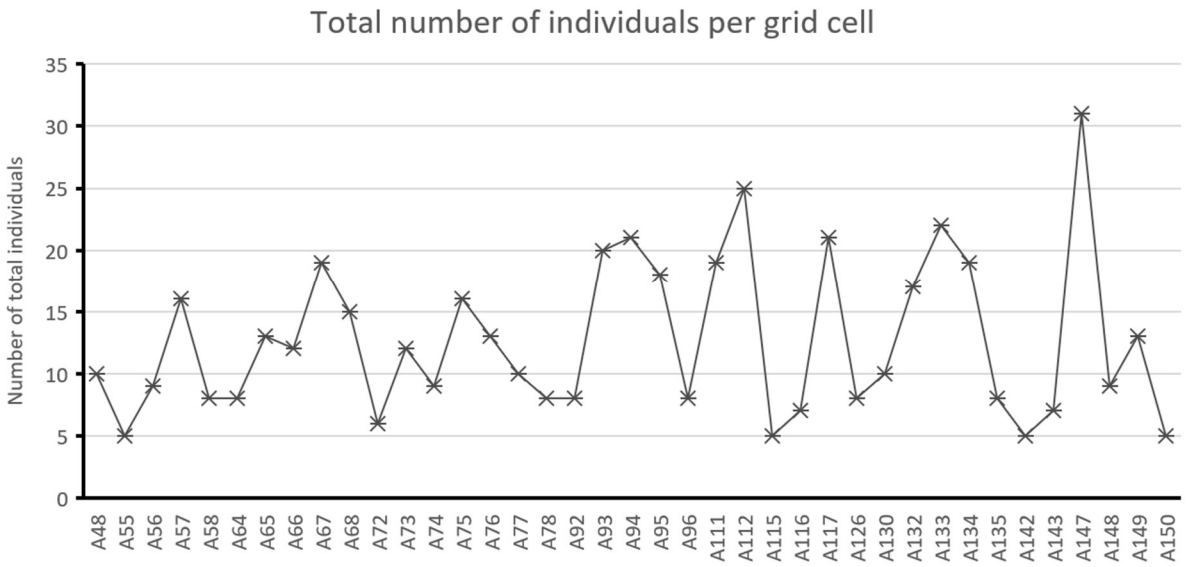

Figure 11 Total number of Ficedula hypoleuca individuals per grid cell over all observation dates, only including grids which show an overall minimum occupation of five or more birds.

On 4 May (phase 1), when the first sighting of *F. hypoleuca* occurred in the main study area, 39 males and 22 females were already observed. The specimens were already distributed

throughout the main area and only in the second part of the main area on the eastern side no birds were detected (Figure 12). A few males began to sing, but the most common activity recorded was birds making warning sounds. Some individuals were also feeding, flying from one tree to another or resting in the canopy of the sycamore maple trees. Only in the south were birds detected near or at the transition line to the forest.

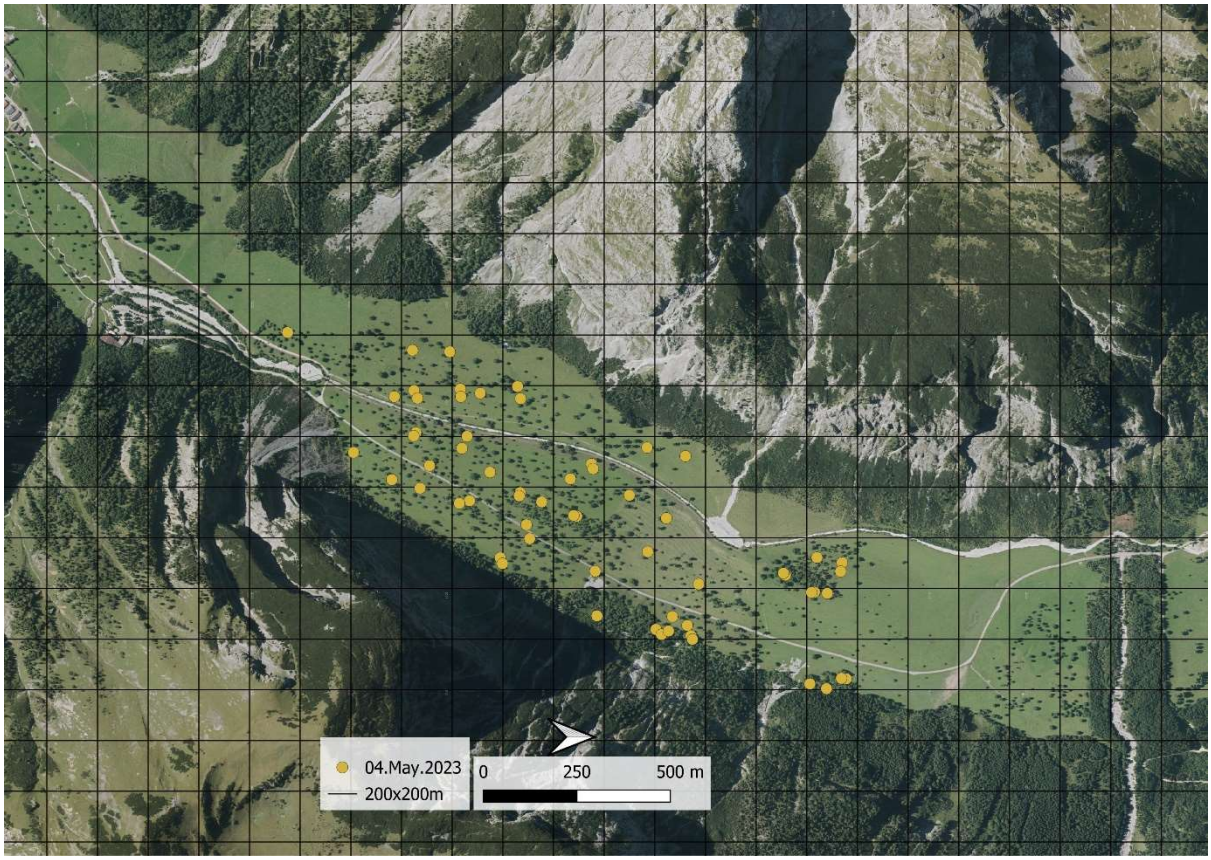

Figure 12 Distribution of Ficedula hypoleuca in phase 1 in the area Großer Ahornboden. The yellow dots represent an individual on 4 May 2023.

The observation dates of 9 May and 13 May were connected into phase 2, because at this time the singing activity of the males increased immediately, which distinguishes this phase from phase 1 (Figure 13). The birds were still distributed throughout the area, but in this phase birds could also be observed in the easternmost part of the main area. Most of the males were singing or sitting on a tree near a nest box. Some birds were observed in pairs. On 13 May, a male was observed with a *Dendrocopos major* pair fighting over a tree hole near the transition to the forest in the southern part of the site. Females were observed making warning sounds or carrying nest material. During this phase several birds were detected near the main road to the Eng Alp, which was still in rough use at the time.

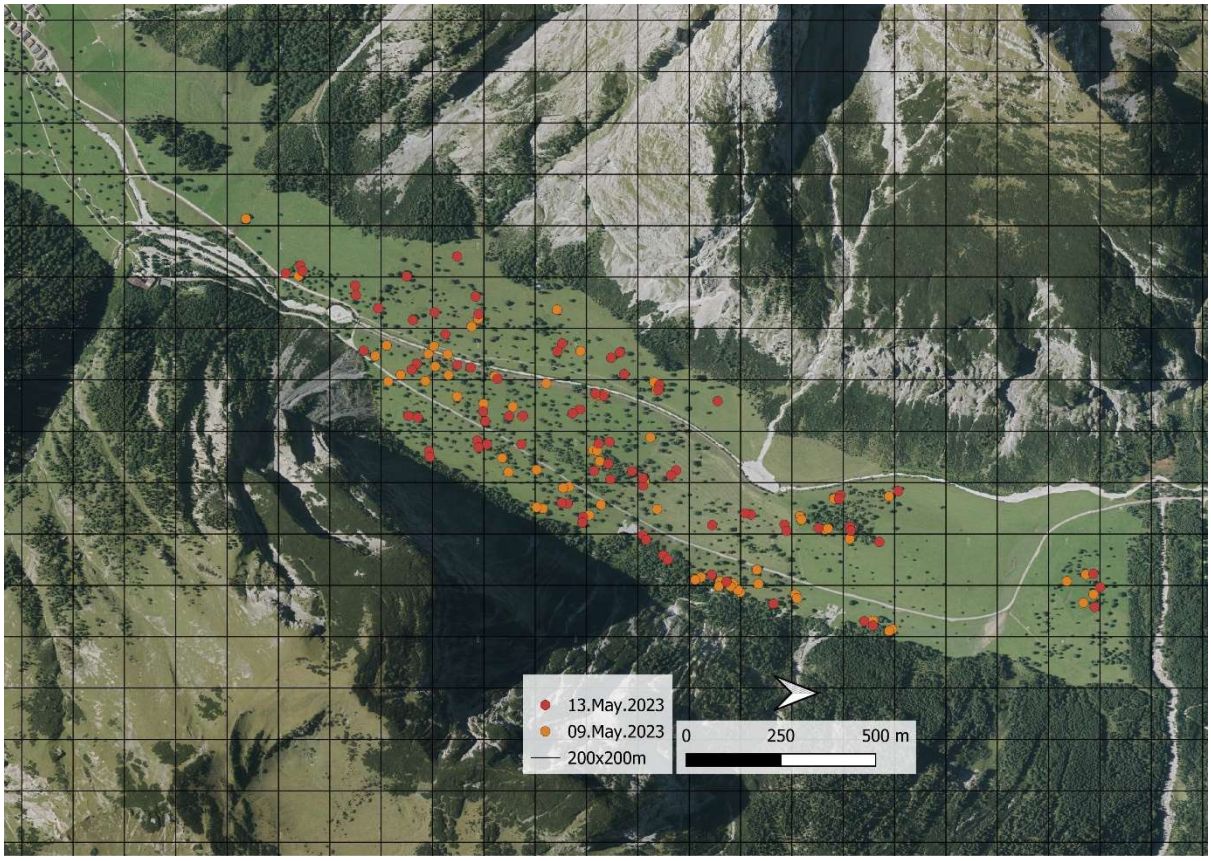

Figure 13 Distribution of Ficedula hypoleuca in phase 2 in the area Großer Ahornboden. The orange dots represent individuals on 9 May 2023 and the red ones individuals on 13 May 2023.

Phase 3 shows a lower density of birds in the centre of the area, but more birds at the edge of the observation area and also some that have moved to A 3 and A 4 (Figure 14). This phase includes the observations dates on the 21 May and the 29 May. Both of these observations were already part of the territory mapping and compared to phase 2, most birds were spotted in pairs. They were mostly either flying around or sitting near nest boxes and making warning sounds. In comparison to phase 2 the singing activity of the males decreased. The female birds were collecting nest material and bringing it to the nest boxes. On 21 May the first eggs in the nest boxes were visible.

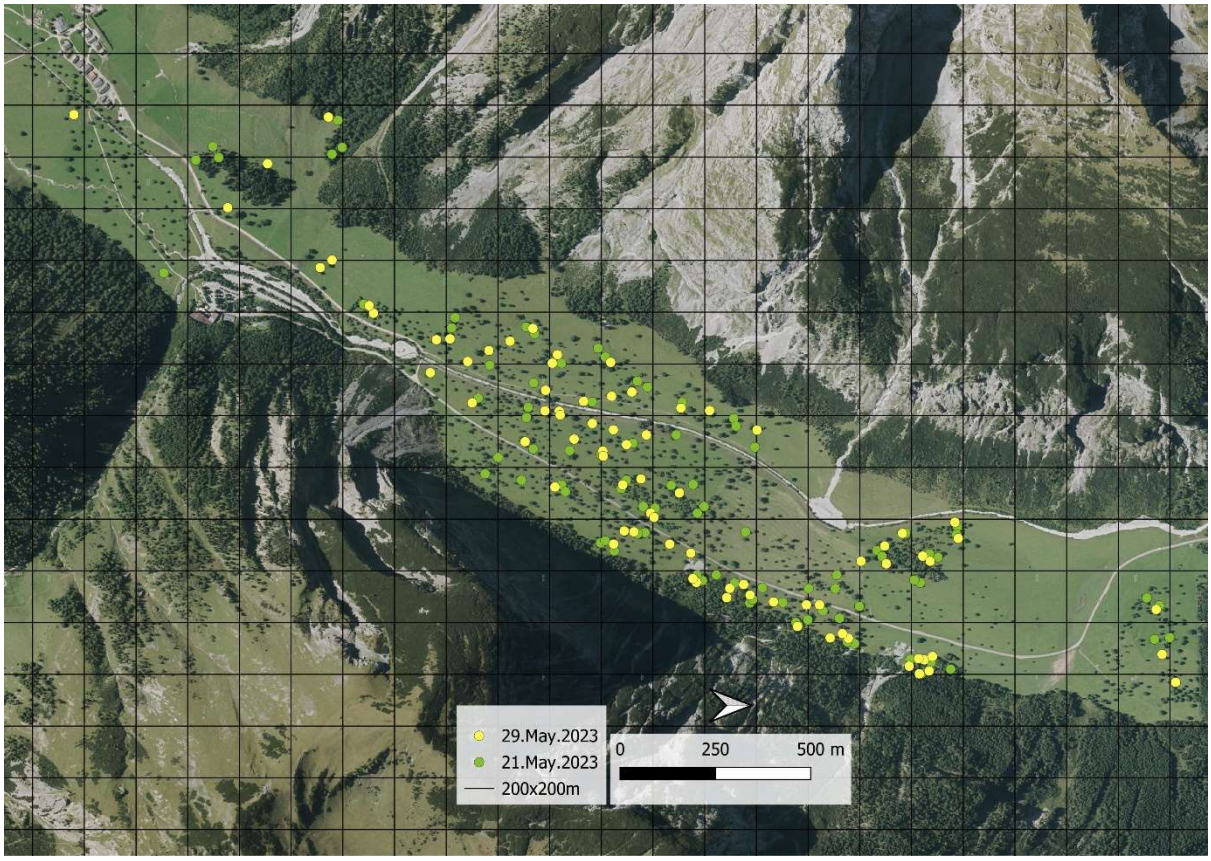

Figure 14 Distribution of Ficedula hypoleuca in phase 3 in the area Großer Ahornboden. The green dots represent individuals on 21 May 2023 and the yellow dots individuals on 29 May 2023.

The territory mappings of 10 and 19 June form phase 4 (Figure 15). The dots of the two observation days partly overlap, which shows that the distribution of *F. hypoleuca* is similar on both days. During this phase, females were mostly observed incubating eggs or already feeding their first hatchlings. Males were mostly spotted near nest boxes, making warning sounds when approached or foraging near the breeding site. The density of birds per grid in the southern part of the main area at the transition to the forest is higher than in the northern part. This fact can also be seen in Figure 14.

