Stable or changed? Migratory numbers in three rare breeding bird species from Luxembourg

Charel Klein and Merit Finia Pokriefke E-mail cee.kaa@hotmail.com

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Abstract
Many bird species have experienced population declines in recent years and are forced to deal with climate change effects, causing some species to adjust their migratory patterns. While numerous studies have addressed this issue, research from Luxembourg is currently still lacking. Therefore, this study investigated how the migratory numbers of three rare breeding bird species have changed over a time period of 10 years. For this purpose, the ringing data of the two largest bird ringing stations in Luxemburg were analysed. The results showed over time an overall increase in migratory numbers for Bluethroats (*Luscinia svecica*) due to increasing numbers in fall that more than compensated the decrease in spring. There were no significant changes in migratory numbers for Sedge Warblers (*Acrocephalus schoenobaenus*) and Whinchats (*Saxicola rubetra*). These differing results underline the importance of migratory bird research and highlight the importance of stopover site conservation.

Zusammenfassung: **Stabil oder verändert? Zugzahlen bei drei seltenen Brutvogelarten aus Luxemburg**
Viele Vogelarten haben in den letzten Jahren einen Bestandsrückgang erlebt und sind gezwungen, sich mit den Auswirkungen des Klimawandels auseinanderzusetzen, was dazu führt, dass einige Arten ihre Migrationsmuster anpassen. Während sich zahlreiche Studien mit dieser Frage beschäftigt haben, fehlt es derzeit noch an Forschungsergebnissen aus Luxemburg. Daher wurde in dieser Studie untersucht, wie sich die Zugzahlen von drei seltenen Brutvogelarten über einen Zeitraum von 10 Jahren verändert haben. Dazu wurden die Beringungsdaten der beiden größten Vogelberingungsstationen in Luxemburg analysiert. Im Verlauf der Zeit ergab sich für das Blaukehlchen (*Luscinia svecica*) ein allgemeiner Anstieg der Zugzahlen, dies aufgrund steigender Zahlen im Herbst, die den Rückgang im Frühjahr mehr als kompensierten. Beim Schilfrohrsänger (*Acrocephalus schoenobaenus*) und Braunkehlchen (*Saxicola rubetra*) wurden keine signifikanten Veränderungen in den Zugzahlen festgestellt. Diese unterschiedlichen Ergebnisse unterstreichen die Bedeutung sowohl der Zugvogelforschung als auch des Erhalts von Rastplätzen.

Résumé: **Stable ou modifié? Nombre de migrateurs chez trois espèces d'oiseaux rares nicheurs au Luxembourg**
De nombreuses espèces d'oiseaux ont connu des déclins de population ces dernières années et sont obligées de faire face aux effets du changement climatique, forçant certaines espèces à ajuster leurs schémas migratoires. Alors que de nombreuses études se sont penchées sur cette question, des recherches au Luxembourg sur ce sujet font encore défaut à l'heure actuelle. Par conséquent, cette étude a examiné comment le nombre de migrateurs de trois espèces d'oiseaux nicheurs rares a changé sur une période de 10 ans. A cet effet, les données de baguage des deux plus grandes stations de baguage d'oiseaux au Luxembourg ont été analysées. Les résultats ont montré au fil du temps une augmentation globale du nombre de migrateurs pour les Gorgebleues à miroir (*Luscinia svecica*), ceci suite à l'augmentation du nombre en automne qui a plus que compensé la diminution au printemps. Il n'y a pas eu de changements significatifs dans le nombre de migrateurs pour la Phragmite des joncs (*Acrocephalus schoenobaenus*) et le Tarier des prés (*Saxicola rubetra*). Ces résultats divergents soulignent l'importance de la recherche sur les oiseaux migrateurs de même que l'importance de la conservation des haltes migratoires.

One of the most spectacular and largest migrations takes place among birds (Dokter et al. 2018, Haest et al. 2020). In order to increase their chances of reproductive success and survival (Bauer & Hoye 2014, Dokter et al. 2018) most bird species of the northern hemisphere migrate to the south every fall and return at the beginning of spring (Miller-Rushing et al. 2008, Haest et al. 2020). For success, timing is important and a fitting migration strategy is crucial (Cotton 2003, Lehikoinen et al. 2004,, Miller-Rushing et al. 2008). If birds return too early in spring, bad weather conditions may be life-threatening (Peach et al. 1991, Visser et al. 2015, Askeyev et al. 2020). If they come back later, it is usually safer, but they risk to loose valuable breeding time and can probably no longer acquire the best resources for their fledglings, the best breeding territories having already been occupied (Both et al. 2010, Visser & Gienapp 2019, Askeyev et al. 2020). In fall, the birds are faced with the conflict of staying as long as possible and using the existing resources (e.g. for a second brood) and the risk of reducing the probability of survival if they depart too late (Cotton 2003, Tøttrup et al. 2006, Zając et al. 2015).

