Do Environmental Variables Affect The Reproductive Success of the Corn Bunting, *Emberiza calandra*?

Lattion Camille

University Neuchâtel

Master thesis

Supervisors : Prof. Dr. Clara Zemp, University Neuchâtel

and Julien Mazenauer, BirdLife Switzerland

Abstract

During the 20th century, agricultural intensification led to a significant decline in farmland birds across Western Europe. Among them the Corn Bunting, *Emberiza Calandra*, is placed in the "Critically Endangered" category of the Red List of Switzerland. To help the population recover, this study aimed to better understand the link between environmental variables and the reproductive success of the Corn Bunting. Territories were identified in the region of the Seeland (BE/FR) and environmental variables (height and number of vertical structures, type of crop, height and surface of woody vegetation, Shannon index) were recorded. Generalized linear models (GLM) and multinomial logistic models were performed. Results showed a negative effect of the woody vegetation height on the pairing success. No other variable had a significant effect on the reproductive or pairing success of Corn Buntings. Other factors such as the presence of conspecific, the abundance of arthropods and the type of habitat around territories must be further investigated to gain a broader understanding of the reproductive success of this species.

Keywords : Reproductive success, Corn Buntings, farmland birds conservation

unine
Université de Neuchâtel

1. Introduction

During the 20th century, agricultural practices intensified across Europe to support the growing of the human population. Consequently, the Common Agricultural Policy (CAP), established by the European Union, evolved and was adapted in response to agricultural intensification (Taylor and O'Halloran, 2002). This process led to negative consequences, such as the increase of pesticides (Taylor and O'Halloran, 2002) and landscape homogenization (Lefebvre et al., 2012), which negatively impacted biodiversity. As a result, farmland biodiversity declined (Hristov et al., 2020). Indeed, it has been shown that countries in the EU observed a significant decline in farmland bird populations, especially ground-nesting species (Guerrero et al., 2012), due to changes in the CAP (Butler et al., 2010, Tscharntkea and Batáry, 2023). The Corn Bunting, *Emberiza Calandra*, is one of these threatened farmland species. Another driver of Corn Bunting decline may be the loss of spring-sown cereals in favor of winter-sown crops (Taylor and O'Halloran, 2002). Indeed, the mowing period occurs earlier with winter-sown crops, coinciding with the nesting period of the Corn Bunting, which is a ground-nesting species (BirdLife International, 2023). The earlier mowing period may also reduce the nesting site availability, and inhibit potential second clutches (Perkins et al., 2017). In addition, winter-sown crops provide fewer invertebrates during the breeding season (Taylor and O'Halloran, 2002), which mainly compose the species' diet during breeding season.

In Europe, Corn Bunting populations have decreased by 75% since 1960, and the same trend has been observed in Switzerland (Fehlberg, 2022). During the 1990s', the Corn Bunting was widely present in Switzerland, for example in Zürich, Klettgau (AG/ZU), Lake Constance (TH/SG), Champagne genevoise (GE), Seeland (BE/FR). Currently there are only three large populations remaining : one in the Seeland (BE/FR), one in Plaine de l'Orbe (VD) and the other one in the Champagne genevoise (GE). Some isolated individuals can be observed in other locations, but they do not form populations (Maumary, 2007). Since 2021, the Corn Bunting is considered as critically endangered (CR) on the Red List of Switzerland due to the strong population decline, whereas it was in the least concerned (LC) category on the 2010 Red List (Liste rouge des oiseaux nicheurs, 2021).

A solution to prevent a continuous decline of farmland birds is the implementation of Agri-Environmental Schemes (AES). AES are "strategies of agriculture management that aim to increase and protect the biodiversity in agricultural ecosystems" (Lécuyer et al., 2021). Farmers are paid in exchange to apply less intensive measures and provide targeted habitats separated from crops (Perkins et al., 2017). In Switzerland, farmers can also receive subsides if they keep part of their agricultural lands for what is called Surfaces for the Promotion of Biodiversity (SPB) (Nucera et al., 2019) which can be considered as AES (Federal Office For the Environment, 2014). Indeed, since Switzerland is not part of the European Union, it has its own agricultural policy, apart from the CAP (Herzog et al., 2017). Some AES

such as unharvested crops, fallows, wild bird seed mix and species rich grasslands are most likely to provide great amounts of invertebrate to chicks of Corn Buntings in summer, and food to adult Corn Bunting during winter (Perkins et al., 2017). Setchfield et al. (2012) found that Corn Buntings' breeding attempts occur twice more on AES extensive crops than on intensive ones and that the former also attracts more females.