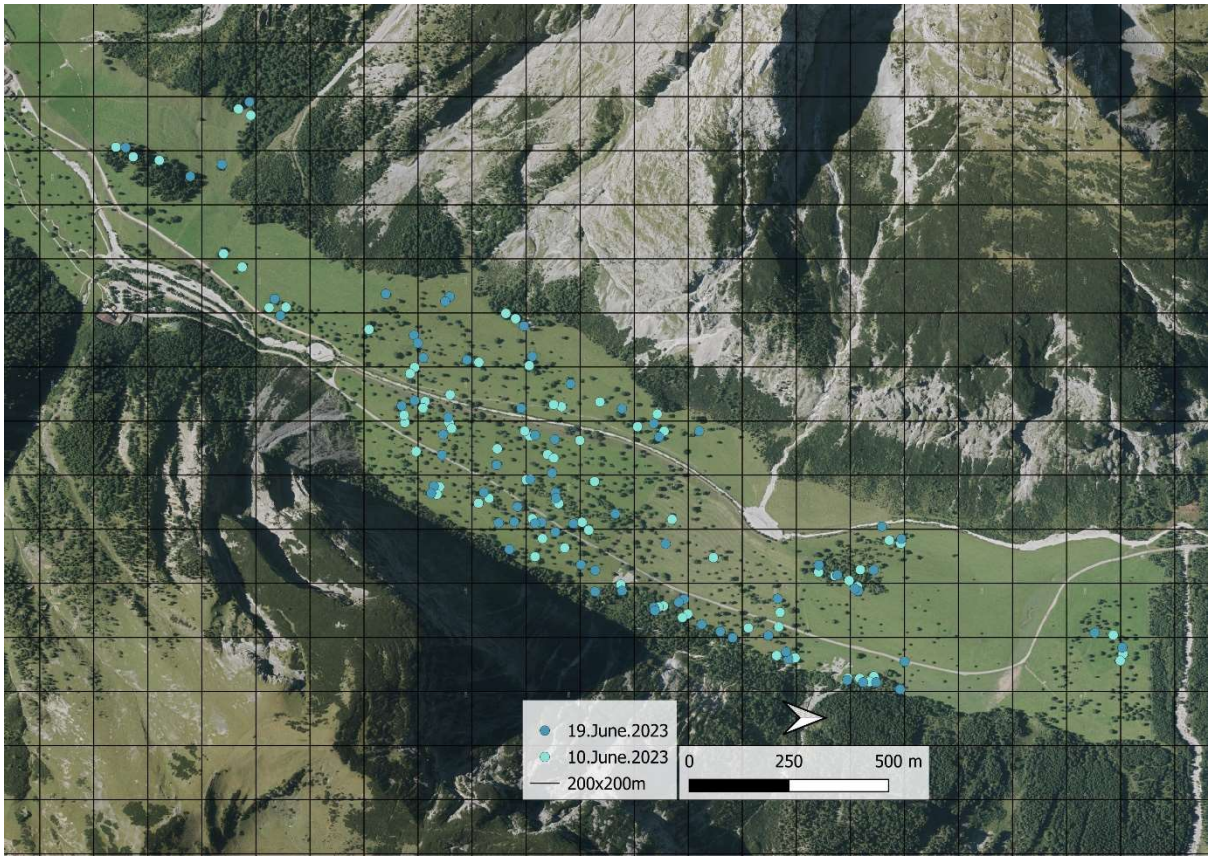

Figure 15 Distribution of Ficedula hypoleuca in phase 4 in the area Großer Ahornboden. The light blue dots represent individuals on 10 June 2023 and the dark blue dots individuals on 19 June 2023.

Phase 5 began on 1 July and in total 40 birds were observed in the main area on this day (Figure 16). The population decreased mainly in the centre of the main area and concentrated more on the edges of the study site. On 11 July and on 22 July only three individuals of *F. hypoleuca* were spotted. On 11 July two nest boxes were still occupied and the birds were observed by feeding their fledglings. On 22 July, only one nest box in the southern part of the area was occupied with fledglings and one pair was sitting on the tree where the nest box was attached. The other female, which was counted on this day was resting in the canopy nearby. After the 22 July, no individuals of *F. hypoleuca* were detected in any parts of the main area or the additional areas for the rest of the observation period.

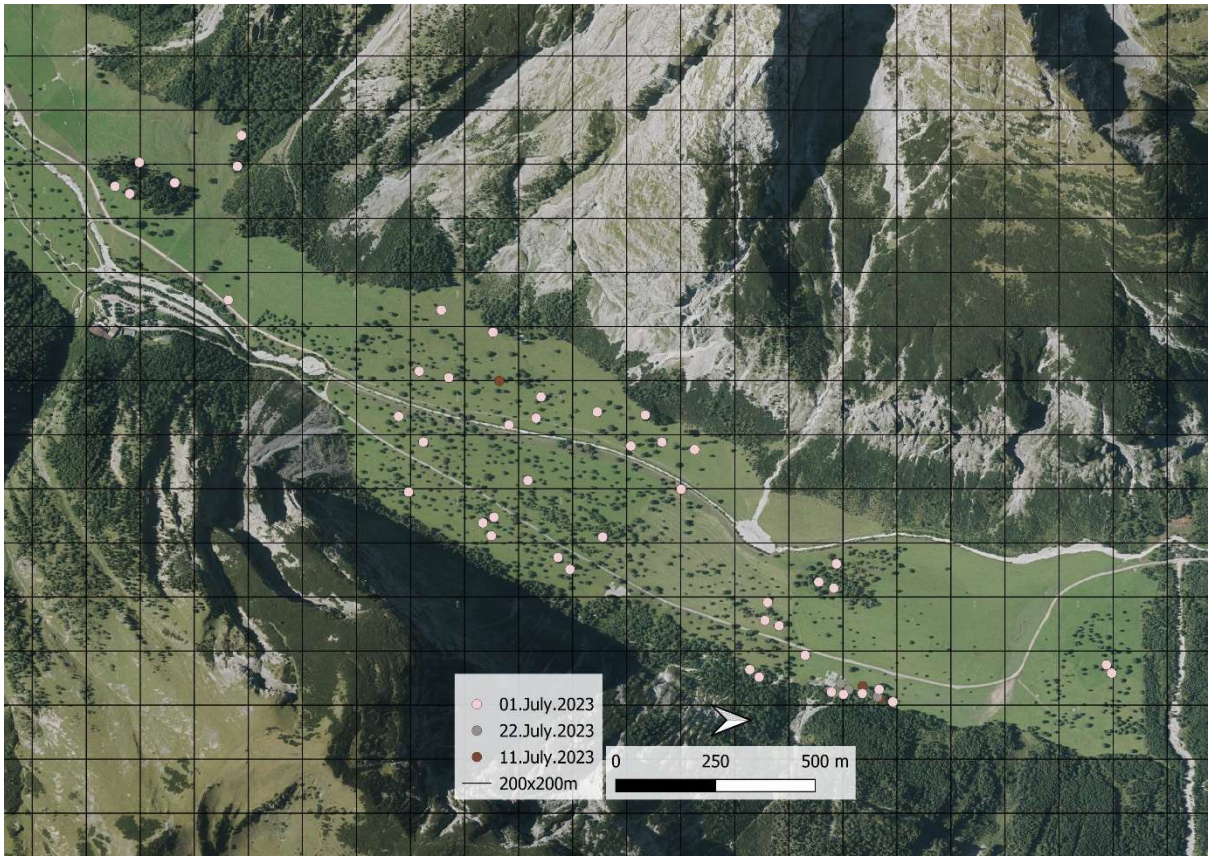

Figure 16 Distribution of Ficedula hypoleuca in phase 5 in the area Großer Ahornboden. The light dots represent individuals on 1 July 2023, the grey dots individuals on 22 July 2023 and the brown ones individuals on 11 July 2023.

The density in the grids ranged from zero to 31 detected birds (Table 8 Appendix). The grids with the highest densities across all field dates were: A 93, A 94, A 112, A 117, A 133 and A 147. In all of these, more than 20 birds were detected over the observation period, bearing in mind that it may be the same birds on different days. The location of the high-density grids included the central area and some parts of the southern area. The average number of birds per occupied grid per observation day is one bird per grid (standard deviation = 1.4). In terms of territories, there were several ones that were not only part of one grid, but extended into two or even three grids. A 56 and A75 contained two whole territories in one grid. On the other hand, there were also grids where birds were detected during the mapping but no territory was included in the grid. However, the average number of territories per occupied grid is 0.7 (standard deviation = 0.6).

In order to visualise the change between the phases, maps were produced with QGIS, showing the grids that did not change and those where the number of detected birds increased or decreased. From phase 1 to phase 2 most of the grids show an increase of one to five birds (Figure 17). This underlines the numbers presented in Table 1, where it was shown that the total number of birds in the main area increased from phase 1 to phase 2. Further, there were stronger increases of six to ten individuals per grid, observed in A 93, A 117 and A 112. On the other hand, seven grids, including A 66, A 91, A 94, A 118, A 130 and A 134 showed a decrease in the number of the birds between one and five individuals.

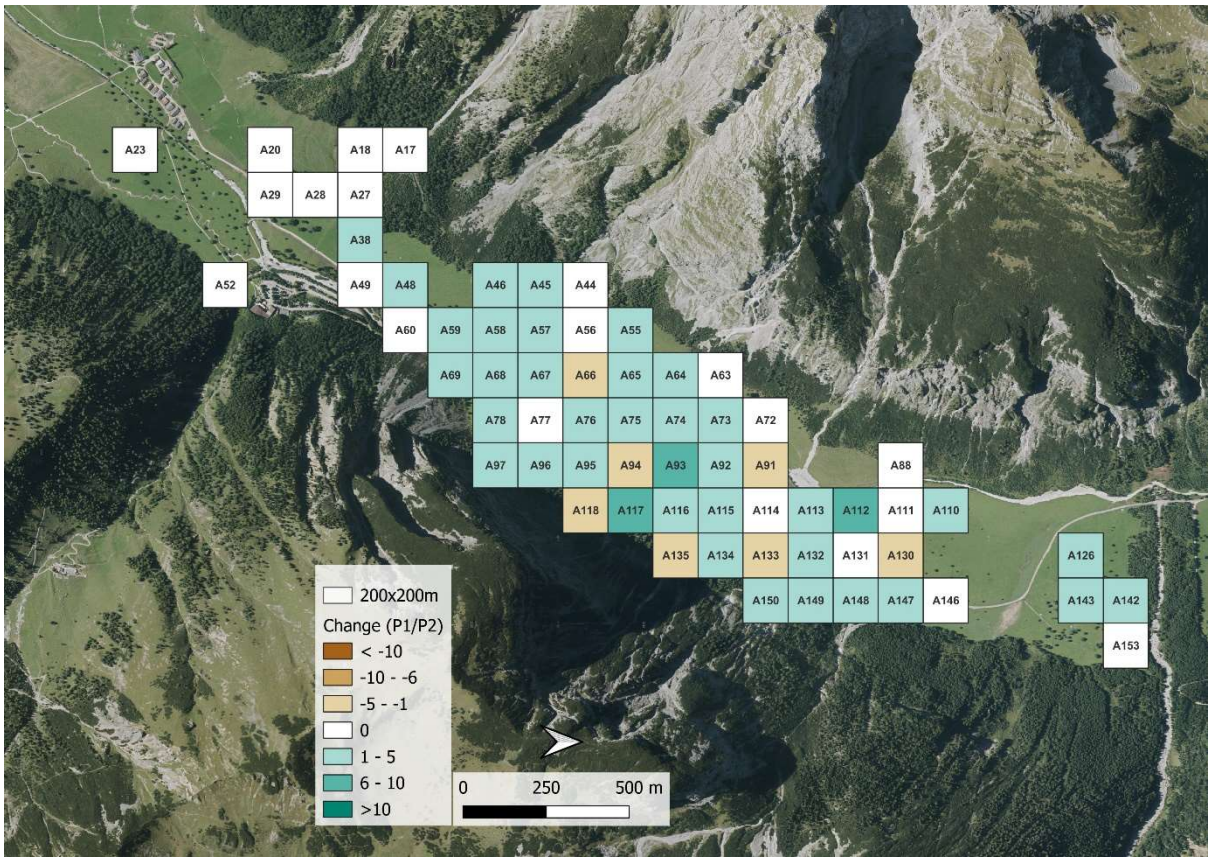

Figure 17 Showing the change from phase 1 to phase 2. The colours show in which grid the number of detected birds increased (blue) and where it decreased (brown). The intensity of the colour indicates the rate of change and the colour white displays no change.

From phase 2 to phase 3, most of the squares had previously decreased between one and five birds. (Figure 18). On the other hand almost half of the sites showed an increase between one and five birds, including almost all the grids belonging to the additional areas 3&4. Overall, there was no indicative change in number of individuals than a maximum of five birds, which shows that the movement of *F. hypoleuca* is heavily linked to the territories. One third of the grid cells did not change between the two observation dates.

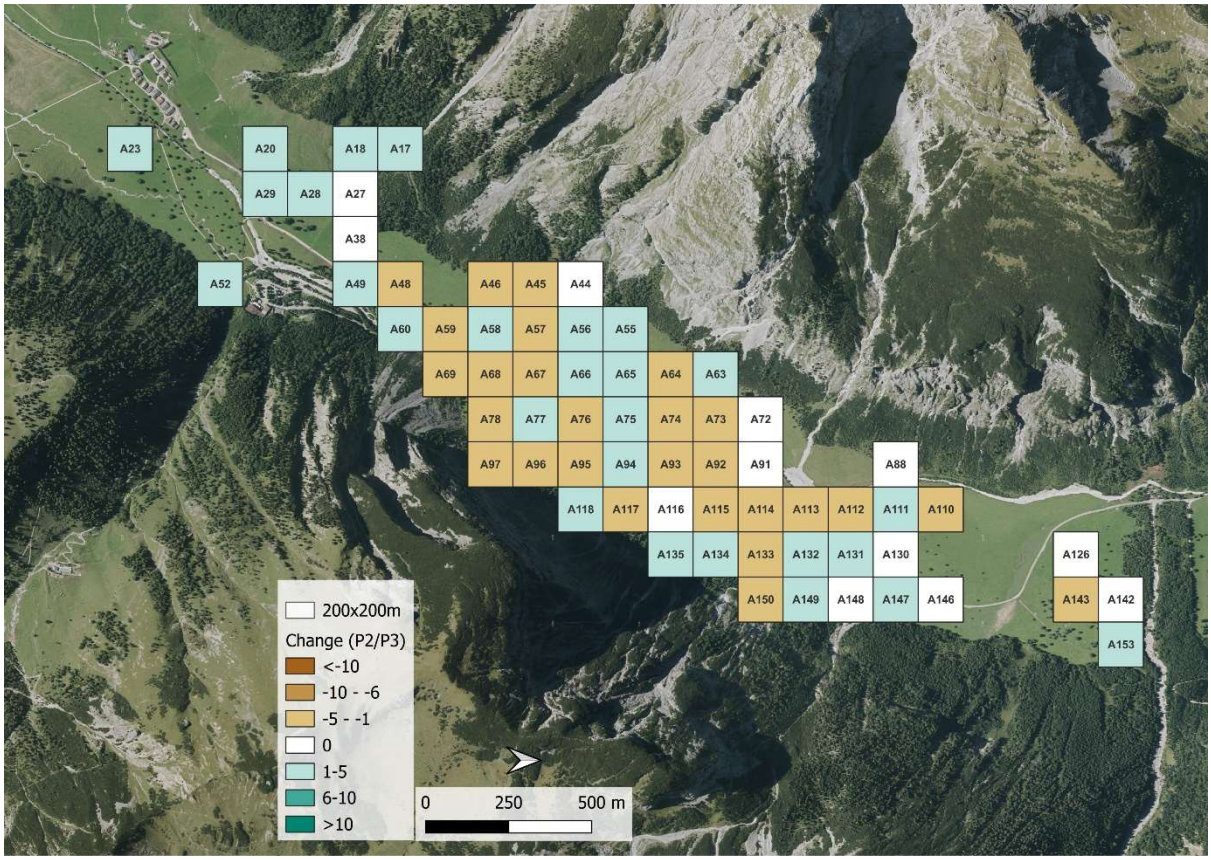

Figure 18 Showing the change from phase 2 to phase 3. The colours show in which grid the number of detected birds increased (blue) and where it decreased (brown). The intensity of the colour indicates the rate of change and the colour white displays no change.

There was no change in the bird density from phase 3 to phase 4 visible in most of the squares that are centred on the main area (Figure 19). In 19 grid cells the number of birds decreased between one and five birds. In all the other areas a decrease of one to five individuals was registered, particularly in the eastern part of the main area. Again, in this map, no major change of more than five individuals per square was observed. Phase 3 and 4 are the time points when most birds were observed incubating eggs or feeding the hatchlings.