Under constant environmental conditions, the scheduling of migration presents only a minor concern (Parmesan 2006). In recent decades however, changes in migration phenology have been observed for some species (Miller-Rushing et al. 2008, Van Buskirk et al. 2009, Both 2010, Radchuk et al. 2019). One of the main drivers for these migratory alterations is climate change and the resulting variations in weather conditions, especially in spring (Lehikoinen et al. 2004, Parmesan 2007, Knudsen et al. 2011). Temperatures increase sooner and the growing season begins earlier in the breeding area (Jenni & Kéry 2003, Menzel et al. 2006, Haest et al. 2018). Still, the weather in the wintering area and in the passage zone does play an important role too (Robson & Barriocanal 2011, Hewson et al. 2016, Haest et al. 2018). In contrast to spring, the effects of climate change in fall are much more diverse and difficult to determine (Lehikoinen et al. 2004, Haest et al. 2019). The right timing for fall migration is therefore driven by many factors such as life-history traits, migration strategy, environmental conditions and annual cycles (Jenni & Kéry 2003, Gallinat et al. 2015, Visser & Gienapp 2019). It is certain that these environmental changes can have consequences for the survival and fitness of birds (Cotton 2003, Hewson et al. 2016, Visser & Gienapp 2019).

One way to document these changes in bird populations and migratory periods is to record the number of migrating birds by counting (Knudsen et al. 2007, Martín et al. 2016, Dunn 2016). Especially when citizen science platforms are included, to cover a large area simultaneously becomes possible (Tulloch et al. 2013, Bitterlin & Van Buskirk 2014, Moreira et al. 2022). One option for recording the numbers of migratory birds is bird ringing at specific places (Şekercioğlu 2012, Askeyev et al. 2020, Maggini et al. 2021). By using mist nets, it is possible to catch a large number of species (Wang & Finch 2002, Maggini et al. 2021). The method has furthermore the advantage that very cautious species may be recorded and the physiological state can be documented (Wang & Finch 2002). Moreover, it is possible to detect and avoid double counting as all birds are individually marked (Wang & Finch 2002).

In most cases, these surveys are carried out on islands or on mountain passages, so-called bottlenecks, as only such locations offer a distinction between breeding and migrating birds (Jenni & Kéry 2003, Hüppop & Hüppop 2011, Maggini et al. 2020b). In the inland, such studies are more difficult, as the transition between still breeding birds and already migrating birds is overlapping. Nevertheless, in order to study the migration numbers of inland birds (Maggini et al. 2021) more research at stopover sites is needed (Mehlmann et al. 2005). An opportunity for this emerges in the Grand Duchy of Luxembourg as the distinction between breeding and migrating individuals can be made here. Unfortunately, there is no uniform survey programme for migratory birds in Luxembourg. The number of birds caught depends on how many days the nets are opened, which in turn depends on weather conditions and the number of volunteers or bird ringers that are currently available. Even though important parameters for standardization purposes, such as net meters or net hours, are recorded for every ringing session, most of the information is so far not digitalised. Thus, it is not directly usable for further research.

Hence, we suggest in this study a method to compare ringing stations with different workloads to analyse the data of the last 10 years of three non-breeding species in Luxembourg. The investigated species were Sedge Warbler (*Acrocephalus schoenobaenus*), Bluethroat (*Luscinia* **svecica**) and Whinchat (*Saxicola rubetra*). The aims of this study were to determine if a change in migratory bird numbers would be detectable, whereby we assumed a negative tendency over time.

1. Material and methods

1.1 Study site

The study was conducted in Luxembourg, central Europe, including the data of two bird ringing stations "Schlammwiss" (49,63°N 6,27°E) and "Brill" (49,50°N 6,00°E) (Fig. 1). The station Schlammwiss is located in Uebersyren, eastern Luxembourg, in the nature reserve "Schlammwiss-Brill (ZH51)". It is part of Luxembourg's largest reed belt within the bird protection area Natura 2000 "Vallée de la Syre de Moutfort à Roodt/Syre". This protected area covers almost 30 ha at approximately 240 m above sea level. It includes wetlands, reeds, meadows, orchards, forests, softwood floodplains and ponds. The station and nature reserve is regularly flooded by the river Syr.