They also found that females Corn Bunting breeding on extensive crops had higher probability to do a second clutch than the one in intensive breeding site. This could be explained by the greater amount of invertebrates in extensive crops. Even if the management of the crops helps to protect the farmland species, the problem remains for species that nest on the ground. Since the mowing period occurs during the nesting period, it increases the number of dead offspring (Setchfield et al., 2012). It is particularly true for the Corn Bunting which has a breeding season later than most of other farmland birds (Setchfield et al., 2012). An adapted mowing time could protect the nest and increase survival of offspring, thus reproductive output.

However, even with the conservation measures taken by European countries, the trend is still going down. Indeed, despite the increased number of SPBs such as flower strips and fallow specific for Corn Buntings, the species is still in decline (Fehlberg, 2022). One of the explanation is that even in SPBs, some individuals fail to reproduce. However, no studies are available on factors affecting the reproductive success of the Corn Bunting and the causes of such failure are still unknown. Nevertheless, reproduction is a key event to prevent the decline of a species. Knowing which habitat and/or environmental variable are required for a successful reproduction can enable the creation of suitable habitat to, hopefully, allow the population to recover.

By focusing on the population of the Grosses Moss (Seeland), this study, in collaboration with Birdlife Switzerland (www.birdlife.ch), aims at disentangling the respective role of each environmental variable on the pairing success and reproductive success. To do so, I looked at the vegetation type and height, the vertical structures type and height (e.g. artificial singing posts, fences post, other artificial vertical structures) and the type of crops on the different territories. These are important points to understand for the conservation of the Corn Bunting : by targeting environmental variables that increase the reproductive success, conservation plans could be set up to preserve and increase that habitat type.

I hypothesize that environmental variables influence formation of pairs and reproductive success. The prediction is that there will be more pairs formed and higher reproductive success in habitat with lots of vertical structures used as singing perch, open habitat, and high quality SPBs (flower strips, extensively managed meadows and fallows).

2. Methods

2.1. Study species

The Corn Bunting is a passerine bird species breeding in extensive and open farmlands. Its habitat is mostly composed of agricultural lands with scarce bushes. In the northern part of its distribution, including Switzerland, this species is mostly found in cereal fields and hay meadows (BirdLife International, 2023). Besides the breeding season they mostly eat plant seeds but during the latter their diet is mainly composed of small insects in order to feed nestlings. Diet of nestlings mostly consist on insect larvae and Orthoptera. During the breeding season, the nest is built by the female, on the ground and hidden by the vegetation (BirdLife International, 2023). Females lay between 2 and 6 eggs per clutch from the end of May until mid-June. A second clutch is rare but can happen in July. The incubation lasts between 11 and 13 days. Fledglings leave the nest after 9 to 11 days and are still fed by the female during 1 to 3 weeks (Maumary, 2007). The Corn Bunting is not a monogamous species but promiscuous. Males can reproduce with several females (Mollers, 1983). During the reproduction, males can easily be distinguished from females. They sing on the top of singing perch with a characteristic sound (Mollers, 1983).

The Corn Bunting is a migratory species. In Switzerland, individuals start the migration at the end of September until December and come back in the middle of March for males and in April for females. During the summer, they regroup in reed beds to spend the night. Some individuals overwinter in Switzerland, but these are mainly individuals coming from colder, northern regions and they remain mostly quiet (Maumary, 2007).

Figure 1 - Corn Bunting © Lattion Camille

Even if the Corn Bunting is considered as Least Concern (LC) on the European Red List, the general trend is negative. Indeed, since it has a large range and the decrease is not severe enough, it is not classified as Vulnerable (VU) (BirdLife International, 2023). On the opposite, in Switzerland, the species is classified as Critically Endangered (CR) because of the small population and strong decline (criteria C) (Liste rouge des oiseaux nicheurs, 2021). Until 2010, the species was considered as Vulnerable (VU) on the Swiss Red List, but shifted that year because of the faster decline. In Switzerland, the number of breeding pairs during the period 1993-1996 was estimated at 400 to 600. Between 2009 to 2011, the number of breeding pairs was 93 to 103. The estimated decline is about 80% since the mid 1990s (Fehlberg, 2022).