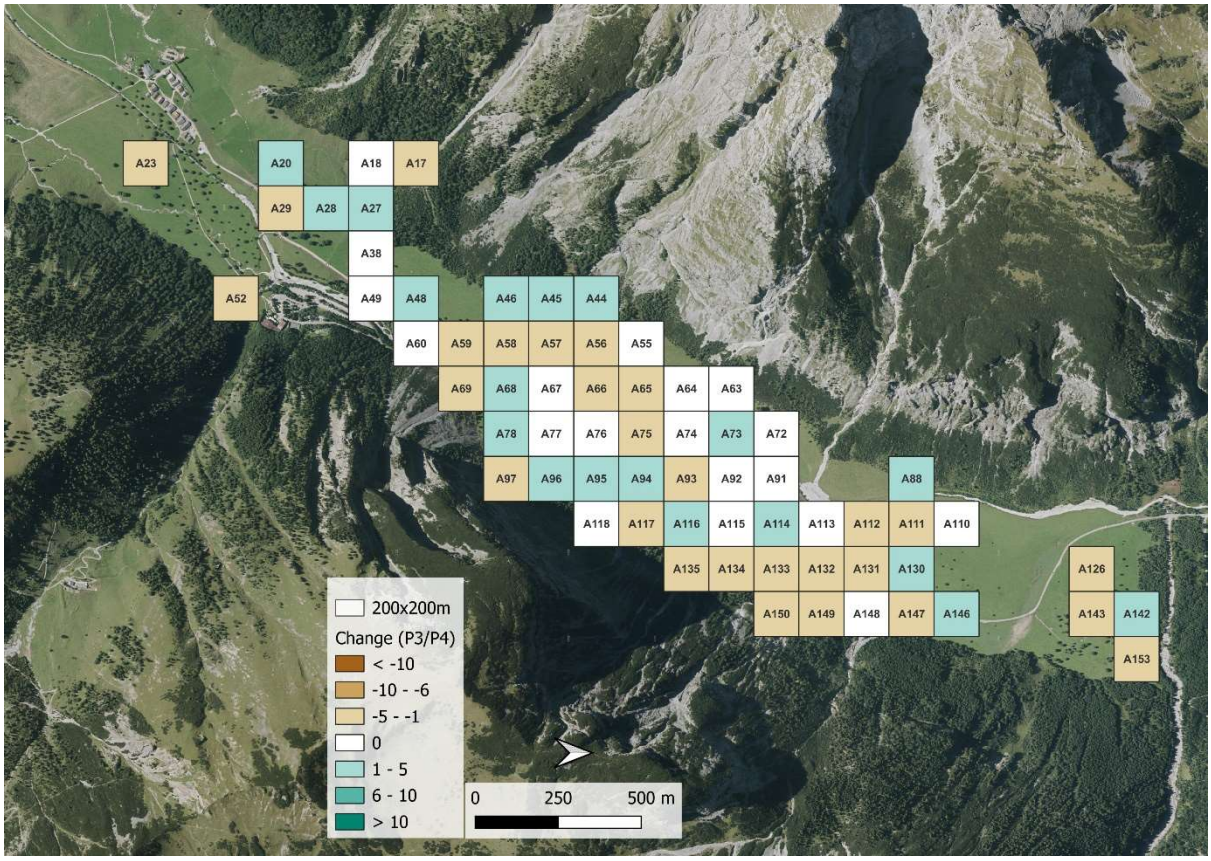

Figure 19 Showing the change from phase 3 to phase 4. The colours show in which grid the number of detected birds increased (blue) and where it decreased (brown). The intensity of the colour shows the rate of change and the colour white displays no change.

The change in bird density between phase 4 and phase 5 showed the strongest decrease compared to the previous phases (Figure 20). In the fields A 34 and A 134 was even a decrease of between six and ten birds counted. This fact is supported by the total number of *F. hypoleuca* counted in the main area in phase 5, where a strong departure from this area was observed. On the other hand, there were six grid cells that increased by between one and five birds, which were located on the edges of the field and near the transition line to the forest. The last occupied nest box, where juveniles were still inside in phase 5, was located in two of the increasing areas.

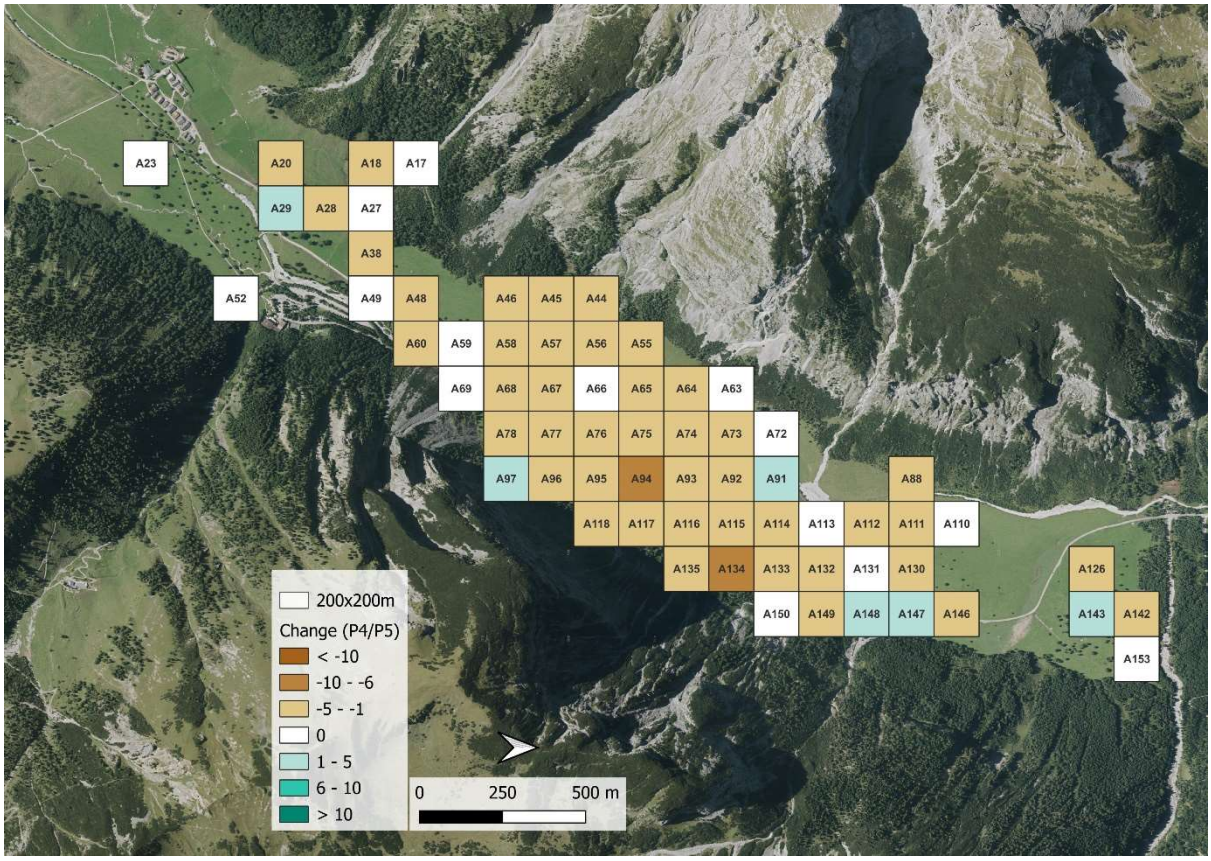

Figure 20 Showing the change from phase 4 to phase 5. The colours show in which grid the number of detected birds increased (blue) and where it decreased (brown). The intensity of the colour indicates the rate of change and the colour white displays no change.

3.3 Breeding behaviour

Breeding locations (Nest boxes)

A total of 43 bird nest boxes were available, distributed over the Großer Ahornboden area (Figure 21). All these boxes were emptied of old nesting material on 15 March. Most of the boxes consisted of the same type as those used in the Alpenzoo Innsbruck and were made out of concrete (Figure 22). The entrance hole had a diameter of 3.2 cm and the distance from the hole to the bottom of the box was 13.5 cm, measured from outside. The diameter of the internal floor was 10.6 cm with a height of 24 cm tapering towards the roof, and the external dimensions were 14 cm in diameter. This model was installed in 2012 by the Karwendel Nature Park on *A. pseudoplatanus* trees, with different heights ranging from 150 cm to 250 cm as well as different orientations. Previously, there were nest boxes set up earlier with different models, one made of wood (hole: 3.2 cm, distance to the ground: 13.5 cm, base: 17x14 cm, height: 19 cm) and one made of concrete with the same dimensions as the wooden ones. However, most of them had already been destroyed and only one of the wooden boxes and four boxes of the other type were still available for *F. hypoleuca*. The airline between the nest boxes was

measured through a distance matrix in QGIS and the average distance between two nest boxes was 89.6 m (standard deviation= 80). The nearest nest boxes V 27 and V 28 showed a distance of 14.6 m. Except for one nest box (in A 4), all boxes were part of the main area.

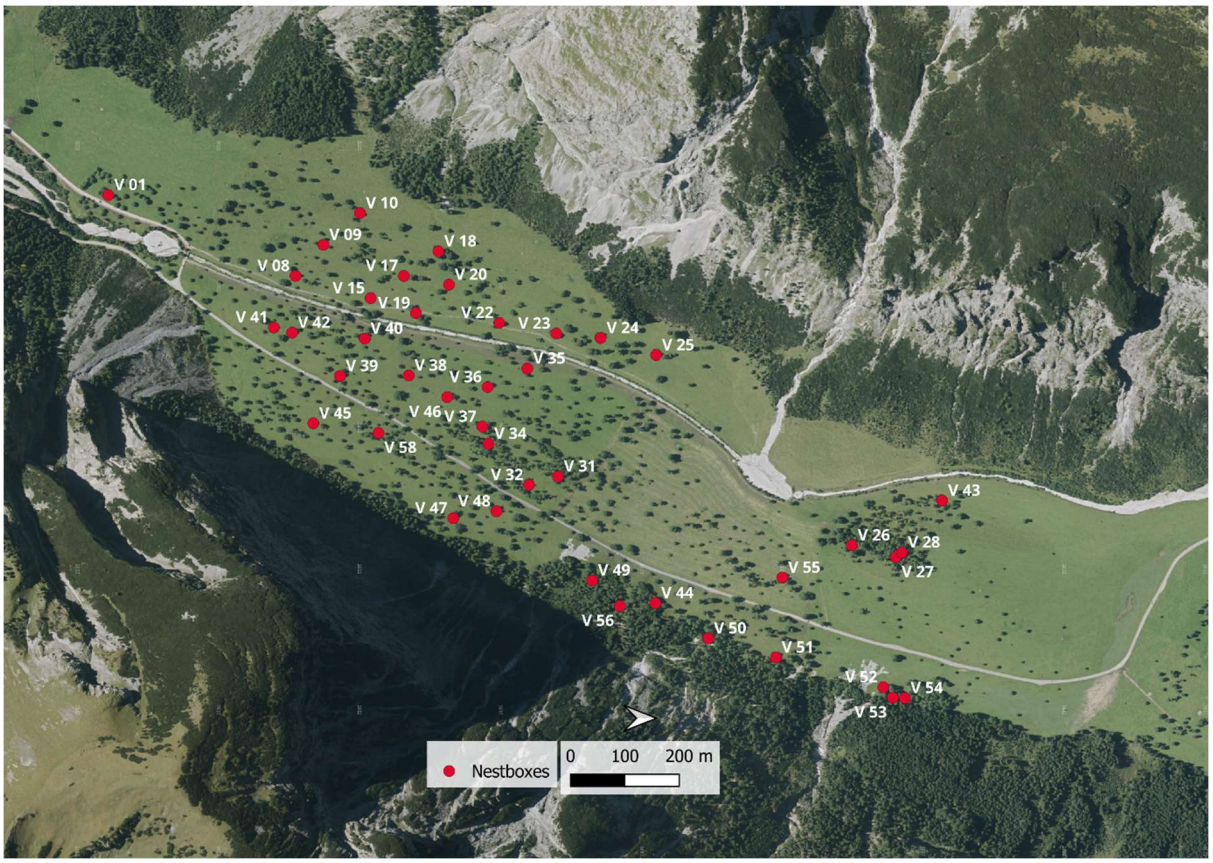

Figure 21 Displaying the available nestboxes, which were attached on sycamore maple trees in the main area.

Figure 22 Picture of the nest box model. © Sandra Schallhart

During the breeding period 2023, 41 breeding locations were identified, which were occupied with either eggs, hatchlings, nestlings or all of these (Figure 23). Only two breeding locations were in natural tree holes and not in any of the artificial nest boxes. All the other 39 breeding sites were in nest boxes. Comparing the breeding locations with the territories identified for *F. hypoleuca,* it was noticeable that almost all territories contain a breeding location. Most of the time the breeding site is dependent on the location of the nest box and on the border of the territory. The two breeding locations, which were in natural tree holes, were located in the eastern part of the area and in the northern part, already in the denser forest. Eight of the territories detected did not contain a breeding box within their location, but two of these had an occupied nest box nearby. In some parts of the study area breeding locations were densely close together. Only older males with black plumage were observed breeding, not one-year olds males with grey plumage.

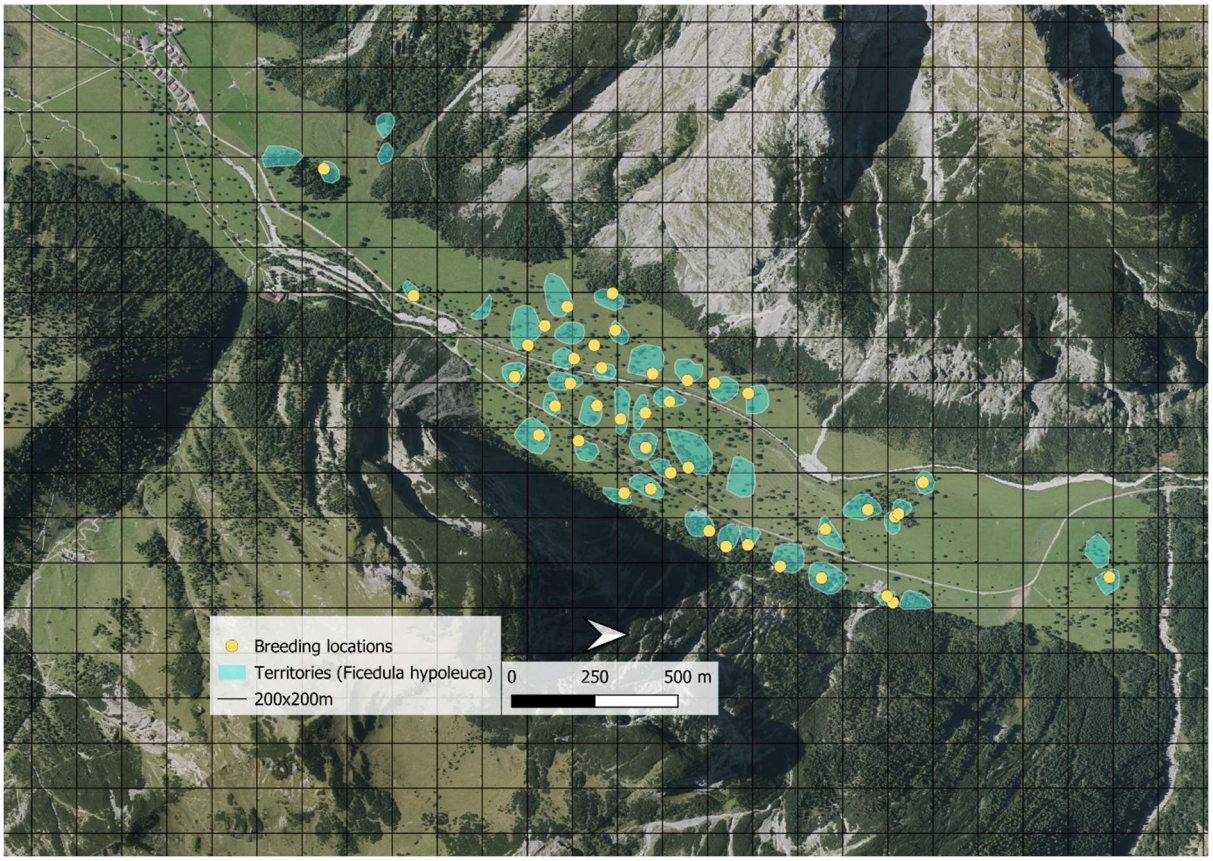

Figure 23 Locations were breeding was verified (yellow) in comparison with the detected territories (blue) of Ficedula hypoleuca.

Although almost all of the available nest boxes were occupied by *F. hypoleuca,* there were four nest boxes, which were not used for breeding until the end of the observation period (Figure 24). These four included the numbers 20, 42, 37 and 54 and were all located in the main area. Nest box 20 was placed at a height of 2 m and facing south-west. This box was occupied early on by *P. major*. Box number 37 was also attached on a height of 2 m and facing to the west. This box remained empty throughout the whole observation period. Nest box number 42 was placed at a height of 1.8 m and facing to the northeast. It was empty until the 29 May, after which a bat rested in it, although there are also special habitat boxes for bats in the area. Nest box number 54 was attached to the tree at 1.8 m and directed to the south. Interestingly, this box was visited by a male *F. hypoleuca*, but on 21 May *P. major* took over the nesting box. It was still checked each time and when the eggs were laid, there were four *P. major* eggs and one blue coloured egg in the middle. However, only the eggs from *P. major* hatched in the end.