The bird ringing station "Schëfflenger Brill" (short: Brill) is located north-west of Schifflange, southern Luxembourg, at 280 m above sea level. It is part of the nature reserve "Brill (ZH 44)" and the bird protection area Natura 2000 "Vallée supérieure de l´Alzette in Schifflange". The ringing station covers 18 ha and is situated in the valley of the river Alzette. The habitat of this study area is similar to the Schlammwiss area. However, it contains a smaller proportion of wetland meadows and has no orchard. The ringing data of the bird ringing station Brill were used for comparison with the bird ringing station Schlammwiss.

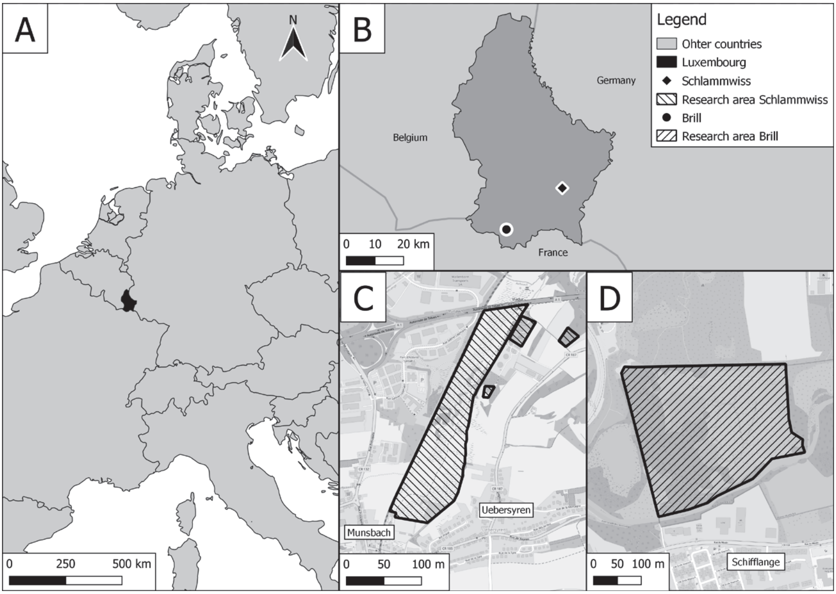

Figure 1:A) Location of Luxembourg (black), B) the two bird ringing stations Brill (black circle) and Schlammwiss (black rhombus) in Luxembourg (dark grey), C) the study site of the bird ringing station Schlammwiss (black shaded), D) the study site of the bird ringing station Brill (black shaded).

1.2 Capture method

The management and scientific monitoring of bird ringing in Luxembourg is carried out by the Central Ornithologique du Luxembourg (COL). The birds are captured with mist nets (length: 6-20 m, height 2.5-3 m, mash width 16 mm) at both bird ringing stations. The location of the nets has remained roughly the same over the last few years and they are distributed throughout the whole study area. There was a great difference between the stations in the number of catching days (Appendix, Table A1), net meter length and number of volunteers.

During spring and fall (Appendix, Table A1) the birds were attracted with playback to the nets. The playback was individually configured for different net sites, based on years of experience and shared knowledge with other ringing station across Europe. The start of the playback took place in the evening before the ringing activity was planned and ended with closing of the nets. Every hour the nets were controlled for birds caught. In case of cold weather or light rain the interval of net control was increased to every half hour. The nets were closed during heavy rain or strong wind, as this may have affected the birds' welfare.

Every captured bird was ringed with a coded aluminium ring of the Belgium Bird Ringing Central "Royal Belgian Institute of Natural Science". According to the ring status, birds could be divided in first capture (first time the bird gets a coded ring), control (recapture of bird with a ring, but not from the same year or capture of a bird with a foreign ring) and recapture (capture of an individual that was already ringed that year or an additional recapture of a control bird within the same year). Further ringing measurements, like morphological parameters and physiological state were taken and the bird was released within a short time after capture.

1.3 Data selection

For better comparability in ringing methods and working process, only data from the period from 2011 to 2020 were used in this study. Prior to 2011, the stations' working methods and ringing intensities were not stable enough for comparisons.