2.1. Study site

The study was conducted in the Grosses Moos, in Switzerland between Lakes Neuchâtel, Morat and Bienne, a region called Seeland (Fig. 2). It is considered as the Swiss largest vegetable production area. It used to be marshlands until the correction of the Jura water in 1861-1891 and 1962-1973 that enabled agricultural land-use (Lüscher, 2005)

Since the beginning of the exploitation, there has been an intensive farming system which resulted in the loss of biodiversity. It is only since 1990 that SPBs were implemented in order to increase the biodiversity (Fehlberg, 2022). SPBs aims to compensate for damages and to increase the fauna and flora diversity. In the Grosses Moss, the creation of these new SPBs were successful for the Corn Bunting. The number of territories increased since 2015 in flower strips (SPBs) but continued to decrease in arable land (non SPBs). Furthermore, in previous studies, the species occurred almost only on SPBs, with one third of territories in arable lands in 2020 (Fehlberg, 2022).

Figure 2 - Study site (Seeland). Brown polygons are the territories of Corn Bunting during the 2024 season. Number are the identity of the Corn Bunting present in the territory.

2.1. Monitoring Methods

A pre-study was conducted in the beginning of the season, in mid-March, to estimate the population of the Corn Bunting. The Seeland region was monitored with the help of several volunteers to find as many singing males as possible.

After this pre-study, the first step was to identify the territory and the status (single or paired) of each singing male. Each male was monitored twice a week. Movements of each one were followed with binoculars during 20 minutes and data were entered into on a QGIS

project created by BirdLife. For each observation, the identity of the bird, the number of male and female, the activity (singing, flying, resting, feeding), the atlas code, the height of the individual, the height and type of vegetation were recorded. The atlas code gives information on the reproduction probability (possible, probable or certain) based on birds' behavior or signs of reproduction (Vogelwarte, 2024).

Some remarks could be added if something unusual, such as specific sounds or behavior, was observed. Information was based on the males since they delimit the territory, but I also recorded the number of females present with males. Since Corn Bunting are territorial birds during the breeding season (Perkins et al., 2015) when an individual was seen at the same place as in the previous days, it was assumed to be the same one.

When the nesting period started, the approximate position of the nest was also registered. The identification of a nest was made by watching the female either diving several times at the same place to the ground in order to bring food, or with food/nest material in the beak. Those two factors were sufficient to assume that a nest had been built, without necessarily seeing the fledging young. Thus, reproductive success was assumed only based on the nest detection, since the monitoring of fledging is too hard.

After that, environmental variables around all territories were taken in order to characterize territories and were entered on the QGIS project (Fig. 3.A). Summary of the variables is shown in Table 1. The whole process was repeated during the 2023 and 2024 seasons.

Table 1 - Environmental variables recorded on the field

Parameter	Description
1. Type of crop	Eight categories : Cereals, Oilseed rape, Vegetable Crop, Extensive grasslands, Grassland, Fallow, Rich grasslands, Others
2. Type of woody vegetation	Four categories : Bushes, Group of bushes, Trees, Group of trees
3. Type of vertical structure	Two categories : Artificial singing posts, Other vertical structures
4. Height of vertical structure	Height of each vertical structure (cm)
5. Number of vertical structure	Discrete numbers
5. Height of vegetation	Mean height of the woody vegetation (cm)

2.2. QGIS Analysis

Pairing success and reproductive success were coded as binary variables. Paired males were assigned the state 1 (otherwise 0) and an achieved reproduction was assigned the state 1 (otherwise 0). The reproduction success was determined by the presence of a nest.

After having attributed each individual its code, analysis on QGIS began. Individuals with three occurrences or fewer were removed because they are not considered as territories, but rather migratory. The threshold of three occurrences was chosen because the average stopover time of many passerines (e.g. reed warblers, garden warblers) is approximately 10 days (Chernetsov, 2012, Ernin et al., 2002). Since each male was monitored twice a week, three occurrences is an appropriate threshold to determine migratory individuals. Outlier occurrences were also deleted because males can sometimes fly away from their territories to follow females, or to feed. Then, radiuses of 50m and 20m around the main singing post (Fig 3.B), the center of the territory (Fig 3.C) and the nest (Fig 3.D) were created. Those distances were chosen to estimate at which scale environmental variables impact the reproductive success. The distance 50m was chosen because the nest is estimated to be within this perimeter, and the 20m distance was chosen because the habitat in direct proximity to the nest may be determinant for the male to choose its territory.