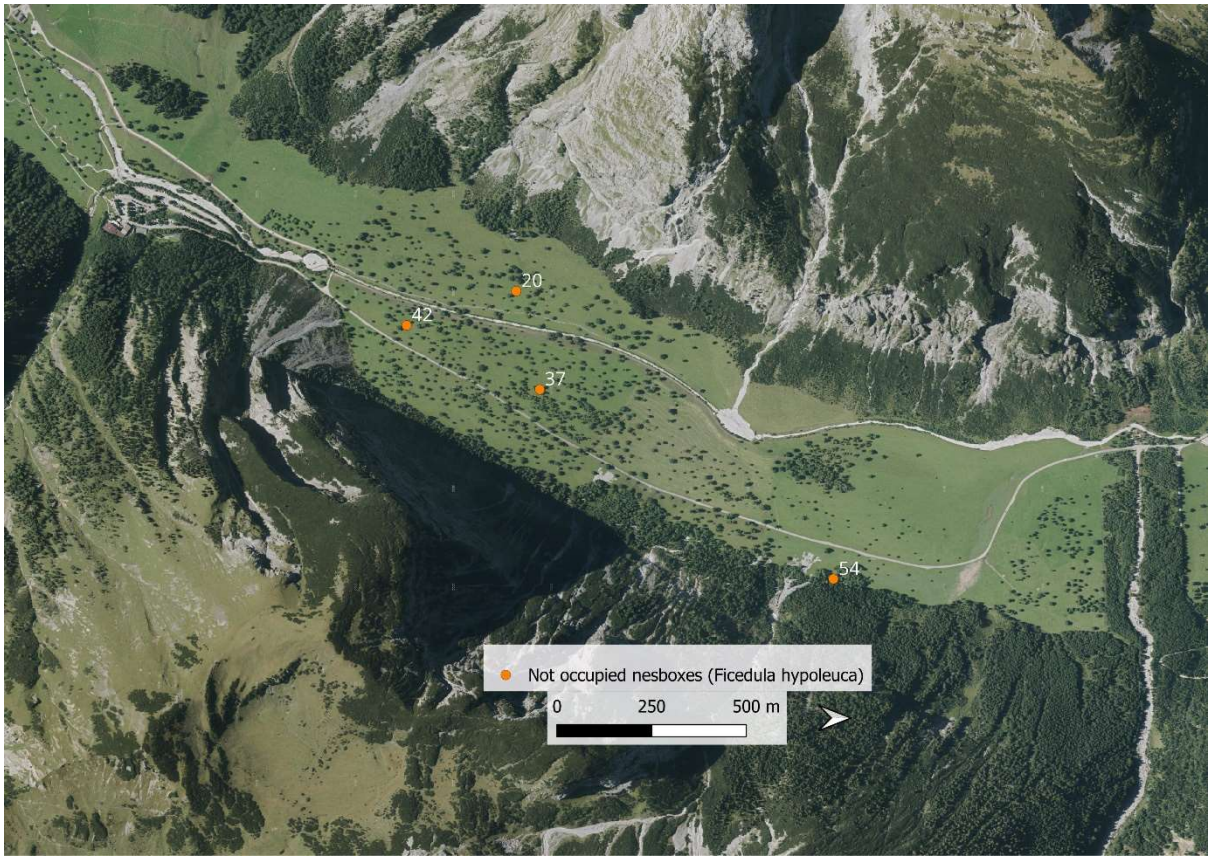

Figure 24 Showing the nest boxes in the main area, which were not occupied by Ficedula hypoleuca during the breeding season 2023.

Breeding biology

By checking the nest boxes (Figure 22) on each observation day, after the territory mapping, the breeding process in each nest box could be determined (Table 3). The first occupied nests were found on 4 May in the boxes 15, 20 and 28. On the second observation day, activities such as warning or bringing in nest material were observed in or around the nest boxes. The nest material consisted of a layer of old leaves and bark of *A. pseudoplatanus,* a second layer, which consisted mostly of grass blads and a layer of moss and feathers on top. The first detected eggs were in the boxes 15 and 20 on 13 May. Both boxes were 2 m high and facing south-west. On 21 May and 29 May the females continued to breed the eggs and on the 29 May already some nests were observed in which a total of seven eggs were laid. The beginning of the hatching time was on 10 June in the boxes 18, 26, 32, 34, 35, 38, 40, 43 and 50. All these boxes were positioned at different heights, but facing either south, west or south-west. By 21 June almost all eggs had hatched, except those in the nest boxes 45 and 53. Eggs in box 45 were still observed on 2 July, and only cracked and opened eggs were seen thereafter, but no hatchlings were ever detected in this box. The eggs in box 53 hatched on 22 July and were detected in association with the last observed *F. hypoleuca* in the area. In

these two boxes the eggs were last laid on 21 June, in all the other boxes the eggs were laid earlier. Compared to the literature, a clutch size of 4-8 eggs and an air temperature of 10–11° C is typical for *F. hypoleuca* in Central Europe (Glutz von Blotzheim & Bauer, 1993). The mean temperature in May 2023 was 10.3 °C and in June 14.6° C, which was measured by the GeoSphere Austria in Rißbach (Hinterriß).

The exact date, when the first juveniles started to fly and how many survived at the end, was not observed as it did not occur during the observation dates. According to (Bauer et al., 2012), fledging takes place 13 to 17 days after the hatching, which would be between the 23 and 27 June, calculated from the first hatched eggs in the area. This period lies directly in between the observation days 21 June and 2 July.

In total, approximately 208 eggs were laid in all boxes together and 189 hatched juveniles were detected. This is only an approximation, as in five boxes the number of eggs laid before hatching could not be observed, because the females were sitting inside the nest box when it was checked. Between four and seven eggs were laid with an average of 5.6 eggs and a standard deviation of 1.01 (n = 33), excluding those that could not be counted at the end. Between three and seven eggs hatched with a mean value of 5 and a standard deviation of 1.12 (n = 38). For further evaluation of breeding success the hatching success, the hatchlings per breeding pair, were calculated according to (Glutz von Blotzheim & Bauer, 1993). For hatching success, only nest boxes with data on eggs laid shortly before hatching were included. The hatching success for *F. hypoleuca* in the study area was 89.5 % (n = 32), which is close to the 92.8 % reported by (Glutz von Blotzheim & Bauer, 1993) for a favourable breeding season. Including the 42 identified territories in the main area and A 4, there would be 4.4 nestlings per territory.

Table 2 Showing the results of the nest box checking with the endoscopic camera. The abbreviations are based on the territory mapping: f = female, m = male, # = new nest material, < = warning, o = occupied nest, j = juveniles, c = couple, e = eggs, P.m. = Parus major.

Box number	4. May	9. May	13. May	21. May	29. May	10. June	21. June	2. July	11. July	22. July
1		#	#	3 e	f	7 e	5 j			
8		# <m	# +f	#	7 e	7 e	7 j			
9		# <m	# 2 c	#						
10		#	# +f	1 e	6 e	6 e	6 j			
15	o	o	1 e		f	5 e	5 j			
17				#	5 e	f	5 j			
18		#	#	#	f	5 j	5 j			
19			#	#	#	f	3 j			
20	o	o	3 e *P.m.*	*P.m.*	*P.m.*	f	5 j *P.m.*			
22		#	#	4 e	4 e	f	4 j			
23		#	#	#	f	f	5 j			
24		#		#	4 e	f	4 j			
25		#	#	#	f	6 e	6 j			
26				1 e	f	5 j	3 j			
27						5 e	5 j			
28	o					4 e	3 j			
31		# <m	# c	#	#	5 e	5 j			
32		#	#	#	4 e	4 j	4 j			
34		#	#	#	6 e	4 j	6 j			
35		+m	#	#	6 e	4 j 2 e	5 j			
36					#	5 e	4 j	5 j		
37										

Box number	4. May	9. May	13. May	21. May	29. May	10. June	21. June	2. July	11. July	22. July
38		#	#	f		5 j	6 j			
39				#	5 e	6 e	4 j			
40		#	#	#	6 e	5 j 1 e	6 j			
41		#	# c	#	f	5 eg	4 j	1 e dead		
42						bat	bat			
43		# <f	#	#	7 e	4 j	6 j			
44		#	#	#	5 e	5 e	5 j			
45		#	#	#		#	4 e	4 e		
46				#	# c	6 e	6 j			
47					f	5 e	5 j			
48		#	#	2 e		7 e	7 j			
49		#	#	# c	f	7 e	6 j			
50		#	#	#	7 e	5 e 2 j	6 j	1 e dead		
51		#	#	# <m	5 e	6	5 j			
52			#	#	7 e	f	7 j			
53			#				1 e	5 e	4 e	3 j
54		m	m	*P.m.*		*P.m.*	*P.m.*			
55						3 j	4 j			
56				#	f	6 e	5 j			
57				#	2 e	f	4 j			
58				4 e	7 e	f	6 j			

To analyse the correlation between the number of eggs/ hatchlings and the characteristics of the nest boxes (height & orientation), a Pearson linear regression was calculated using the program PAST 4.13. However, no significant correlation (with $r > 0.7$ & $p < 0.05$) was found,

suggesting that nest box characteristics do not have a significant effect on the breeding success. However, the first laid eggs were in the nest boxes 15 and 20 on 13 May, both of which faced south-west.

Further, a map was created with tirisMaps to analyse whether the solar radiation on the area had an impact on the breeding process, e.g. egg laying, hatching, breeding duration etc. (Figure 25). Therefore, the area could be divided into two categories: yellow (> 700–900 kWh/m^2/year) and orange (>900–1100 kWh/m^2/year) and was compared to Figure 21, to count which boxes were in which category. Further, a Pearson linear regression (with $r > 0.7$ & $p < 0.05$) was calculated to analyse whether solar radiation correlates with the numbers of eggs or hatchlings and the incubation period. But no significant correlations between the breeding data and the solar radiation were found. The yellow area, with less solar radiation, contained 16 nest boxes. The two nest boxes, that started and ended the breeding process later in the season, were in the orange area. However, the average number of hatchlings in the yellow zone was 5.3 (n = 16, standard deviation = 0.9) with a hatching success of 92 % and in the orange zone 4.7 (n = 23, standard deviation = 1.2) with a hatching success of 89 %. Therefore, the hatching success in the zone with less solar radiation is slightly higher than the average value, taking into account the low number of data collected with only 16 nest boxes in this zone.

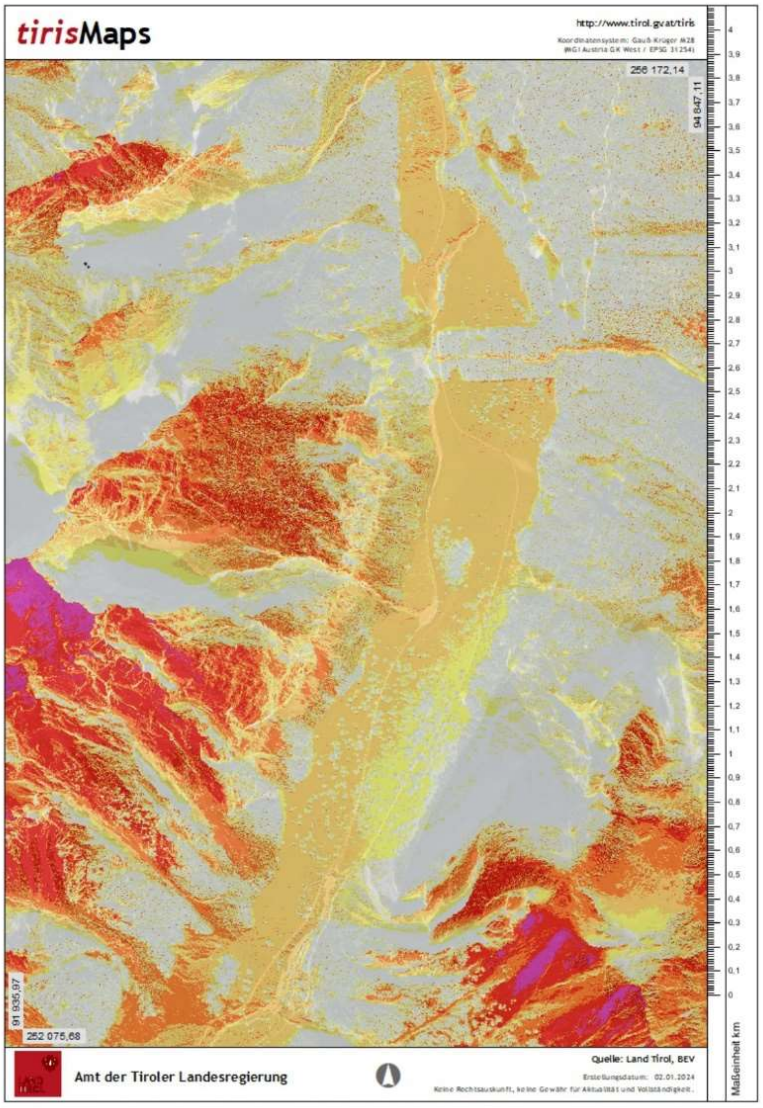

Figure 25 Solar radiation in the area Großer Ahornboden in kWh/m² / year created with tirisMaps. White < 700, yellow > 700 – 900, orange > 900 – 1100, dark orange > 1100 – 1300, red > 1300 – 1500, purple > 1500.

3.4 Comparison to near-natural habitats

Additional areas A 1-A 4

The additional areas surrounding the main area showed a different effect on the distribution of *F. hypoleuca* during the observation period 2023. In the areas A 1 and A 2, no *F. hypoleuca* were detected throughout the season not even during the migration phase. In A 3, birds were detected twice, once in the grid cell A 23 and once in A 52 (Table 4). However, only flying birds were observed and no territorial signs were shown. As mentioned above four territories were recorded in A 4. These four are in the area of the grids A 18, A 20, A 27, A 28 and A 29. One territory was located around a nest box, which was the only nest box located in an additional area. An average of 3.25 (standard deviation = 2.2) birds per occupied grid was recorded over all observation days.

Table 3 Showing grids, in which birds were detected on the field dates 2023 in A 3 & A 4. The total number of birds per grid and how many territories are part of a grid.

Grid	4.5	9.5	13.5	21.5	29.5	10.5	19.5	2.5	11.5	22.5	Total	Territories
A17	0	0	0	1	0	0	0	0	0	0	1	0
A18	0	0	0	2	1	2	1	1	0	0	7	1
A20	0	0	0	1	0	1	1	1	0	0	4	0.5
A23	0	0	0	0	1	0	0	0	0	0	1	0
A27	0	0	0	0	0	0	1	1	0	0	2	1
A28	0	0	0	0	1	1	1	1	0	0	4	1.0
A29	0	0	0	2	1	1	0	2	0	0	6	0.5
A52	0	0	0	1	0	0	0	0	0	0	1	0

Schloss Tratzberg (TZ)

The appearance of *F. hypoleuca* in the additional area TZ was different compared to the main site at Hinterriß (Figure 26), with an earlier arrival on 26 April, when four individuals were observed. However, the number of individuals decreased to two birds and the last individuals were observed on 31 May. After this date no individuals of *F. hypoleuca* were seen on the routes around Schloss Tratzberg during the whole observation period, not even through the use of acoustic sounds.