The selection of the studied bird species (Table 1) was based on the following criteria. In order to have sufficient quantity of data to examine the research issue about migration numbers, at least 200 individuals of a species (ring status: first captured and control) must have been captured in the past 10 years at the bird ringing station Schlammwiss. Further, the species had to be a non-breeding species at Schlammwiss to achieve a clear distinction between breeding and migratory season. The classification for breeding and occurrence status was determined on the basis of Lorgé and Melchior (2015), Lorgé (2020) and Steinmetz et al. (2021).

Furthermore, birds were excluded from this study i) if a species was caught only during special events (e.g.: heavy rain causing migration stops of for example House Martins (*Delichon urbicum*) in specific years), ii) if the total number of catches was strongly depending on the work effort and special catching events (e.g. Skylarks (*Alauda arvensis*) during night catches) or iii) if they were part of a special capture monitoring (e.g. Water Pipits (*Anthus spinoletta*) as overwintering guest). Hence, for this study, three species fulfilled the criteria: Sedge Warbler, Bluethroat and Whinchat (Table 1).

Table 1: Sum of ringed individuals from the last 10 years
(ring status: first captured and control) from non-breeding bird species at the ringing station Schlammwiss. The table is sorted in descending order, according to the number of catches of the station Schlammwiss (see column Schlammwiss). Number of individuals caught at the station Brill are displayed in the column Brill.

Ranking	Selected	Species	Name	Schlammwiss	Brill
1	1	*Acrocephalus schoenobaenus*	Sedge Warbler	3 247	647
2		*Delichon urbicum*	House Martin	1 988	7
3		*Alauda arvensis*	Skylark	1 116	0
4	2	*Luscinia svecica*	Bluethroat	625	45
5		*Anthus spinoletta*	Water Pipit	624	4
6	3	*Saxicola rubetra*	Whinchat	371	5

At both stations, only the number of catching days (Appendix, Table A1) were available and hence used for this research. The transfer of the ringing data was performed by the bird ringing station Schlammwiss and the COL.

1.4 Statistical analysis

The pre-selection and sorting of the data were performed in Excel (Version 2203). The data analysis and plotting of the graphs were conducted in R (Version 1.4.1717). The maps were created with QGIS (Version 3.16.0-Hannover).

All individuals ringed with the status first capture and control were used to calculate the quantity of birds migrating per year or season. Since the number of catching days per month, year and station differed greatly, the quotient of the number of birds caught and the catching days (hereafter referred to as BD value or birds per day) was calculated (Equation 1). This allowed a better comparability of both stations. In case a bird species was caught only in five or less years, no BD was calculated.

$$BD = \frac{\text{sum of birds caught}}{\text{sum of catching days}} \qquad \text{(Equation 1)}$$

In order to identify population tendencies within the data, we applied linear models (lm). We tested the data for normal distribution through QQ plots and Shapiro-Wilk tests. Given a normal distribution, we calculated lms for each station (Schlammwiss or Brill) and season (spring or fall) with the total number of birds as dependent variable and the year as independent variable. If the data was not gaussian, a square root transformation was applied to the response variable. The previous tests were repeated to confirm a normal distribution of the transformed variable. If those were successful, we calculated a lm. If a transformation did not result in a gaussian distribution we applied a generalised linear model (glm) with Poisson distribution with the total number of birds as response variable and the year as independent variable.

2. Results

2.1 Sedge Warbler

In total 3,894 Sedge Warblers were ringed during the last 10 years in Luxembourg (Table 1). The average BD was 2.33 at the station Schlammwiss and 1.59 at Brill (Appendix Table A2). The mean BD in spring was 0.51 at the station Schlammwiss. Since less than five birds were caught in spring at the station Brill, no BD was calculated. The BD in fall was 3.33 for Schlammwiss and 1.92 for Brill. At both stations no increase or decrease could be detected for the total number of birds or for any season over the investigated time period (p= 0.486 for Schlammwiss, p = 0.334 for Brill, Appendix, Table A3, Fig. A1).

2.2 Bluethroat

During the past 10 years 670 Bluethroats were ringed in Luxembourg (Table 1).
The average BD value was 0.45 for Schlammwiss and 0.15 for Brill (Appendix, Table A2). The total number of birds ringed each year increased at both stations (p = 0.048 for Schlammwiss, p = 0.045 for Brill). On average, the BD was 0.62 for Schlammwiss and 0.17 for Brill during the fall migration. An increase (p = 0.027 for Schlammwiss, p = 0.039 for Brill) was observed in fall (Figure 2 and Table 2).