The analysis around center of territories, main singing post and nest was made in order to determine the relative effect of each variable around those three points. Territories were created using the Minimum Convex Polygon (MCP) function in QGIS. Shannon Index (H) was calculated in order to measure the landscape diversity (Radek Dušek and Renata Popelková, 2012). The Shannon Index is positively correlated with the crop diversity (Hill et al., 2002) To calculate the index, of each type of crop (p_i) was calculated and then multiplied by the natural logarithm of the proportion ($\ln(p_i)$). Then, the negative sum of all the results was calculated.

$$H = -\sum [\, pi \cdot \ln(pi) \,]$$

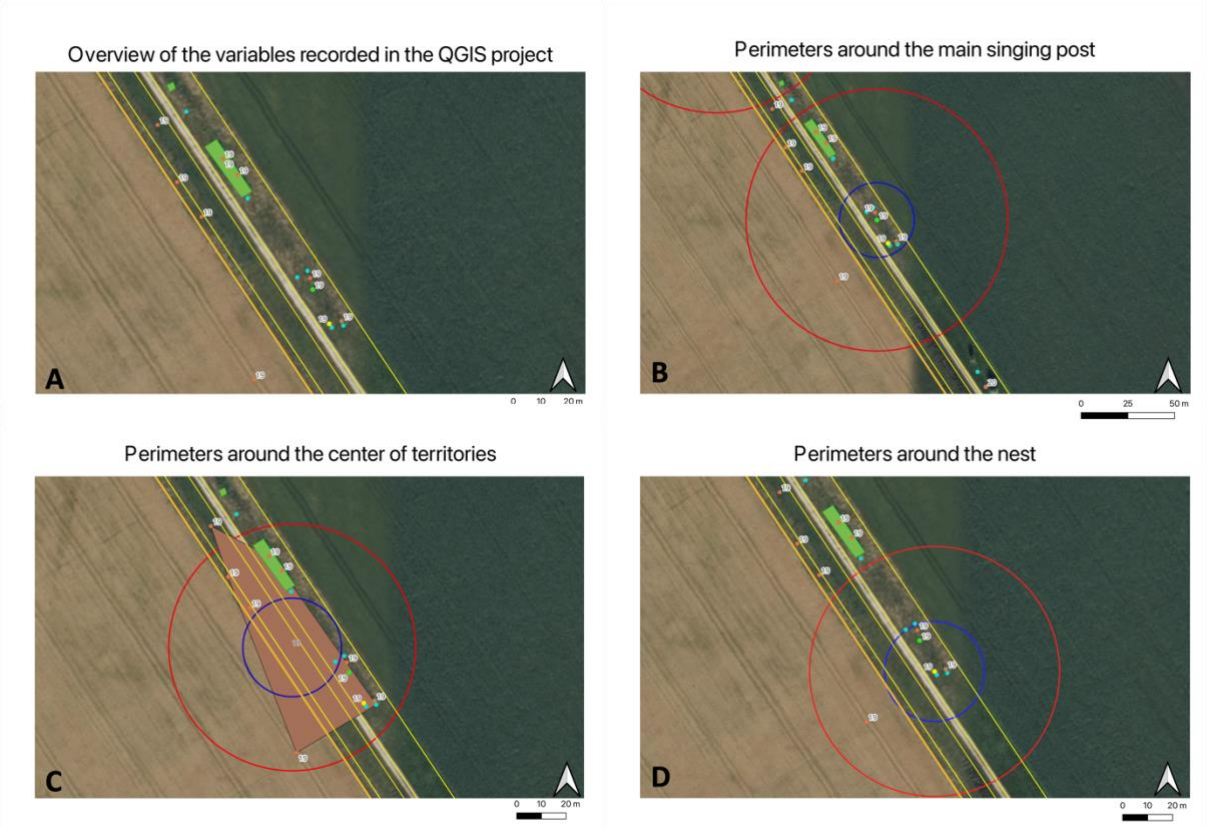

Figure 3 - Maps of A. an overview of the variables recorded in the QGIS project, B. perimeters around the main singing post, C. perimeters around the center of territories and D. perimeters around the nest. Blue circles are 20m perimeters, red circles are 50m perimeters, green polygons are the woody vegetation, brow polygons are the whole territories, yellow lines are the crop parcels, red dots are the different positions of the male, yellow dots are the nests, blue dots are the vertical structures, and green dots are the main singing post of the male.