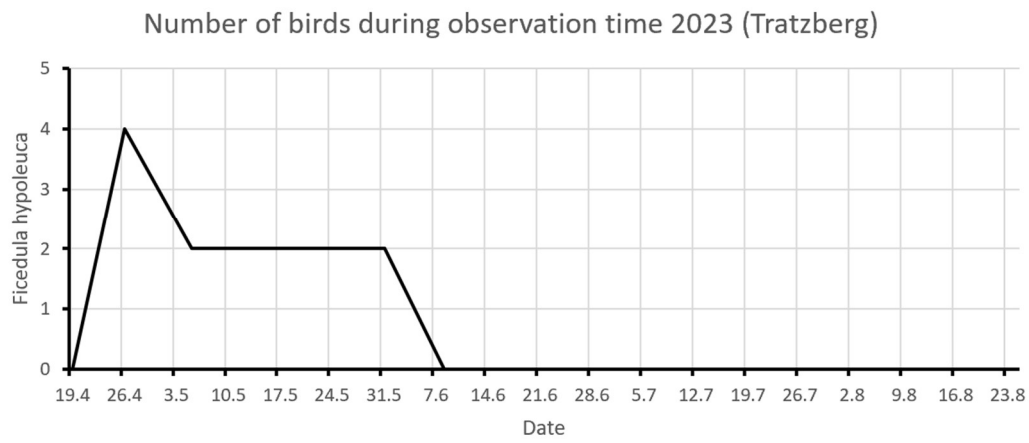

Figure 26 Number of detected Ficedula hypoleuca individuals per observation date in the additional area around Schloss Tratzberg.

The same phases that were applied for the main area, were used for the additional area TZ. However, the observation dates were on consecutive days due to the large size of both areas, which could not be visited within one day. The area of TZ was also divided into grids: T 1-T 64, to get a better understanding of the use of different locations in the area by the birds (Figure 27).

Figure 27 Overview of the grid cells T 1-T 61 of the additional area around " Schloss Tratzberg".

The observation date, when the first birds were detected on 26 April, was part of phase 1 (Figure 28). Four birds were observed on this day, three of them in the forest next to the trail and one at the edge of the area near the road. On this recording day the birds were not singing, they were either resting on the tree branches or searching for food. Three of the individuals were males and one was a female, which was sitting near the two males.

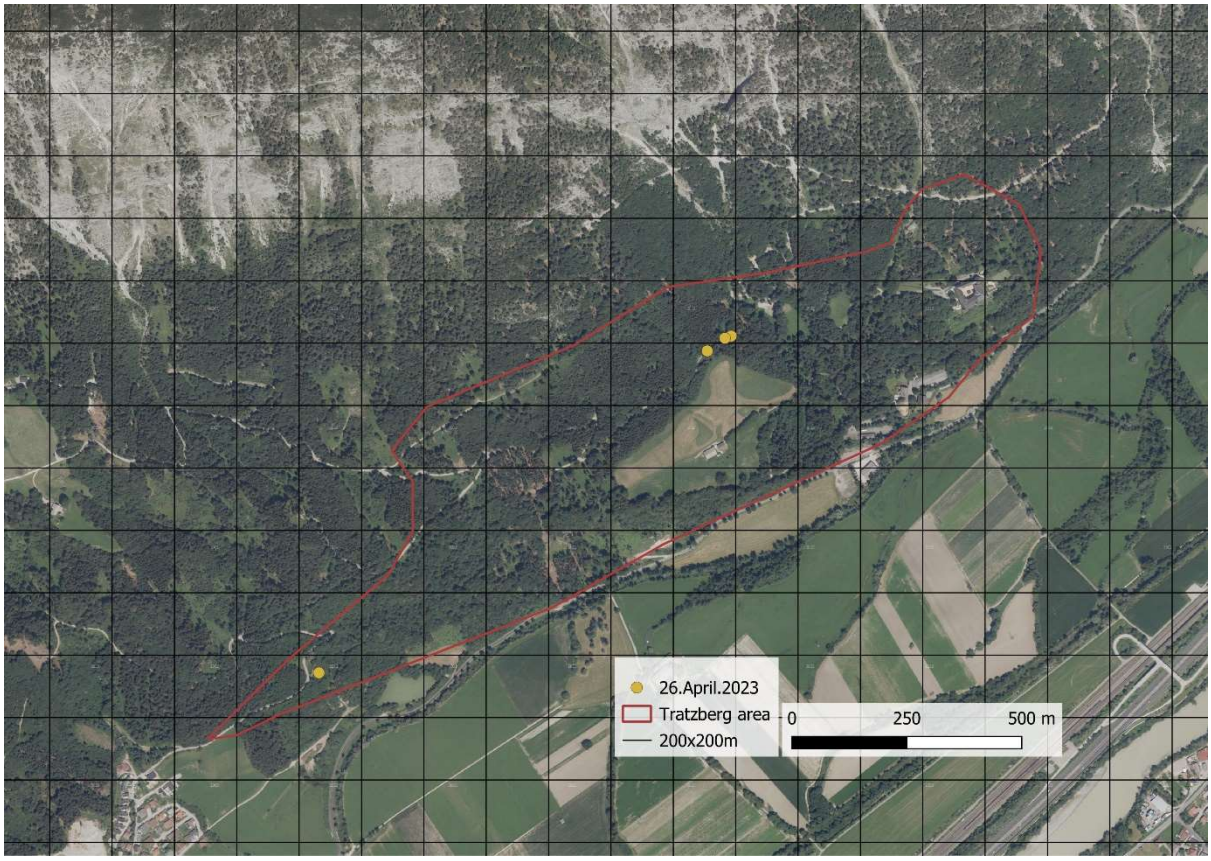

Figure 28 Showing the distribution of Ficedula hypoleuca in phase 1 in the area Schloss Tratzberg. The yellow dots represent individuals on 26 April 2023.

On 2 May, which was representing phase 2, two individuals of *F. hypoleuca* were observed (Figure 29). The location of the birds did not change, as they were again found in the same grid cells (T 36 and T 37) on this observation day. However, no birds were detected at the edge of the area anymore. This time the two males were singing, while sitting on *P. abies* trees.

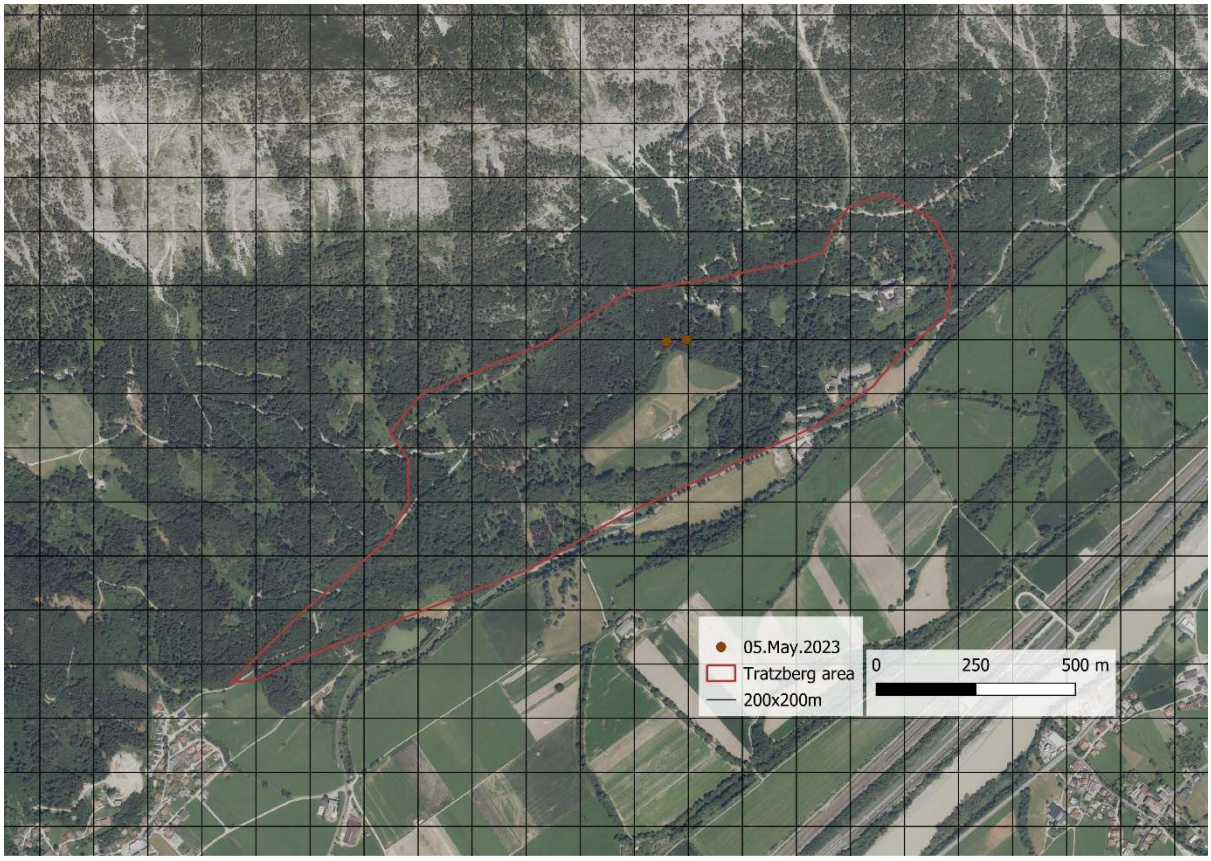

Figure 29 Showing the distribution of Ficedula hypoleuca in phase 2 in the area Schloss Tratzberg. The brown dots represent individuals on 5 May 2023.

During phase 3, which was mostly represented by the birds singing and bringing in nest material to the nest boxes in the main area, a pair of *F. hypoleuca* was also recorded in TZ (Figure 30). On 22 May the male was singing and the female was sitting on the same tree, making warning sounds. On 31 May, two birds were detected again, but this time they were deeper in the forest and making warning sounds. Although, the location remained in the same grid and was also the reason for a territory in this area, which has already been shown above. In phase 4 and phase 5 no *F. hypoleuca* were found in the area TZ.

Figure 30 Showing the distribution of Ficedula hypoleuca in phase 3 in the area Schloss Tratzberg. The green dots represent individuals on 22 May 2023 and the yellow dots individuals on 31 May 2023.

3.5 Syntopic species

Overview of the syntopic species in all areas

In order to gain an understanding of the syntopic bird species occurring in the main area and in the additional areas, point-count mappings were carried out during the territory mappings (Table 5). The species were identified by observation or song activity, which was also recorded at each point-count mapping for later analysis. A total of 38 species additional to *F. hypoleuca,* were recorded in all areas combined. But there were differences between the detected species in the different areas. *Erithacus rubecula, Fringilla coelebs, P. major, Phylloscopus collybita* and *Sylvia atricapilla* are the species, that were observed in all areas. On the other hand, there were also species, which were specific for one area. For the main area these included *Luscinia megarhynchos* and *Phoenicurus phoenicurus.* In the additional area A 4 *Delichon urbicum* was recorded, while in A 2 *Motacilla cinerea* was detected. For the additional area TZ, species, which were not found in any of the other areas were: *Aegithalos caudatus, Cuculus canorus, Cyanistes caeruleus, Falco tinnunculus, Lophophanes cristatus, Passer domesticus, Passer montanus, Poecile montanus, Poecile palustris*.

Table 4 List of all detected syntopic species through the point-count mappings in all areas.

Latin name	Common name	Spotted Area
Aegithalos caudatus	Long-tailed tit	TZ
Alauda arvensis	Eurasian skylark	Main area, A 3
Anthus trivialis	Tree pipit	A 1, A 4
Carduelis carduelis	European goldfinch	Main area, A 1, A 4
Certhia familiaris	Eurasian treecreeper	Main area, TZ
Chloris chloris	European greenfinch	Main area, TZ, A 1, A 3, A 4
Columba palumbus	Common wood pigeon	Main area, TZ, A 3, A 4
Cuculus canorus	Common cuckoo	TZ
Cyanistes caeruleus	Eurasian blue tit	TZ
Delichon urbicum	Western house martin	A 4
Erithacus rubecula	European robin	All
Falco tinnunculus	Common kestrel	TZ
Fringilla coelebs	Eurasian chaffinch	All
Lophophanes cristatus	Crested tit	TZ
Luscinia megarhynchos	Common nightingale	Main area
Motacilla alba	White wagtail	Main area, TZ, A 1
Motacilla cinerea	Western yellow wagtail	A 2
Muscicapa striata	Spotted flycatcher	Main area, TZ, A 1, A 2
Parus major	Great tit	All
Passer domesticus	House sparrow	TZ
Passer montanus	Eurasian tree sparrow	TZ
Periparus ater	Coal tit	Main area, TZ, A 3, A 4
Phoenicurus ochruros	Black redstart	Main area, TZ, A 3
Phoenicurus phoenicurus	Common redstart	Main area
Phylloscopus collybita	Common chiffchaff	All
Phylloscopus trochilus	Willow warbler	Main area, TZ, A 1, A 2
Poecile montanus	Willow tit	TZ
Poecile palustris	Marsh tit	TZ
Prunella modularis	Dunnock	Main area, A4
Pyrrhula pyrrhula	Eurasian bullfinch	Main area, TZ
Regulus ignicapilla	Common fiercrest	TZ, A4
Regulus regulus	Goldcrest	Main area, TZ, A4
Sitta europaea	Eurasian nuthatch	Main area, TZ, A3

Latin name	Common name	Spotted Area
Sylvia atricapilla	Eurasian blackcap	All
Troglodytes troglodytes	Eurasian wren	Main area, TZ, A 2, A 3, A 4
Turdus merula	Common blackbird	Main area, TZ, A 3, A 4
Turdus philomelos	Song thrush	Main area, TZ, A 2, A 3
Turdus viscivorus	Mistle thrush	Main area, TZ, A 2, A 3

To show the frequency of the listed syntopic species in the areas, a frequency table was created (Table 6). The most common species in all areas was *F. coelebs*. This species was present in all observations in the area A 2 and in more than 80 % in the main area and in the additional areas A 1 and A 4. In the main area *P. major, P. collybita, P. trochilus, S. atricapilla, T. troglodytes, T. merula* and *T. philomelos* showed a frequency of more than or equal to 10 %. In A 1, *C. carduelis* and *S. atricapilla* were recorded with a frequency of more than 30 %. In the additional area A 2, *P. collybita* and *S. atricapilla* were detected in more than half of the mappings. *S. atricapilla* was also more frequent in A 3 (25 %) such as *T. merula*. In A 4, the area with the highest abundance of standing dead-wood, *P. collybita* and *E. rubecula* were recorded with a frequency of more than 50 %. In this area and in TZ woodpeckers were observed several times, but this will be described in the chapter 2.6 possible predators. In TZ *E. rubecula, P. collybita, S. atricapilla, T. troglodytes* and *T. merula*, were observed in more than 30 % of the mappings.

Table 5 Showing the frequency of the syntopic species for each area. Ranging from white 0 % to dark green 100 %. Calculated by dividing the number of detected individuals per species in each area by the total number of counts. The number of counts in total were at the main area = 79, A 1 = 15, A 2 = 9, A 3 = 16, A 4 = 19 and TZ = 52.

Species	Main	TZ	A 1	A 2	A 3	A 4
Aegithalos caudatus	0%	2%	0%	0%	0%	0%
Alauda arvensis	5%	0%	0%	0%	6%	0%
Anthus trivialis	0%	0%	13%	0%	0%	11%
Carduelis carduelis	4%	0%	33%	0%	0%	11%
Certhia familiaris	5%	8%	0%	0%	0%	0%
Chloris chloris	8%	2%	27%	0%	13%	11%
Columba palumbus	4%	10%	0%	0%	19%	5%
Cuculus canorus	0%	2%	0%	0%	0%	0%
Cyanistes caeruleus	0%	6%	0%	0%	0%	0%
Delichon urbicum	0%	0%	0%	0%	0%	11%
Erithacus rubecula	8%	38%	20%	11%	6%	47%

Species	Main	TZ	A 1	A 2	A 3	A 4
Falco tinnunculus	0%	4%	0%	0%	0%	0%
Fringilla coelebs	85%	52%	80%	100%	75%	84%
Lophophanes cristatus	0%	2%	0%	0%	0%	0%
Luscinia megarhynchos	1%	0%	0%	0%	0%	0%
Motacilla alba	1%	4%	20%	0%	0%	0%
Motacilla cinerea	0%	0%	0%	11%	0%	0%
Muscicapa striata	6%	2%	27%	22%	0%	0%
Parus major	11%	25%	13%	22%	19%	26%
Passer domesticus	0%	4%	0%	0%	0%	0%
Passer montanus	0%	4%	0%	0%	0%	0%
Periparus ater	10%	6%	0%	0%	13%	11%
Phoenicurus phoenicurus	4%	2%	0%	0%	13%	0%
Phylloscopus collybita	25%	33%	27%	67%	13%	58%
Phylloscopus trochilus	10%	4%	7%	22%	0%	0%
Poecile montanus	1%	0%	0%	0%	0%	0%
Poecile palustris	0%	8%	0%	0%	0%	0%
Prunella modularis	1%	0%	0%	22%	0%	0%
Pyrrhula pyrrhula	1%	2%	0%	0%	0%	0%
Regulus ignicapilla	0%	4%	0%	0%	0%	11%
Regulus regulus	4%	8%	0%	0%	0%	11%
Sitta europaea	1%	8%	0%	11%	0%	0%
Sylvia atricapilla	15%	42%	47%	67%	25%	21%
Troglodytes troglodytes	20%	33%	0%	33%	6%	16%
Turdus merula	10%	35%	0%	0%	25%	5%
Turdus philomelos	13%	29%	0%	11%	13%	0%
Turdus viscivorus	0%	12%	0%	0%	0%	0%

Simultaneous appearance with *Ficedula hypoleuca*

In order to analyse whether there is a typical group of syntopic species appearing together with *F. hypoleuca*, a second frequency table was created (Table 7). This calculation could only be done for the main area and for A 4, because in all other areas no *F. hypoleuca* appeared during the point-count mappings. Again, *F. coelebs* was the most common syntopic species with 63 % in the main area and with 80 % in A 4. In 80 % of the records in A 4 *P. collybita* was

observed, which was slightly higher than the general occurrence. In the main area *S. atricapilla* was more common with a frequency of 29 % in combination with *F. hypoleuca*. In both areas, *P. ater* was recorded 7 % to 9 % more often than without *F. hypoleuca*. However, there were only slight differences compared to the generally syntopic species detected and no specific group was found to appear when *F. hypoleuca* was present. Furthermore, no avoidance of species that are nest competitors, such as *P. major,* was observed, even for *P. major* a higher detection was counted in A 4.