Table 2: Summary of the lm for the number of Bluethroats at the stations Schlammwiss and Brill for the whole study period from 2011 to 2020 for the season spring and fall over all years.

		Coefficients	Estimate	Std. Error	t-value	Pr(>t)	
Schlamwiss	Total	(Intercept)	-50.617	21.885	-2.313	0.050	*
		Year	0.025	0.011	2.333	0.048	*
	Spring	(Intercept)	80.920	36.502	2.217	0.058	.
		Year	-0.040	0.018	-2.208	0.058	.
	Fall	(Intercept)	-97.846	36.318	-2.694	0.027	*
		Year	0.049	0.018	2.711	0.027	*
Brill	Total	(Intercept)	-45.312	19.125	-2.369	0.045	*
		Year	0.023	0.009	2.376	0.045	*
	Fall	(Intercept)	-66.906	27.213	-2.459	0.039	*
		Year	0.033	0.014	2.464	0.039	*

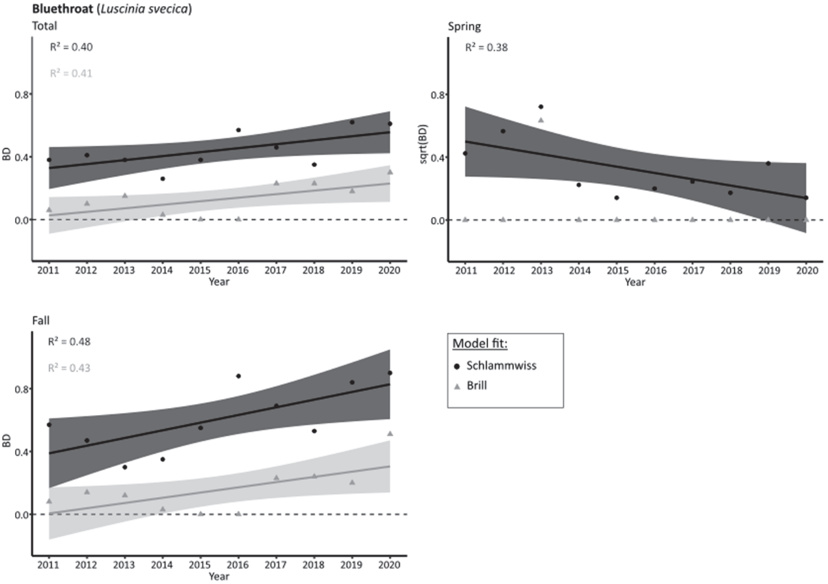

Figure 2: BD number of Bluethroats ringed each year (top left), for spring (top right) and fall (bottom left) at the bird ringing station Schlammwiss (orange) and Brill (grey). Since Bluethroats were only captured in one year in spring at the station Brill, no linear model was calculated (Table 2).

In spring, diminishing numbers of Bluethroats (p = 0.058) were detectable at the station Schlammwiss (Figure 2, Table 2). Except for 2013, no birds were caught in spring at the station Brill and no BD was calculated (Appendix, Table A2).

2.3 Whinchat

In the last 10 years, 371 Whinchats were ringed at the station Schlammwiss (Table 1).
At the station Brill 4 birds were captured, 2 in 2018 and 2 in 2020 (Appendix Table A2). The mean BD value was 0.36 at the station Schlammwiss. In spring the average BD was 0.23. In the years 2011, 2012, 2016 and 2018 no birds were caught and ringed during spring migration in Luxembourg. The mean BD value for fall was 0.53. No significance for an increase or decrease of BD during any period was found (p=0.657, Appendix Table A3 and Figure A2).

3. Discussion

In the present study we investigated the changes in migratory densities for Sedge Warblers, Bluethroats and Whinchats throughout the years 2011 to 2020 in Luxembourg. For Sedge Warblers and Whinchats no significant changes could be shown. However, Bluethroat populations increased in fall, contrary to our assumptions, and decreased in spring as hypothesised.