After this, only the most relevant variables were kept and entered as variables into the models. They are as follows :

1. Number and height of vertical structure, since it is already known that singing perches are essential for the singing male to achieve a reproduction and attract more female (Fehlberg, 2022)
2. Main crop, since the type of crop, especially the winter-sown and spring-sown crops, could have an impact on the Corn Bunting decline (Taylor and O'Halloran, 2002). In addition, Corn Bunting is mainly found in cereal fields and hay meadows, which could explain the success of reproduction (BirdLife International, 2023). Each crop was placed into a category : Cereals, Oilseed rape, Vegetable culture, Extensive grasslands, Grassland, Fallow, Rich grassland, Others
3. Height and surface of the woody vegetation, such as trees and bushes. It may have, or not, the same impact as the vertical structures.
4. Shannon Index of the crop types

2.6 Statistical analysis

First, correlation tests were made in order to find potential relationships between the quantitative variables (Gogtay and Thatte, 2017). Correlation tests showed a strong correlation between the height of vertical structures and the number of vertical structures (r = 0.62). Only the number of vertical structures was kept, since almost all the vertical structure had the same height. In addition, a strong correlation between the height and surface area of woody vegetation was identified (r = 0.76). Only the height of the woody vegetation was kept.

Two separate models were built with i) pairing success and ii) reproductive success as response variables. Explanatory variables were: number of vertical structures, type of crop, Shannon Index and height of woody vegetation. Analyses were only performed on the 50m perimeters, since 20m perimeters were too small and did not contain enough values for statistical analysis.

In order to analyze the importance of the explanatory variables on the reproductive and pairing success of the Corn Bunting, logistic regressions using Generalized Linear Models (GLMs) were first performed with all the variables cited previously. As the response variable is binary, the binomial family was used in the model. Then, the dredge function (MuMIn package in R) was used in order to test all combinations of these variables. After that, an average of the best models with an Akaike's Information Criterion (AIC) ≤ 2, was performed, in order to keep the model that explained the best the variables. Assumptions were verified with the function simulateResiduals (package "DHARMa" in R).

Models were performed on the 50m radius around main singing post, center of territories and nests. For each point, two GLMs models were performed, the first one in order to assess the effect of the variables on the pairing success (single or paired) and the second one in order to assess the effect on the reproductive success (nesting or not).

After that, ordered multinomial logistic models (proportional odds logistic regression) were performed (function polr in R, MASS package). This type of model is a kind of logistic regression, used for ordered response variables with several categories (Kormann et al., 2019). The advantage of this method is that only one model is run for both pairing and reproductive success, where two individuals GLMs must be performed. In this model, the ordered response variable "Status" contained the three levels of reproduction: single, paired and nest. The explanatory variables were the same as those in the GLMs. Selection and averaging of the best model were performed as for the GLMs. However, the analysis was not performed around the nest, since every individual had the same status (nest).

3. Results

3.1 Pairing success

In total, 69 territories were recorded during the two seasons : 36 in 2023 and 33 in 2024. Among the 69 territories, 53 paired males have been recorded

during the two seasons : 31 in 2023 (86% of paired males among all territories in 2023) and 22 in 2024 (67% of paired males among all territories in 2024). Among the four variables (number of vertical structures, type of crop, Shannon Index and height of woody vegetation) only the number of vertical structure, height of woody vegetation and Shannon index were retained into the average best model performed with dredge function around the main singing post, the nest and the center of territories. However, only the height of woody vegetation around the main singing post had a negative impact on the pairing success (estimate = -0.67, p-value = 0.02) (Fig. 4). All other variables around the main singing post, the nest and the center of territories were not significant (Table 2).

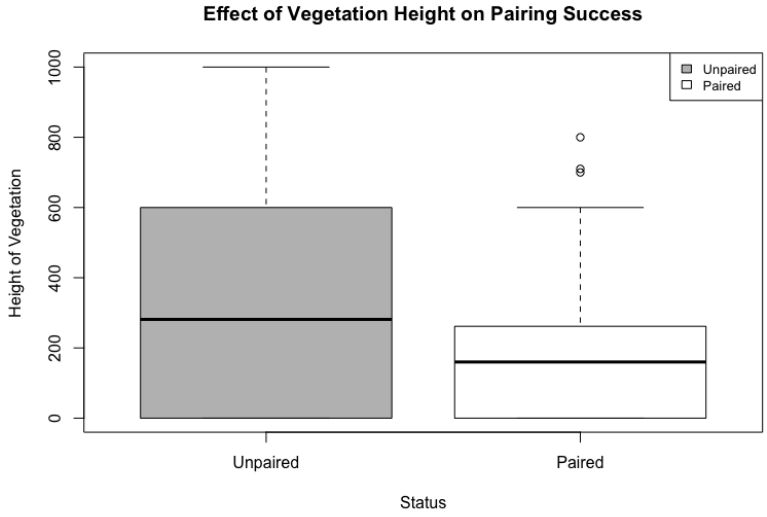

Figure 4 - Effect of vegetation height on the pairing success around the main singing post

3.2 Reproductive success

In total, 46 nests were recorded during the two seasons among the 53 pairs: 31 in 2023 and 15 in 2024. However, some pairs had more than one nest in 2023. Among the four variables (number of vertical structures, type of crop, Shannon Index and height of woody vegetation) only the number of vertical structures, height of woody vegetation and Shannon index were kept into the average best model performed with dredge function around the main singing post and the center of territories. However, none of the variables kept explained significantly the reproductive success (Table 2).