Table 6 Showing the frequency of syntopic species in combination with Ficedula hypoleuca for the main area and A 4. Ranging from white 0 % to dark green 100 %. The number of counts in total were in the main area = 24 and in A 4 = 5.

Species	Main	A 4
Fringilla coelebs	63%	80%
Turdus merula	8%	0%
Chloris chloris	8%	20%
Phylloscopus collybita	21%	80%
Periparus ater	17%	20%
Parus major	4%	60%
Erithacus rubecula	0%	40%
Delichon urbicum	0%	20%
Sylvia atricapilla	29%	20%
Turdus philomelos	8%	0%
Spinus spinus	4%	0%
Certhia familiaris	17%	0%
Troglodytes troglodytes	13%	20%
Columba palumbus	4%	0%
Phylloscopus trochilus	4%	0%
Carduelis carduelis	4%	0%

Description of the surrounding vegetation

During the point-count mappings, also the vegetation was roughly described within a 50 m radius of the walking path, including the most abundant trees and shrubs. In the main area, the typical vegetation consisted of grassland with *A. pseudoplatanus* trees and at the transition to the closed forest, *P. abies* was monitored. The additional areas A 1, A 2 and A 3 were similar in their vegetation to the main area, also with a surrounding dense forest at the border of the

observation areas. The area A 4 contained a small area of *P. abies* to the south, with two *A. pseudoplatanus* trees, which were used as nest box platforms. In the middle of this area there was an open grassland and in the northern part a closed forest with *Pinus sylvestris, Fagus sylvatica, Pinus mugo* containing a lot of standing dead-wood. The area TZ was different in comparison to all other areas, being a dense mixed forest. Typical vegetation found during the mappings contained *P. sylvestris, P. abies, Betula pendula, Larix sp., Tilia platyphyllos, Quercus robur, Corylus avellana, Clematis vitalba, Prunus padus* and *Cornus sanguinea*. In this area standing dead-wood was also quite common, generating a possible habitat for woodpeckers.

3.6 Potential Predators

Through the point-count mappings also potential predators for eggs or juveniles of *F. hypoleuca*, which appeared during these counts, were noted. To analyse this, diagrams were created with the frequency of the possible predators. Species, which come into question as possible predators for *F. hypoleuca*, were defined after (Glutz von Blotzheim & Bauer, 1993). The main area and the additional areas at Großer Ahornboden were combined in this illustration, because of their similarity (Figure 31). In this area *Corvus sp*. was the most commonly detected potential predator with a frequency of 25 %, it was observed over the whole area, either flying or searching for food. *D. major* and *Sciurus vulgaris* were recorded with a frequency of around 5 % and most detections were in A 4. The detections of *Vulpes vulpes* were made in the main area, when feeding on a leg of a dead *Rupicapra rupicapra*.

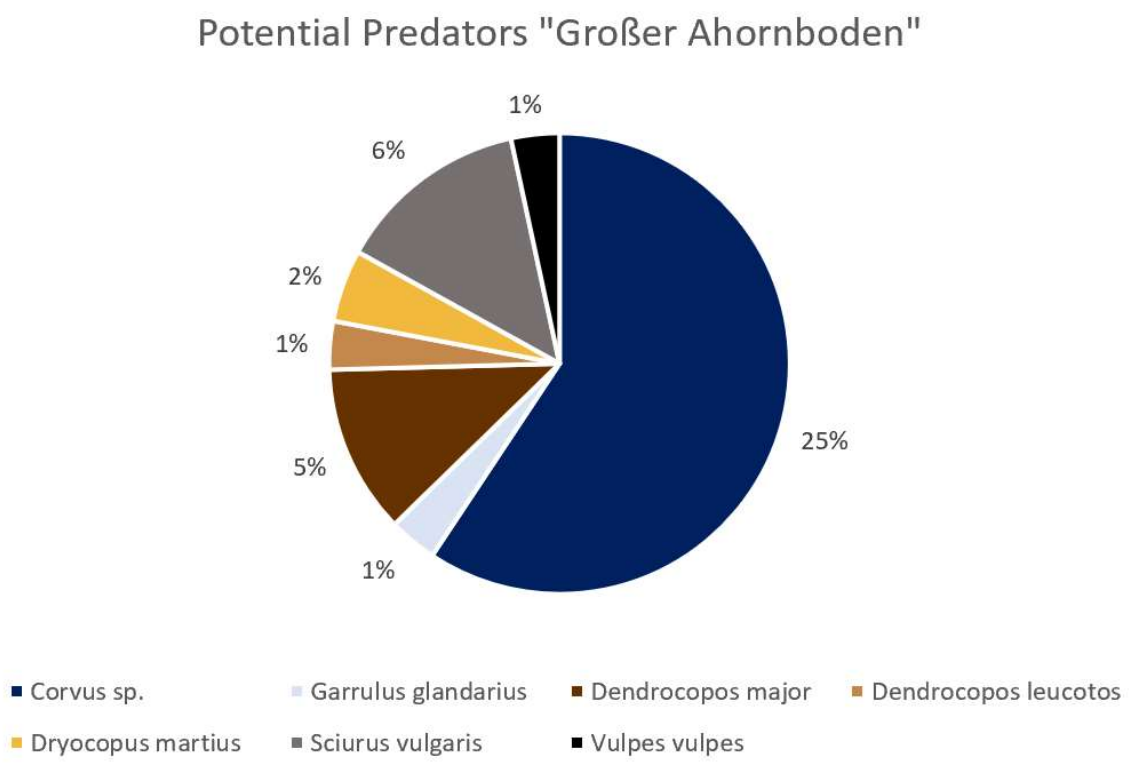

Figure 31 Frequency of potential predators, counted during the point-count mappings around Großer Ahornboden in percent (n = 138).

In the area around Schloss Tratzberg also *Corvus sp.* was the most frequent potential predator with 96 % (Figure 32), mostly observed flying around the area or making warning sounds. In comparison to the Großer Ahornboden observation area *S. vulgaris* was spotted eight times more often than in the TZ area, mostly while climbing on trees. The fourth most common potential predator in this area was *D. major* with a frequency of 17 %, which was three times more abundant than in the area Großer Ahornboden.

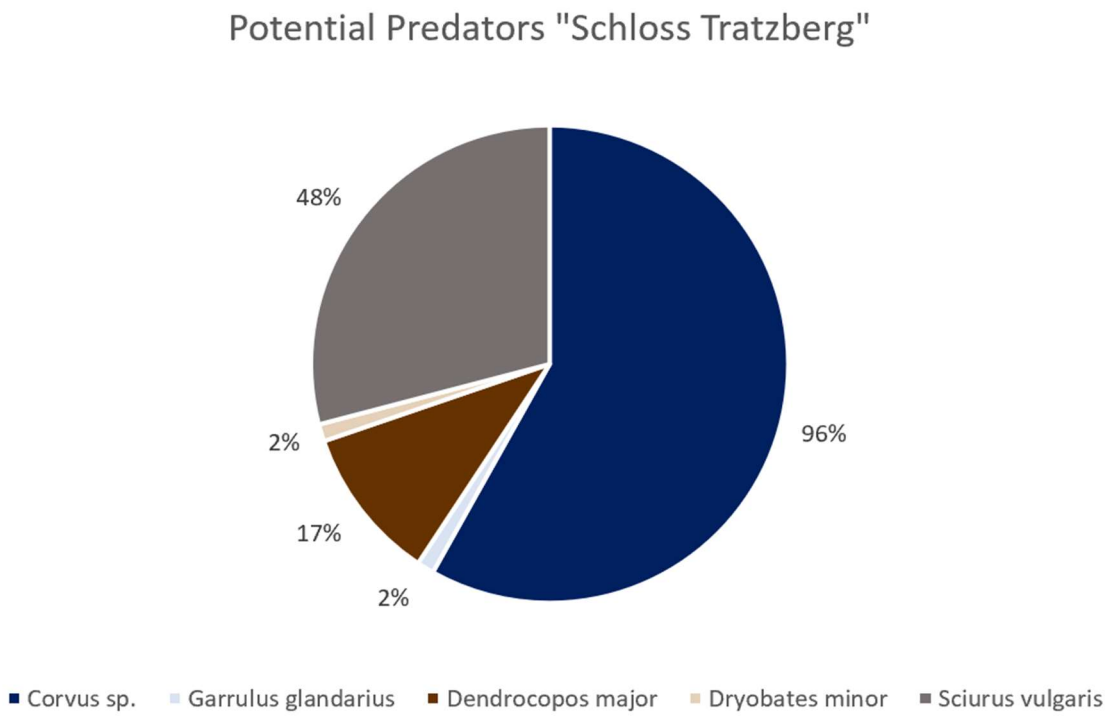

Figure 32 Frequency of potential predators, counted during the point-count mappings around Schloss Tratzberg in percent (n = 52).

3.7 Related Species: *Muscicapa striata* & *Ficedula parva*

M. striata and *F. parva*, two related species of *F. hypoleuca* were also detected in the study areas during a mapping by (Lentner et al., 2022). It was therefore suggested that these two species should be mapped additionally. Therefore, the species were recorded during the mapping of *F. hypoleuca* and the same procedure was used for the subsequent calculations.

Ficedula parva

F. parva was described with 15 to 20 breeding pairs in Tyrol, where two territories were recorded around Schloss Tratzberg. Their preferred breeding habitat are moist, wooded slopes with *Fagus* sp. trees and at an altitude of 600 to 1 400 m (Lentner et al., 2022). During the observation period in 2023, no individuals of this species were observed in Schloss Tratzberg or at Großer Ahornboden.

Muscicapa striata

This species was described with 2 500 to 5 000 breeding pairs in Tyrol, at an altitude of 470 to 2150 m, but mostly occurring in the valleys. They are mostly found in riparian forests, semi – open landscapes, forest edges and loosely built settlement areas. As with *F. parva*, territories have been recorded around Schloss Tratzberg (Lentner et al., 2022).

In total, 23 individuals were detected during the observation period in 2023 in the area Großer Ahornboden and six individuals in the area around Schloss Tratzberg. The first appearance of *M. striata* was on 29 May in the northern part of the main area, where a total of five individuals were spotted and started singing and making warning sounds. On 30 May there were detections in the additional areas A 1 and A 2 noted. The last sighting of *M. striata* was recorded on 11 July in the southern part of the main area, noting that the additional areas at Großer Ahornboden were no longer checked after the completion of the territory mappings for *F. hypoleuca*. In the TZ area the first observation was made on 7 June and the last one on 30 June.

Regarding the calculated territories for this species, using the same criteria as for *F. hypoleuca*, four territories were determined for the main area, two for A 1 and one for A 2 (Figure 33). Interestingly, the territories in the main area were located close to those of *F. hypoleuca,* but were always on the edge of the area at the transition to the dense forest. Although both are hole nesters, there were no evidences of competition for nest boxes observed. In A 3 and A 4 no birds were recorded in 2023. During the observation, from May to July the males either sang or made warning sounds when approaching. In A 1 two females were seen while flying with nest material, but no breeding holes were found in any of the territories.

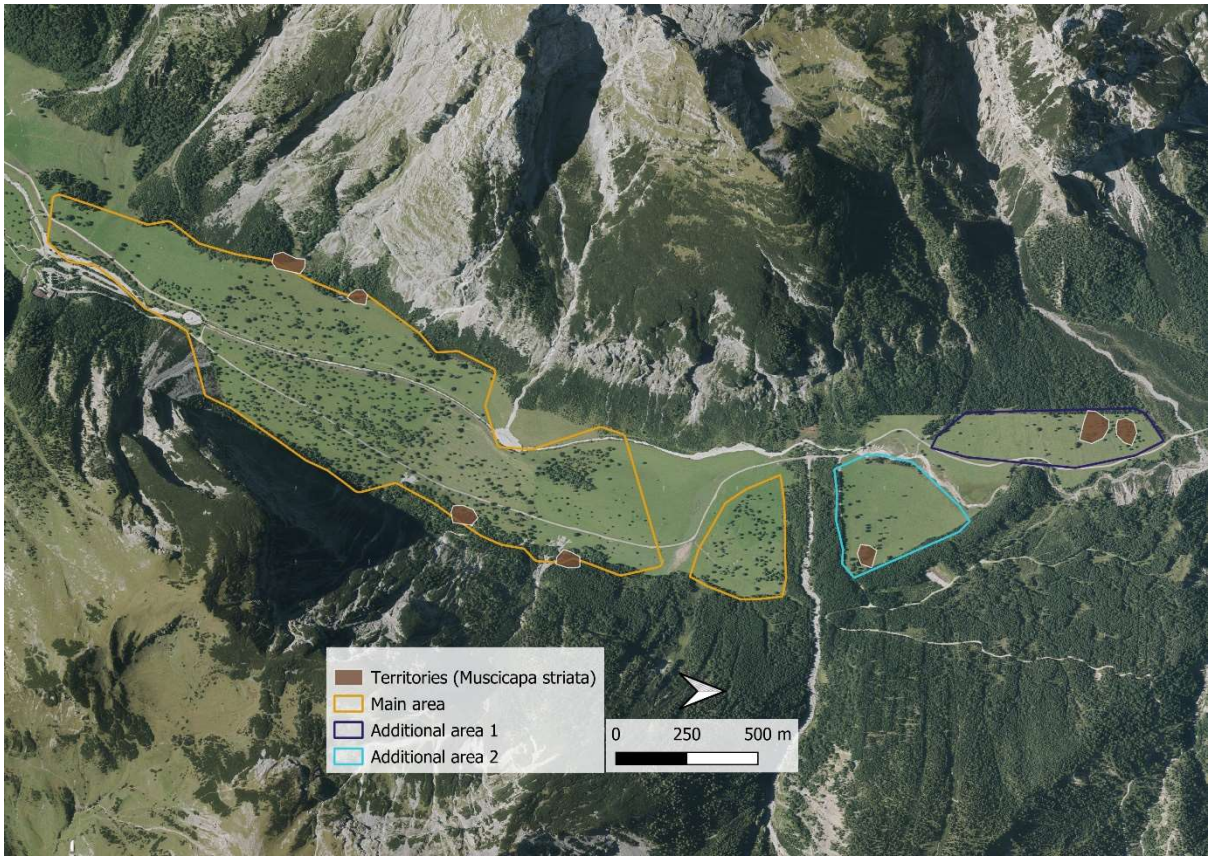

Figure 33 Territories of Muscicapa striata in the area Großer Ahornboden.

One territory of *M. striata* was recorded in the area around Schloss Tratzberg (Figure 34). The location of this territory was at a distance of about 300 m from the territory of *F. hypoleuca*. At this location the forest was dense and contained mainly trees of *P. sylvestris* and *F. sylvatica*. The detection of specimens at this site was made at three different observation times, each time the male bird was singing and the female was resting nearby.