As a result of the preselection, it was possible to calculate the exact density of migratory birds per year and season. Here, Sedge Warblers and Whinchats are considered as long-distance migrants (Shirihai & Svensson 2018, Burgess et al. 2020, Maggini et al. 2020a) while Bluethroats are considered as short-distance migrants (Shirihai & Svensson 2018). The results of this study indicated no changes in migratory numbers for the two former bird species. This is in contrast to the findings of Hüppop and Hüppop (2011) and Haest et al. (2020) who have demonstrated on Helgoland that the numbers of long-distance migrants are generally declining. However, it might be that this applies only for breeding birds with a long-distance strategy in a specific area and cannot be assumed for bird species only migrating through.

3.1. Sedge Warbler

Of the three species studied, Sedge Warblers were the most abundant to migrate through Luxemburg. Though this species was listed as Least Concern with a stable population by the IUCN (BirdLife International 2016a), it was categorised as Critically Endangered and has always been a rare breeding bird in the country (Lorgé et al. 2015, 2020). According to Lorgé et al. (2020), there is a very small breeding population of one to five pairs with a negative long-term tendency in Luxembourg.

Even though the BD value of Sedge Warblers has increased in the past 10 years at the station Brill from 1.55 in 2011 to 2.33 in 2019, reaching now similar levels than the station Schlammwiss, this development was not statistically verifiable. This may have been caused by the low number of catching days in spring at the station Brill, which could have resulted in no caught individuals. Further, it may be that the habitat alterations at the station Brill (Lorgé & Mirgain 2012, Centrale Ornithologique Luxembourg 2021), e.g. improvement of the protected areas or establishment of new sites with reed and wet meadows, still need more time to impact the population. The number of migrating Sedge Warblers caught remained unchanged on average at the station Schlammwiss, which matches the study of Steinmetz et al. (2021) concerning the same area. The ringing data show fluctuations between the years. The cause for this is probably the additional number of juveniles migrating in fall (Hüppop and Hüppop 2011, Birget 2013). Therefore, it can be assumed that the migratory population is stable in Luxemburg and not declining as predicted in the beginning of this study. However, another possible explanation could be the catching method. The use of playback to attract migratory birds probably resulted in more birds choosing this stopover site instead of skipping it and therefore leading to a higher and thereby constant number of Sedge Warblers.

3.2 Bluethroat

The second most abundant species caught in Luxembourg was the Bluethroat. This species was as well listed as having a stable population with the status Least Concern by the IUCN (BirdLife International 2019), but was considered to be extinct as a breeding species in Luxembourg until recently (Lorgé et al. 2015, 2020). For this reason, Bluethroats were listed as “Species with geographical restriction – Category R” (Lorgé et al. 2020).

Encouragingly, this analysis showed that the species was increasing significantly during fall migration in the number of birds per year at both stations, contrary to our predictions. This migratory increase could be a result of the habitat improvements in Luxemburg (Lorgé et al. 2020) and surrounding region (Zink et al. 2003). According to Lorgé et al. (2020), Bluethroats have been able to establish new breeding sites in large agricultural areas with densely overgrown channels in the past few years. Still, this study and most other studies found a negative trend of the migration numbers in spring that might be explained by the birds migrating faster to the north with fewer stops in spring, causing birds to skip other stopover sites (Ellegren 1990, Svanberg & Waldenström 2011, Nilsson et al. 2013).

3.3 Whinchat

At the station Brill, Whinchats were only found in two years. This might be due to the absence of habitat structures, mainly wet meadows (Centrale Ornithologique du Luxembourg 2021). Thus, the two years with two captures are handled as exceptional cases and therefore excluded from this study.

Whinchats were categorised as Least Concern by the IUCN, but the population trend is negative (BirdLife International 2016b) and the species has suffered losses (Strebel 2015, Harry 2021, Kosicki 2022). In Luxembourg, this species has been considered extinct as breeder since 2014 (Lorgé et al. 2015). Although the species was observed every year during migration, the official last breeding record dates back to 2007 (Lorgé et al. 2015). Nonetheless, recent observation data on Ornitho.lu, a citizen science platform in Luxembourg, suggested that there were five breeding attempts and one successful breeding in the last 10 years (from data provided by the COL). A breeding population decline could be observed in the neighbouring regions (Schaub et al. 2013, Both 2021, Harry 2021) and for migratory populations at other ringing stations as well (Maggini et al. 2021).

On the station Schlammwiss, this species was only found in six out of ten years in spring. Whinchats are mainly found during fall migration at the bird ringing station. The number of birds caught in fall, as well as throughout the year, seemed to remain constant. Thus, a declining migration population of Whinchats as mentioned previously could not be verified since the data were too scarcely distributed over the research time span.