Table 2 - Model-averaged parameter estimate

Explanatory variables	Pairing Success				Reproductive Success			
	Estimate	SE	z	P	Estimate	SE	z	P
a) Nest								
Intercept	2.71	0.70	3.87	<0.001***	3.20	1.04	3.00	<0.050**
Height Vegetation	0.97	1.11	0.85	0.39	0.55	1.07	0.50	0.62
Shannon Index	0.1	0.59	0.17	0.86	-0.84	1.45	0.56	0.58
Number Structure	-0.05	0.57	0.09	0.93	-0.27	0.57	0.46	0.65
Year	-0.11	1.27	0.08	0.93	-0.42	1.58	0.26	0.80
b) Main post								
Intercept	1.50	0.52	2.83	<0.005 **	0.43	0.44	0.97	0.33
Height Vegetation	-0.67	0.29	0.29	<0.05 *	-0.36	-0.36	0.27	0.17
Shannon Index	0.14	0.72	0.19	0.85	0.39	0.57	0.66	0.51
Number Structure	0.33	0.38	0.86	0.39	0.31	0.28	1.09	0.28
Year	-0.85	0.64	1.30	0.19	-0.68	0.51	1.31	0.19
c) Center								
Intercept	1.72	0.51	3.32	<0.01***	0.54	0.36	1.46	0.14
Height Vegetation	-0.16	0.28	0.58	0.57	-0.15	0.25	0.60	0.56
Shannon Index	0.12	0.29	0.41	0.68	-0.15	0.25	0.58	0.57
Number Structure	0.11	0.29	0.38	0.71	-0.15	0.25	0.60	0.56
Year	-1.13	0.61	1.82	0.07	-0.75	0.50	1.48	0.14

3.3 Reproductive success and pairing success

The ordered logistic regression showed a negative effect of the height of woody vegetation on the ability to move from one status to another around the main singing post (estimate = -0.51, t = -2.22). However, the height of vegetation only had a negative effect on the switch from single to paired (estimate = -1.48, $p < 0.01$) (Fig. 5). None of the variables had an impact on the shift from paired to nest. This model showed same results as the GLMs.

Same analysis was conducted around the center of territories. Again, only the switch from single to paired was significant, meaning that the model best explains this shift rather than the shift from paired to having a nest (Table 3).

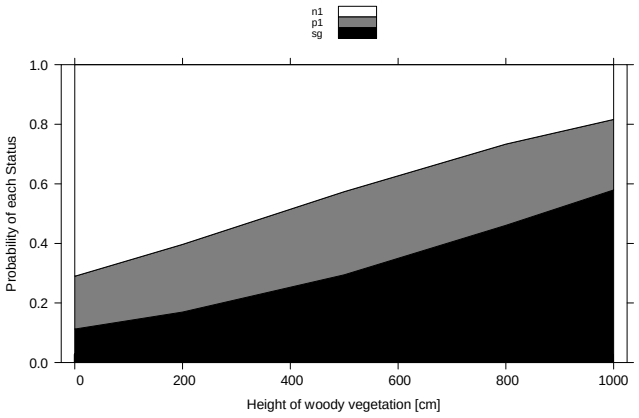

Figure 5 – Cumulative component single (sg) – paired (p1) – nest (n1) along the gradient of woody vegetation height. The probability (x-axis) of the black part, single, increase with the increase of vegetation, while the white part (nest) decrease.