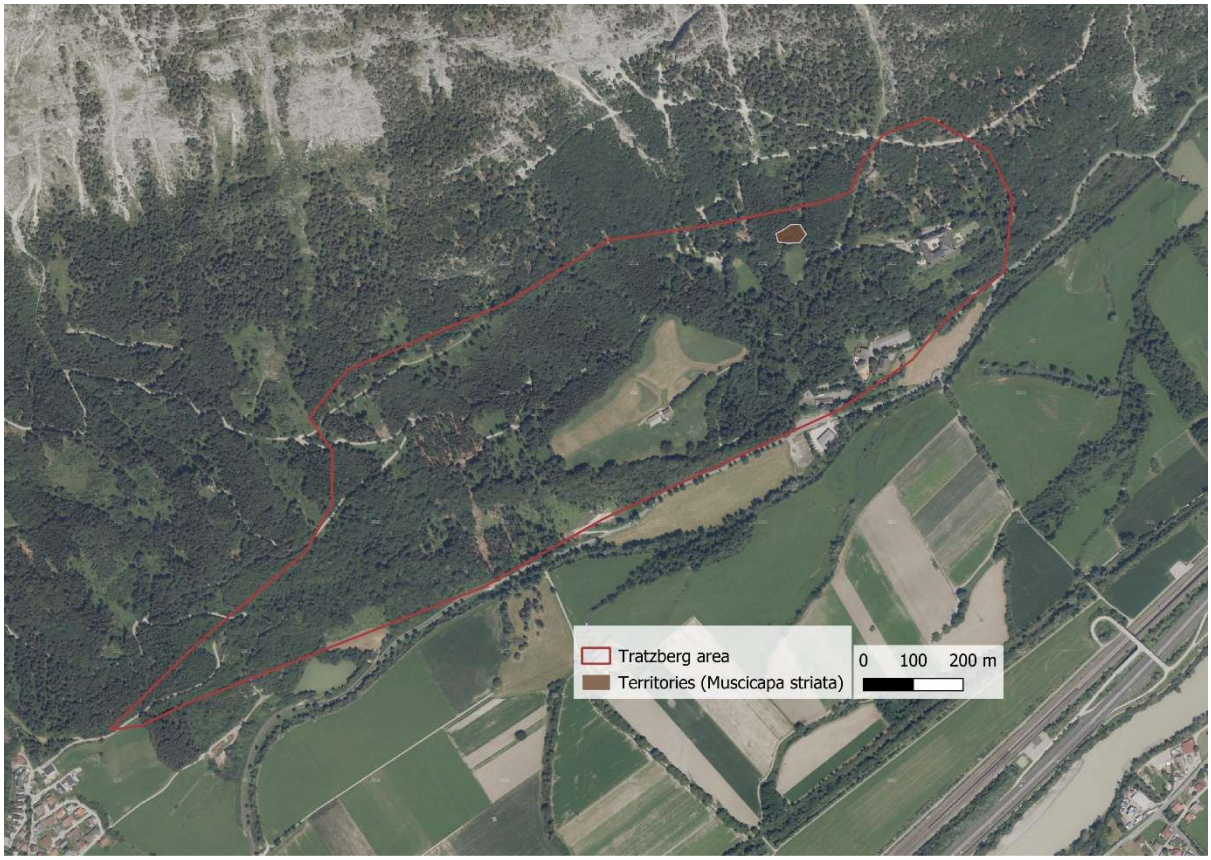

Figure 34 Territories of Muscicapa striata in the area Schloss Tratzberg.

4 Discussion

4.1 Territories and usage of the available area

The 10-day interval mappings outside of the *F. hypoleuca* appearance allowed the arrival and the departure of the birds in the breeding area to be recorded. Arriving first at Schloss Tratzberg on 26 April and about ten days later at Großer Ahornboden. On these observation dates more males were present, suggesting that females arrive later, which is coinciding with the literature. The average arrival date for *F. hypoleuca* in Central Europe ranges from mid/end of April to early May (Bauer et al., 2012). It has been suggested that a well-timed spring arrival improves the survival and reproduction of this species by increasing their chances of finding a high-quality territory and breeding site. However, arriving too early to the breeding area increases mortality due to low food availability and harsh weather conditions. It is known that males arrive before females and that the migration from Africa to the breeding area is completed within 14 days (Ouwehand & Both, 2017). Differences in arrival at the breeding site are consistent with the fact, that populations with different breeding sites in Europe have different overwintering locations in Africa (Ouwehand et al., 2016). The departure of *F. hypoleuca* in the main area started on 2 June and the last birds were observed on 22 July, while in the area around Schloss Tratzberg the last birds were observed on 31 May. This highlights that migration timing in summer/autumn tends to be more flexible than the arrival depending on the breeding process (Ouwehand et al., 2016). According to (Bauer et al., 2012), it was also observed that some females leave as early as mid-June when they have brood loss, while the others leave later, around mid-July. The area around Schloss Tratzberg consists of a dense forest, with only a few paths and only these could be checked for birds. This does not particularly mean, that the birds left this area on 31 May, but this could also indicate a change in location.

According to the atlas for breeding birds in Tyrol (Lentner et al., 2022), the Karwendel region is an important habitat for *F. hypoleuca*, especially the area around Großer Ahornboden. During this mapping in 2023, a total of 46 territories and two potential territories were identified within the selected area, underlined by evidence of breeding in 41 territories. In the area around Schloss Tratzberg several singing males were recorded in 2016 and one pair, breeding in a tree hole in 2017 (Lentner et al., 2022). In 2023, one territory was stated for this area, but due to the density of the forest it was not possible to map the whole area and therefore more territories could be located around the area. The density of *F. hypoleuca* in the main area showed an average number of 0.7 territories within 200 m^2. The highest known densities for this species in Central Europe are 0.4-6.5 territories/ 10 ha within a total area of 100 ha (Lentner et al., 2022).

The movements of the birds in the areas and the locations, which were used during different life stages (phase 1-5) were analysed by detecting individuals in different grid cells on each observation day. During the arrival of *F. hypoleuca*, males are known to fly over the habitat, forage and already search for possible territory locations (Bauer et al., 2012). With regard to phase 1, this life stage had already started before the first observation on 4 May, when some males were already singing and making warning sounds. The density of the birds in phase 1 was highly concentrated in the centre of the area. Comparing phase 2 with phase 1, more singing activity was observed in phase 2 and some individuals extended to the easternmost part of the area. Females were also seen with nesting material, indicating that mating had begun and highlighting the time pressure the birds are under during their breeding process. Because of the short breeding season, it is often discussed how the females select the males for mating (Glutz von Blotzheim & Bauer, 1993). There are several studies, that show that females choose based on the breeding area rather than the characteristics or singing of the males, but there are also analyses, which show that females choose randomly and usually take one of the first males they encounter. The reason for this is that females are constrained by time and energy and therefore random settlement is their best mating strategy (Dale & Slagsvold, 1990). In the phases 3 and 4 it was shown that the movement of birds during the breeding process is strongly linked to their territories. Therefore, the location was not often changed and if it was, then usually for searching food. During this period, the birds were mostly distributed throughout the main area, with a higher density in the southern part of the observation area at the transition to the dense forest, while only a few were recorded in the northern part. Phase 5 already includes the migration of *F. hypoleuca* from the Großer Ahornboden area, as a total of 40 birds were recorded on 1 July. The last individuals in this area were observed on 22 July. The majority of the population left early compared to the literature, which defines the migration as mid-July (Bauer et al., 2012). As mentioned above, the migration time for leaving the breeding areas is variable for this species. Another possible explanation for this could be that the area Großer Ahornboden becomes more touristy during the summer period and that around 500 cows (Tappeiner et al., 2007) graze around the nest boxes. During the observation period, high numbers of tourist buses, motorcycles, cars, etc. were observed. The main area is mostly separated from the road by electric fences erected for the farmer´s cows. However, several times people were seen walking through the area and some nest boxes were set up on trees right next to the road. Further, cows were observed scratching themselves on trees with nest boxes attached. Although this had no visible effect on nest box selection and breeding success in this study, however the first cows arrived on 29 May, where *F. hypoleuca* was already in the middle of the breeding process. Overall, the most used areas of *F. hypoleuca* were scattered throughout the main area and were depending on

the locations of the nest boxes, underlined by the fact that almost all territories included a nest box within their territory.

4.2 Breeding success and usage of the available nest boxes

In total, 39 of the 43 available nest boxes were occupied by *F. hypoleuca* and two natural tree holes were detected. Almost all of these boxes were surrounded by a territory of *F. hypoleuca*. The four boxes, which were not occupied, were either occupied by *P. major* or very close to another box, but the characteristics (orientation & positioning) of these boxes were different. This result highlights the fact that this species prefers nest boxes to natural tree holes (Goodenough et al., 2009). Box characteristics did not correlate with breeding success, but interestingly all boxes, in which the first eggs were laid and hatched were either south or south-west facing, indicating a faster breeding process. There is a suggestion in the literature that nest boxes for this species should not face south-west as it is associated with reduced nestling survival (Goodenough et al., 2009). Further, it is suggested that the distance between nest boxes should be at least 150 m (Bauer et al., 2012), however the smallest distance between two nest boxes at Großer Ahornboden was 14.6 m and the average distance 89.6 m.

The nesting material was similar in all boxes and consisted of a layer of old leaves and bark of *A. pseudoplatanus*, a second layer of grass blads and a layer of moss and feathers on top. The leaves, which are found in *F. hypoleuca* nests mostly reflect the availability within the locality and the area around their nest box. No avoidance or preference of typical tree species were observed, but differences in the amounts of leaves, moss and bark were detected in different locations (Briggs & Deeming, 2016).

The first occupied nests in the main area were recorded on 4 May and the first eggs laid on 13 May. The egg laying and incubation period ranged from 13 May until 10 June or 21 June, except in two nest boxes, where the whole process was delayed. The average incubation time, after all eggs were laid was 12 days and the clutch size ranged from four to seven eggs at a mean air temperature of 10.3°C during egg laying. These results are in line with the data measured for Central Europe, where four to eight eggs were laid, one egg per day except when the weather changed, at an air temperature of 10-11°C (Glutz von Blotzheim & Bauer, 1993). The last eggs were laid on 21 June, in the box that was left delayed. The exact date of the first flight of the juveniles could not be determined, but it was recalculated according to (Bauer et al., 2012), where it is reported 13 to 17 days after hatching, which would be between 23 and 27 June and thus in the middle of two observation days. However, it is also mentioned that a prolonged nestling period would improve the flight ability of the fledglings. Therefore, a good food supply, through providing plants that attract insects especially lepidopteran, before the hatching of the young birds is important for the adults (Moreno, 2022). In Europe, the

hatching success of *F. hypoleuca* during a favourable breeding season is 92.8 % (Glutz von Blotzheim & Bauer, 1993). During the 2023 season, a hatching success of 89.5 % was measured for the Großer Ahornboden area, indicating a favourable breeding habitat at this site, despite the potential for high levels of disturbance, including tourist activity and grazing cows.

These results highlight the importance of nest boxes for *F. hypoleuca* and show that they select their territory based on the location of nest boxes, which makes the area Großer Ahornboden to such an important breeding site. The concrete nest box model attached to *A. pseudoplatanus* trees in this area, seems to provide a good breeding opportunity for the birds. It is important that the entrance hole has a maximum diameter of 3.5 cm and the distance from the entrance hole to the ground is approximately 12 cm on order to supply favourable conditions. The height of the boxes showed no differences in this study, but it would probably be good to place them at a minimum height of 1.5 m so that they cannot be reached and destroyed by the cows. The orientation is also variable, except that it should not face south-west (Goodenough et al., 2009). Further, it would be useful to keep a distance between two nest boxes of at least 150 m and to avoid attachments on trees next to the road. Prior to this study, all nest boxes were emptied of old nesting material, as the old material already reached all the way to the entrance, which may be problematic for new nest building (Bauer et al., 2012). This information can be used as a maintenance guide for the Großer Ahornboden area and is based on the data collected in our study.

4.3 Appearance in near-natural habitats

The near-natural habitats (A 1-4 & TZ) were chosen to compare the occurrence of *F. hypoleuca* in these areas with the main area. The additional plots A 1-4 surrounded the main area and were similar to the habitat of the main area, including *A. pseudoplatanus* trees. Except for one nest box in A 4, none of the additional plots contained a nest box. The area around Schloss Tratzberg was chosen, because *F. hypoleuca* has been observed in this area in previous mappings (Lentner et al., 2022). Only in A 4 and TZ individuals of *F. hypoleuca* were regularly registered, in all other areas not. Four territories were identified in area A 4, with breeding observed in two territories, and one territory was recorded in area TZ. The breeding process in the nest box A 4 started later than most of the breeding in the main area (21 May) and only four eggs were laid and hatched, but the flight of the birds was at the same time as in the main area. However, one explanation for the small clutch size could be the late start of the breeding, as it is known that the clutch size is smaller with a later start (Skwarska et al., 2012). Still, in this study there were different results with delayed oviposition, where the numbers of juveniles ranged from three to five. The additional area A 4 showed three territories without a nest box nearby, but in this area a higher number of woodpeckers were observed during mapping and

therefore also more possible natural tree holes for breeding are available. In TZ the last birds were observed on 31 May, but due to the density of the forest, it is possible that they did not leave the area at this date, but flew deeper into the forest.

4.4 Syntopic and related species

The detection of syntopic species by point-count mappings, revealed differences in the species composition in all areas. However, the most abundant species in all areas was *F. coelebs*, with a frequency of more than 50 % in all detections. This suggests that, *F. coelebs* belongs to one of the most common bird species in Tyrol. Further, *E. rubecula, P. major, P. collybita* and *S. atricapilla* were also regularly found in all areas. However, all these species are frequently found in the Karwendel region (Lentner et al., 2022). The comparison of syntopic species occurring simultaneously with *F. hypoleuca*, to determine whether there is a characteristic species composition or an avoidance visible, showed no major differences. On the contrary, *P. major* was observed more often together with *F. hypoleuca* in area A 4. Although, these two species are known as nesting competitors (Slagsvold, 1975), which was also observed in two of the nest boxes in the main area.

Two species, which are also known to nest in tree holes, are *F. parva* and *M. striata*. They are related to *F. hypoleuca* and were also observed during this mapping. *F. parva,* described with 15 to 20 breeding pairs in Tyrol (Lentner et al., 2022), could not be detected in our observations. *M. striata* is known to occur in Tyrol with 2 500 to 5 000 breeding pairs, and territories have already been detected around the Schloss Tratzberg area in the last years (Lentner et al., 2022). A total of 23 individuals of *M. striata* were observed during the mapping in 2023, with the first appearance on 29 May in the northern part of the main area. Four territories were recorded for this species in the main area, two in A 1, one in A 2 and one in TZ. All territories were close to territories of *F. hypoleuca* and in the main area only on the edges at the transition to the dense forest. Despite their occurrence in dense areas, no evidence of nest site competition was observed. This was also described in other studies, where it was mentioned that no interspecific effects were observed in passerines, although the niches overlapped (Fasola & Fraticelli, 2010). Another explanation could be the late arrival of this species, which arrived when *F. hypoleuca* was already in the breeding process.

4.5 Potential predators & threats

To gain an overview of the potential predators that are present in the areas, predators of eggs and juveniles were recorded during the point-count mapping. The most common potential predator was *Corvus sp*. in all areas, but it was never observed raiding a nest. Further, *D. major* and *S. vulgaris* were also recorded during the mapping, indeed the frequency of

S. vulgaris was eight times higher in the area TZ. However, competition was only once observed when a pair of *D. major* fought with a male *F. hypoleuca* over a tree hole.