The number of catching days, the duration of net hours, the opening time of the nets and the locations where the nets were used were strongly dependent on several factors e.g., the season, the weather conditions and the number of bird ringers or volunteers available at the stations. There existed no standardized catch per unit effort (CPUE, as proposed in Maggini et al. 2021) for both stations that would have allowed a more accurate comparison of the ringing results between each other and with other studies. Nonetheless, with the BD value an approximated CPUE was calculated. With this standardization method, the data of both ringing stations could be compared with each other despite different workloads. Thus, it could be verified if the following findings occurred only at one site or if they could be detected elsewhere in Luxembourg, indicating a general pattern. Furthermore, the preselection of rare birds allowed to determine numbers of migratory birds correctly without confusion with breeding individuals, but not all species were similarly abundant at both ringing stations, thus impeding comparison of both stations. For improvement of comparability of the two stations, we suggest for further studies to select species that are numerous at both locations

4. Conclusion

The effects of current climate change on migratory bird numbers can be noticed in Luxembourg like in many other regions. Especially in the case of the Bluethroat, differences have been found over the last 10 years. By using the method of calculating the BD value, it was possible to compare the results of the two bird ringing stations Schlammwiss and Brill even though they have different workloads and amounts of catching days. For further studies however, the aim of the two stations should be to use the standardized catch per unit effort as proposed by Maggini et al. (2021). Hence, the number of net meters and net hours of each ringing session should be documented and digitalised. This should enable a better comparison of the ringing results between the station in Luxembourg and between other studies and stations. When studying migratory birds, it becomes clear how important stopover site conservation and habitat improvement are, especially when facing the endangerment of our current time.

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Appendix

Table A1: Number of catching days for each month and sum per year separated for the stations Schlammwiss and Brill.
For spring, the months March, April and May were used. The months July, August, September and October were used for fall (NA= no data available).

Station	Year	March	April	May	July	August	September	October	Total
Schlammwiss	2011	24	22	16	14	22	11	16	125
	2012	16	25	22	18	30	27	23	161
	2013	17	15	16	19	26	23	15	131
	2014	10	14	14	25	30	25	15	133
	2015	12	18	18	24	30	23	25	150
	2016	24	11	15	30	29	15	11	135
	2017	13	15	22	27	29	17	16	139
	2018	9	13	17	21	24	18	11	113
	2019	11	15	20	25	30	24	23	148
	2020	5	19	28	26	31	28	22	159
Brill	2011	NA	5	7	10	10	11	8	51
	2012	5	1	6	9	10	8	10	49
	2013	1	NA	4	7	9	9	9	39
	2014	NA	NA		7	6	12	6	31
	2015	NA	1	4	10	8	8	5	36
	2016	NA	1	2	6	3	6	6	24
	2017	NA	NA	1	8	10	8	4	31
	2018	NA	NA	2	10	8	9	6	35
	2019	2	NA	1	9	6	8	7	33
	2020	14	11	7	11	12	19	5	79

Table A2: Mean BD with standard deviation (sd) for the season spring and fall over the years and total mean BD with sd over the years for the three species.
Results for the station Schlammwiss in the first row and for the station Brill in the second row of each species.

Species	Station	Spring		Fall		Total	
		BD	sd	*BD*	sd	BD	sd
Sedge Warbler	Schlammwiss	0.50	0.20	3.35	0.95	2.32	0.59
	Brill	0.10	0.12	1.89	1.20	1.65	1.14
Bluethroat	Schlammwiss	0.32	0.19	0.61	0.20	0.44	0.11
	Brill	0.06	0.19	0.15	0.15	0.13	0.10
Whinchat	Schlammwiss	0.05	0.06	0.53	0.10	0.37	0.09
	Brill	0.00	0.00	0.01	0.03	0.01	0.03