Table 3 - Model-averaged parameter estimates

Explanatory variables				
	Estimate	SE	z	P
a) Main Post				
Height Vegetation	-0.51	0.25	1.99	<0.05 *
Year	-0.75	0.50	1.47	0.14
sg | p1	-1.48	0.49	3.00	<0.005**
p1 |n1	-0.44	0.45	0.97	0.33
Number Vertical	0.29	0.27	1.03	0.30
Shannon Index	0.32	0.56	0.57	0.57
b) Center				
Height Vegetation	-0.17	0.24	0.69	0.49
Year	-0.91	0.48	1.85	0.06
sg | p1	-1.71	0.47	3.57	<0.0005 ***
p1 |n1	-0.71	0.42	1.66	0.097
Number Vertical	0.065	0.24	0.26	0.79
Shannon Index	-0.22	0.57	0.38	0.70

4. Discussion

Given the circumstances of agricultural intensification and the decrease in farmland biodiversity, setting conservation measures is imperative to save endangered species (Hristov et al., 2020). The Corn Bunting, *Emberiza Calandra*, has suffered from strong decline, and is classified as Critically Endangered (CR) on the Red List of Switzerland (Liste rouge des oiseaux nicheurs, 2021). This study aimed at disentangling the role of each environmental variable on the reproductive success of the Corn Bunting, in order to implement efficient measures for its conservation. After monitoring each male, and recording environmental variables, statistical analyses were performed and showed some unexpected results.

The only parameter that significantly impacted the reproductive success of the Corn Bunting was the height of the woody vegetation such as bushes or trees, in a perimeter of 50m around the main singing post. However, the negative impact only concerned the pairing and not the nesting. This results was supported by both the GLMs performed individually, and the ordered multinomial logistic model. A study in Spain showed the same trend. Breeding densities were higher in treeless cereal croplands. (Stoate, 1999). One hypothesis could be that since Corn Buntings are mainly found in cereal fields and hay meadows (BirdLife International, 2023) they tend to pair in this type of habitat rather than habitat with higher trees. In order to increase the reproductive success, open habitat should be guaranteed where populations remain in Switzerland.

The type of crop seems to have no significative effect on the Corn Bunting reproductive success, nor on the pairing success. Surprisingly, fallows did not play an important role in the Corn Bunting reproduction neither in the Corn Bunting pairing. Even if they were expected to increase the reproductive success through provision of nestling sites and feeding grounds (Altewischer al., 2015), this study showed no effect of any the type crop. This factor was indeed excluded from every model after

performing the selection of the best model. Perkins et al. (2017), also found in their study no significative change in Corn Bunting density between the non-AES farms, and the farm that provided food resources for Corn Bunting and delayed mowing period. They also found it surprising, since weed-rich and insect-rich foraging and nesting habitats have been shown to be important for the reproductive success of Corn Buntings. This type of habitat is provided for instance by species-rich grasslands and grass margins that were present in the study area (Perkins et al., 2017). One potential reason could be that Corn Buntings having their territories in non-AES but near fallows or weed/insect-rich habitats used them as resources, even if they were not within the radius around their nest nor in their territory (Perkins et al., 2017). Studies at bigger scale should be conducted in order to better understand the role of crop around the territories. It could also be possible that Corn Bunting choose their territories considering the best type of crop for breeding. Therefore, crop type in the territory may have no impact, either because they selected the best crop type to settle their territory, or because the suitable crop type is present around it, and not in the selected perimeter. However, further studies should be done, taking into account the type of crops around the territories. Studies testing territories and controls without any Corn Bunting could also be investigated, in order to see whether the type of crop influences the settlement of territories rather than the reproductive success itself.

Number of vertical structures neither had an impact on the reproductive success, which was not expected. Indeed, vertical structures are known to be essential for the singing males (Altewischer et al., 2015). They help attracting more female and conspecifics (Fehlberg, 2022). Other parameters must then be investigated to understand the reproductive success of the Corn Bunting. For instance, arthropods abundance could be a key element for the success of the Corn Bunting, that could be further investigated. Since nestlings are fed with arthropods (Altewischer et al., 2015) this parameters could have an influence on the reproductive success. Benton et al (2002) found that farmland birds were positively correlated with the number of arthropods. The latter were negatively correlated with the increase of farmland intensification (Benton et al., 2002). Farmland intensification may have reduced the key invertebrate used as food for the Corn Buntings (Wilson et al., 1999), through for example increase of pesticide (BirdLife International, 2023). This is also supported by Julseth (2019), who found that breeding time of another insectivore passerine, the House sparrow, is set to happen when the level of arthropods is maximal, in order to provide food. Visser et al. (2006) also found that the breeding time of the insectivorous Great tit was set when caterpillar biomass was the higher.

In addition, the clustering of individuals due to social attraction may be a variable to take into account. Indeed, Ahlering et al. (2006) found that male Baird's Sparrows were attracted to previously unoccupied breeding sites, when a playback conspecific sound was played. This may be used by males to attract conspecifics to potential suitable breeding site. In addition, Fehlberg (2022) found that the probability of colonization of Corn Buntings increased from < 0.15 to > 0.7 when there were nine or more conspecifics. This variable should be further investigate, in order to understand its importance for the attraction of the Corn Bunting. This may also explain why some site that had all

the theoretical variables required for a successful reproduction (fallows, many vertical structure,…) did not attract male Corn Buntings.