Due to its wide distribution throughout Europe, *F. hypoleuca* is listed as least concern on the IUCN Red List of Endangered Species, but it is mentioned that the population trend is declining (IUCN, 2023). However, in Austria it is categorized as potentially threatened (Dvorak et al., 2017). Possible explanations for the decline include habitat damage, competition and predation, and weather changes due to climate change (Bauer et al., 2012) (Goodenough et al., 2009). The decline of *F. hypoleuca* may be site-specific, particularly in terms of competition and predation. Smaller brood clutches have also been observed due to changes in food availability for the adults and the juveniles, in particular a decrease in caterpillar food, which is one of the main food sources for this species (Goodenough et al., 2009). Long-distance migrants such as this bird species are affected by climate change, particularly changes in the weather patterns. The breeding process and the migration of *F. hypoleuca* are strongly dependent on the air temperature, implying that warmer spring temperatures will affect the arrival on the breeding site and the breeding process in terms of egg laying and hatching. The migration of the birds from the wintering grounds to the breeding site may be affected by climate change, due to warmer conditions in Africa and an earlier spring migration, where they may face harsher conditions during migration (Gonzáles-Braojos et al., 2017). Another potential threat to *F. hypoleuca* is the observed decline of the *A. pseudoplatanus* trees in their breeding area. Since 1950, an intensification of alpine agriculture has been observed in the Großer Ahornboden area, leading to a higher land use of the area for grazing. The increased nitrogen input, due to fertilisation, into the soil, has not yet shown a negative effect on the trees, but the high pressure of the cows on the soil leads to root damage of the trees in waterlogged soils and further to fungal infections and core rot. It is therefore important to adjust the use of the pasture, protect the old *A. pseudoplatanus* trees and thus protect the environment of *F. hypoleuca* (Tappeiner et al., 2007). However, within this study no visible impact of the intensification of the agriculture on the breeding process was detected, but a high breeding success was achieved due to the availability of the nest boxes.

In conclusion our findings provide insights into the territorial behaviour, the appearance in the area Großer Ahornboden and the breeding behaviour and success of *F. hypoleuca* in the Karwendel region. Key findings include the migration patterns of the species, the importance of nest boxes for successful breeding, territorial preferences and interactions with syntopic species. This study highlights the importance of the area Großer Ahornboden as a breeding site, where the presence of nest boxes impacts the selection of territories. The high breeding success, measured by the hatching rates, underlines the significance of the area as a great breeding habitat due to the availability of artificial nest boxes and further habitat factors for

instance the availability of food. Additionally, this study shows potential threats faced by *F. hypoleuca*, including habitat change, competition with other nest competitors and the effects of climate change. A particularly concerning factor for this habitat is the decline of *A. pseudoplatanus* trees in the breeding area, highlighting the importance of conservation to protect both, the bird species and its habitat. Although, during our observations the intensive agricultural use of the area had no impact on the breeding success of *F. hypoleuca* and the appearance of cows could also include an increased food source in Diptera for the birds. Overall, this study highlights the vulnerability and connection of *F. hypoleuca* in its habitat and provides valuable information for the conservation of this species in the Karwendel region, which is one of the most important habitats for Austria. In order to improve the conservation *of F. hypoleuca* in this region, it is proposed to extend the provision of nestboxes to near-natural habitats in order to increase the population in the Karwendel region. Further, it would be interesting to analyse the availability of food sources for insectivorous birds and how this is connected to the agricultural use of the area. Additionally, it is necessary to implement a monitoring for *F. hypoleuca* in this important habitat, e.g. by including recording devices, to gain more insight into the appearance of this species over a long time period.

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6 Appendix

Appearance of *Ficdeula hypoleuca*

Through the data visualisation with QGIS and the classification of the area into different grid cells, an overview of the *F. hypoleuca* individuals per field day in the different locations was created (Table 8).

Table 7 Showing grids, in which birds were detected on the field dates in the main area. Also indicating the total number of birds per grid and how many territories are part of a grid.

Grid	4.5.	9.5	13.5	21.5	29.5	10.6	19.6	2.7	11.7	22.7	Total	Territories
A38	0	0	0	0	1	0	1	0	0	0	2	0
A44	0	0	0	0	0	1	0	0	0	0	1	0
A45	0	0	1	0	0	0	2	1	0	0	4	0.5
A46	0	0	1	0	0	0	1	0	0	0	2	0
A48	1	1	3	1	1	2	1	0	0	0	10	1.0
A49	0	0	0	0	1	1	0	1	0	0	3	0
A55	0	1	0	1	1	1	1	0	0	0	5	0.5
A56	0	0	0	2	2	2	1	1	1	0	9	2.0
A57	2	2	3	2	2	0	3	2	0	0	16	1.0
A58	0	0	1	2	3	1	1	0	0	0	8	0.8
A59	0	0	3	0	1	0	0	0	0	0	4	0.5
A60	0	0	0	0	1	0	1	0	0	0	2	0
A63	0	0	0	0	1	1	0	1	0	0	3	0.5
A64	0	0	3	1	1	1	1	1	0	0	8	1.0
A65	1	1	2	2	2	2	1	2	0	0	13	1.0
A66	4	1	1	1	3	0	1	1	0	0	12	1.5
A67	4	4	3	2	2	3	1	0	0	0	19	1.5
A68	1	3	2	2	1	3	2	1	0	0	15	1.2
A69	0	1	1	0	1	0	0	0	0	0	3	0
A72	1	0	1	0	1	0	1	2	0	0	6	0.5
A73	1	2	2	2	0	1	2	2	0	0	12	1.0
A74	3	2	2	1	0	1	0	0	0	0	9	1.0
A75	0	1	2	2	4	3	3	1	0	0	16	2.0
A76	2	2	4	1	2	1	1	0	0	0	13	1.0

Grid	4.5.	9.5	13.5	21.5	29.5	10.6	19.6	2.7	11.7	22.7	Total	Territories
A77	1	1	0	2	1	2	2	1	0	0	10	1.5
A78	2	2	2	0	0	2	0	0	0	0	8	0
A88	0	0	0	0	0	0	1	0	0	0	1	0
A91	1	0	0	0	0	0	0	0	0	0	1	0
A92	1	2	3	1	0	1	0	0	0	0	8	0.3
A93	2	3	5	4	2	2	1	1	0	0	20	1.2
A94	4	1	0	3	3	4	6	0	0	0	21	1.5
A95	2	2	2	2	1	2	4	3	0	0	18	1.0
A96	1	0	2	1	0	2	2	0	0	0	8	0.5
A97	0	0	2	1	0	0	0	1	0	0	4	0.5
A110	0	0	1	0	0	0	0	0	0	0	1	0
A111	3	1	2	4	4	3	2	0	0	0	19	2.0
A112	3	4	3	3	4	3	2	3	0	0	25	1.0
A113	0	0	4	0	0	0	0	0	0	0	4	0
A114	1	0	1	0	0	1	0	0	0	0	3	0.5
A115	1	1	1	1	0	0	1	0	0	0	5	0.5
A116	1	2	0	0	2	0	2	0	0	0	7	0.2
A117	2	4	4	4	3	3	1	0	0	0	21	1.5
A118	1	0	0	1	0	0	1	0	0	0	3	0.5
A126	0	2	1	2	1	1	1	0	0	0	8	1.0
A130	3	1	1	2	0	1	2	0	0	0	10	1.0
A131	0	0	0	1	0	0	0	0	0	0	1	0
A132	0	2	0	6	1	3	2	3	0	0	17	1.2
A133	7	4	2	3	2	1	3	0	0	0	22	1.1
A134	0	0	4	4	4	3	4	0	0	0	19	1.5
A135	1	0	0	2	2	1	2	0	0	0	8	0.8
A142	0	0	1	1	0	2	1	0	0	0	5	0.5
A143	0	2	1	1	1	0	0	2	0	0	7	0.5
A146	0	0	0	0	0	0	1	0	0	0	1	0
A147	4	3	2	3	5	3	3	4	2	2	31	1.5
A148	0	2	0	1	1	1	1	2	0	1	9	0.5
A149	0	1	1	2	3	2	2	2	0	0	13	1.0

Grid	4.5.	9.5	13.5	21.5	29.5	10.6	19.6	2.7	11.7	22.7	Total	Territories
A150	0	3	0	1	1	0	0	0	0	0	5	0.2
A153	0	0	0	0	1	0	0	0	0	0	1	0

GPS Tracks

During the territory mappings the taken routes in all areas were tracked with the device GPSMAP 60 CSx. This tracks are shown in Figure 35 for the site Großer Ahornboden and in Figure 36 for Schloss Tratzberg.

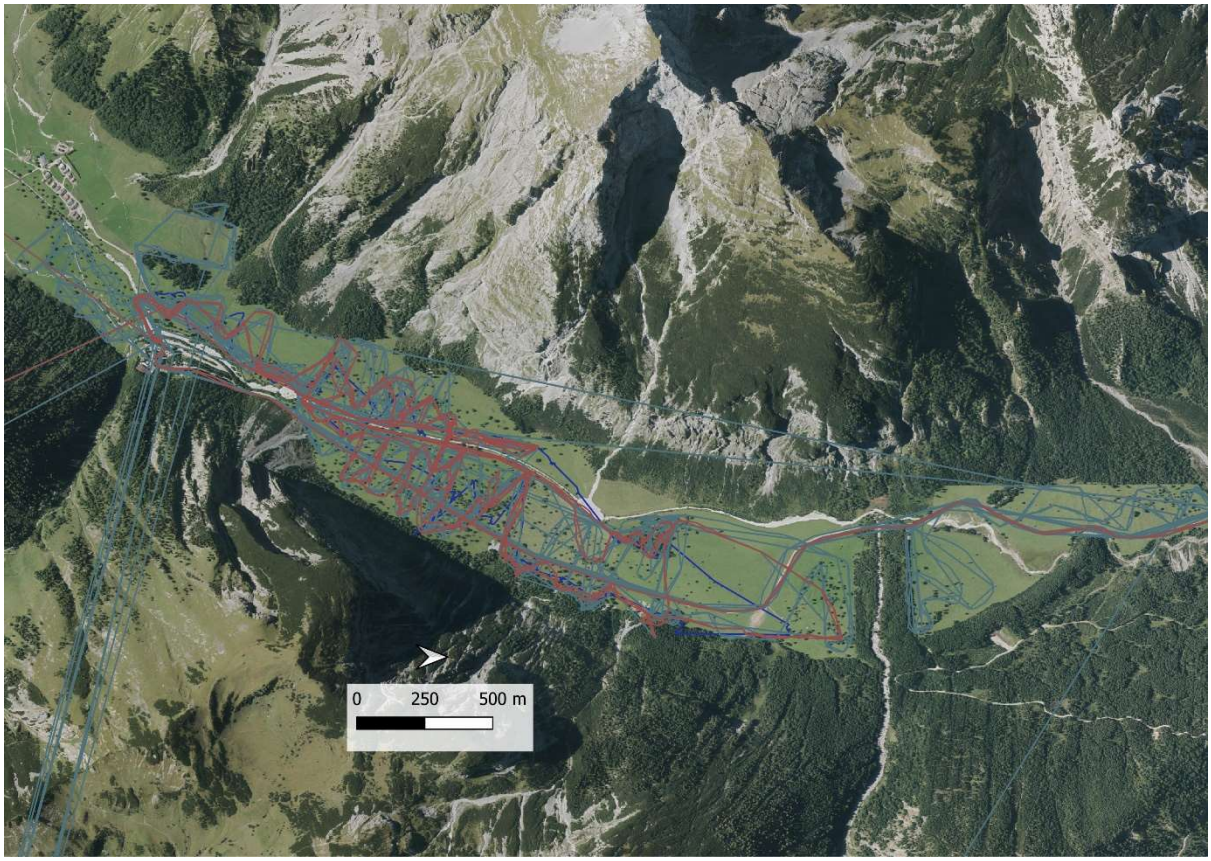

Figure 35 Additional figure showing all tracks from the territory mappings in the area Großer Ahornboden.

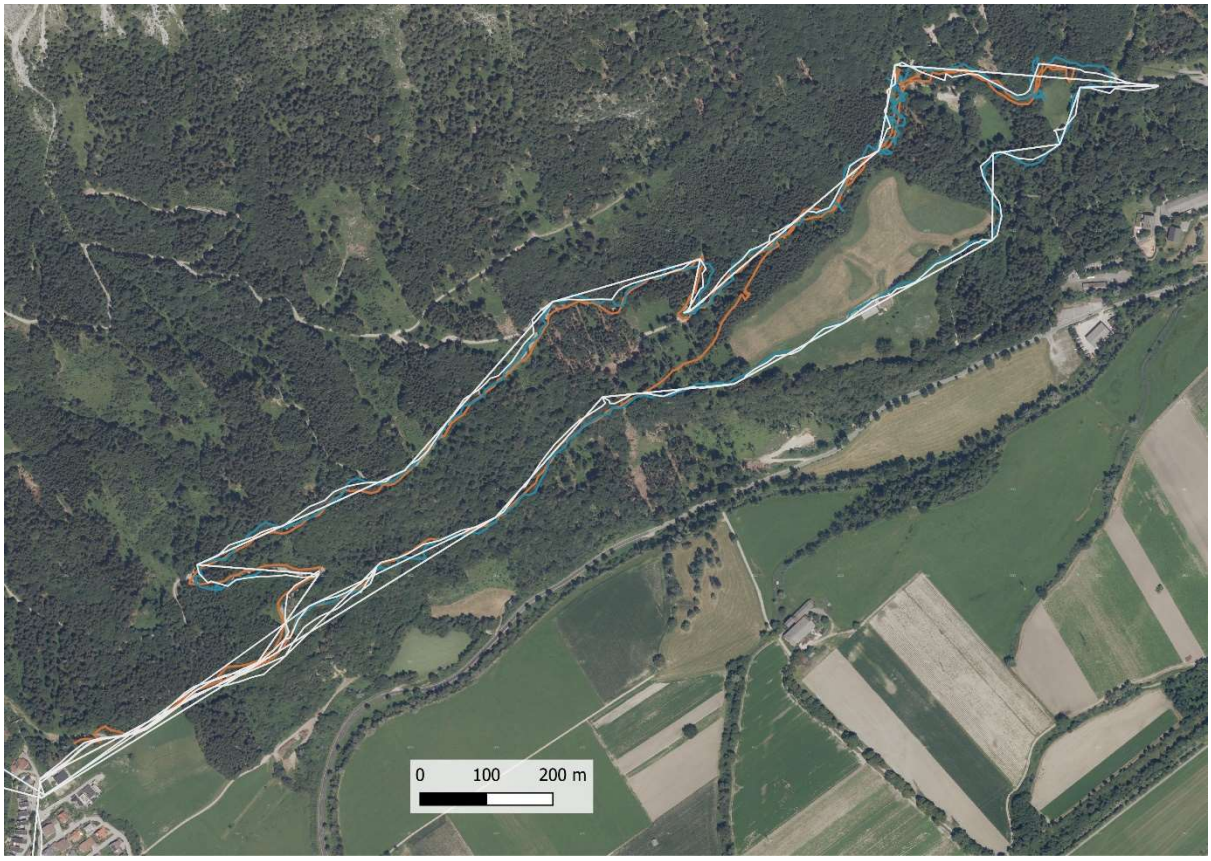

Figure 36 Additional figure showing all tracks from the territory mappings in the area TZ.

Point-count mapping protocol

For the field observations a protocol was created to get an overview of the weather conditions, possible predators, syntopic species and other parameters of the observation day. Depending on the mapping also the point-count mappings were noted in this table.

Table 8 Additional table showing the table for the mappings, where parameters like time, weather conditions, predators, syntopic species, etc. can be noted.

<table>
<tr><td colspan="4">Allgemein
Datum: Protokoll Nr.:
Beobachtung von: bis:
Standort:</td></tr>
<tr><td colspan="4">Witterung
o wolkenlos o leichter Regen o Schneehöhe
o bewölkt o Dauerregen o windig
o nebelig o Schneefall o dämmrig</td></tr>
<tr><td>Zufallska.:
Nr:</td><td>Vegetation:</td><td>Räuber:</td><td>Arten</td></tr>
<tr><td colspan="4">Verhalten/Phase zb. Zug</td></tr>
<tr><td colspan="4">Sonstiges</td></tr>
</table>

7 List of Figures

8 List of Tables

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Ich erkläre hiermit an Eides statt durch meine eigenhändige Unterschrift, dass ich die vorliegende Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel verwendet habe. Alle Stellen, die wörtlich oder inhaltlich den angegebenen Quellen entnommen wurden, sind als solche kenntlich gemacht.

Die vorliegende Arbeit wurde bisher in gleicher oder ähnlicher Form noch nicht als Magister-/Master-/Diplomarbeit/Dissertation eingereicht.

24.03.2024	Schaffhauser S.
Datum	Unterschrift