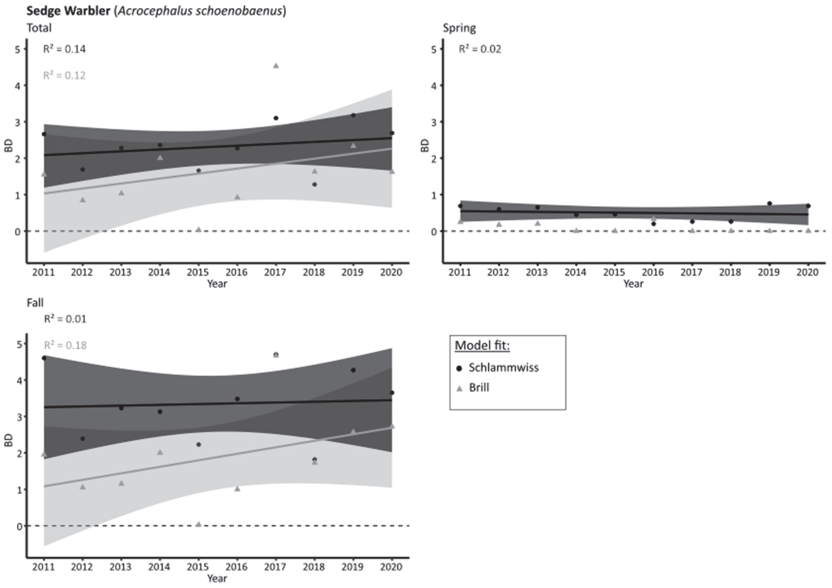

Figure A1:BD of Sedge Warblers ringed each year (top left), for spring (top right) and fall (bottom left) at the bird ringing station Schlammwiss black circle) and Brill (grey triangle).

Table A3: Summary of the linear models for the number of Sedge Warblers and Whinchats at the stations Schlammwiss and Brill

for the whole study period from 2011 to 2020 and for the seasons spring and fall over all years. Due to insufficient sample size no linear models were calculated for i) Sedge Warblers at the station Brill in spring and for ii) Whinchats at the station Brill in spring and fall.

Species	Location		Coefficients	Estimate	Std. Error	t-value	Pr (>t)
Sedge Warbler	Schlammwiss	Total	(Intercept)	-101.878	142.512	-0.715	0.495
			Year	0.052	0.071	0.073	0.486
		Spring	(Intercept)	20.779	47.978	0.434	0.676
			Year	-0.010	0.024	-0.423	0.683
		Fall	(Intercept)	-39.647	233.792	-0.170	0.870
			Year	0.021	0.116	0.184	0.859
	Brill	Total	(Intercept)	-273.316	265.994	-1.028	0.334
			Year	0.136	0.132	1.034	0.332
		Fall	(Intercept)	-357.849	269.469	-1.328	0.221
			Year	0.179	0.134	1.335	0.219
Whinchat	Schlammwiss	Total	(Intercept)	-9.870	22.199	-0.445	0.668
			Year	0.005	0.011	0.461	0.657
		Spring	(Intercept)	-41.330	36.185	-1.142	0.286
			Year	0.021	0.018	1.147	0.285
		Fall	(Intercept)	-2.269	25.850	-0.088	0.932
			Year	0.001	0.013	0.108	0.916

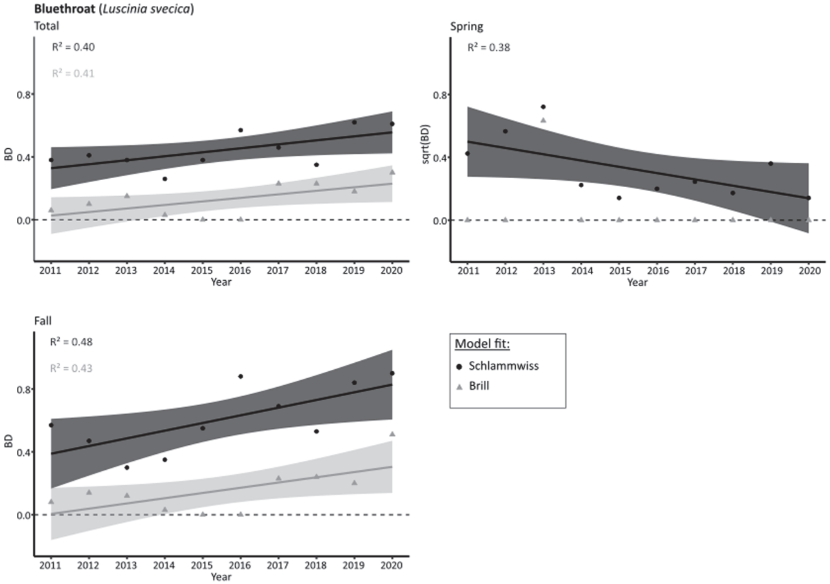

Figure A2: BD of Whinchats ringed each year (top left), for spring (top right) and fall (bottom left) at the bird ringing station Schlammwiss (black circle) and Brill (grey triangle).