Concerning the perimeters, 20m perimeters were too small, even if they contain the habitat in direct proximity to the potential nests. This study shows that the limit in order to have enough variables for statistical analysis is more than 20m and that variables at this level do not explain the reproductive success of Corn Buntings.

However, this study has some limitations. Indeed, I did not include "controls" which would have consisted of area without any territories. This could have been useful to see whether environmental variables impact the territory settlement, and thus if they provide a higher reproductive success. In addition, the reproductive success was only recorded through nest detection, and not fledging detection. Fledging detection was too hard to make only with binoculars, but could be detected with camera around the nest. This could be a more accurate way of detecting reproductive success.

5. Conclusion

Agriculture intensification and changes in the Common Agricultural Policy (CAP) during the 20th century led to a significant decline of farmland birds, including the Corn Bunting. Focusing on the environmental variables that could help a successful reproduction and the suitable habitat is a key to understand the reproduction, and help the population of Corn Bunting to recover.

However, this study showed that reproduction is complex and relies on many factors. Some of them remain unknown and must be further investigated such as the decline of arthropods, the number of conspecific, the type of crop (fallow, SPBs, etc.) around the parcel of interest… Nevertheless, the height of vegetation such as bushes and trees seems to be a variable to take into account in order to have an increase of reproduction. Smaller vegetation height seems to encourage pairing between males and females. Thus, this kind of habitat should be more guaranteed where Corn Bunting population are established in order to increase the reproductive success.

6. Acknowledgments

Thanks to Julien Mazenauer, Urs Kormann and Lucas Lombardo for their assistance with field work and thesis redaction, to Paul Mosimann, Bradley Ludovic, Siffert Océane, and all the volunteers in collaboration with BirdLife for their help during the monitoring. Thanks to Prof. Dr. Clara Zemp for her supervision and Dr. Gabriel Marcacci for his help during the thesis redaction.

7. References

Ahlering, M. A., Johnson, D. H., & Faaborg, J. (2006). Conspecific attraction in a grassland bird, the Baird's Sparrow. Journal of Field Ornithology, 77(4), 365-371. https://doi.org/10.1111/j.1557-9263.2006.00066.x

Altewischer, A., Buschewski, U., Ehrke, C., Fröhlich, J., Gärtner, A., Giese, P., Günter, F., Heitmann, N., Hestermann, M., Hoffmann, H., Kleinschmidt, F., Kniepkamp, B., Linke, W., Mayland-Quellhorst, T., Pape, J., Peterson, T., Schendel, V., Schwieger, S., Wadenstorfer, A., & Fischer, K. (2015). Habitat Preferences of Male Corn Buntings Emberiza calandra in North-Eastern Germany. Acta Ornithologica, 50(1), 1-10. https://doi.org/10.3161/00016454AO2015.50.1.001

Ayé, R., Bernardi, E., Christen, W., Horch, P., Hüppin, L., Jenny, M., Lugrin, B., Mosimann-Kampe, P., Müller, W., Posse, B., Rapin, P., Schmid, H., Schwarzenbach, Y., Spaar, R., Strebel, S., & Zollinger, J.-L. (2013). Bestand der Grauammer Emberiza calandra in der Schweiz 2009–2011 und Schwerpunktgebiete für ihre Förderung. Ornithol. Beob., 10.

Benton, T. G., Bryant, D. M., Cole, L., & Crick, H. Q. P. (2002). Linking agricultural practice to insect and bird populations : A historical study over three decades. Journal of Applied Ecology, 39(4), 673-687. https://doi.org/10.1046/j.1365-2664.2002.00745.x

Berg, Å. (2008). Habitat selection and reproductive success of Ortolan Buntings Emberiza hortulana on farmland in central Sweden - the importance of habitat heterogeneity : Habitat selection of Ortolan Buntings in Sweden. Ibis, 150(3), 565-573. https://doi.org/10.1111/j.1474-919X.2008.00825.x

BirdLife International (2023) Species factsheet: *Emberiza calandra*. Downloaded from https://datazone.birdlife.org/species/factsheet/corn-Bunting-emberiza-calandra/text

Bürkner, P. C., & Vuorre, M. (2019). Ordinal regression models in psychology: A tutorial. Advances in Methods and Practices in Psychological Science, 2(1), 77-101. https://doi.org/10.1177/2515245918823199

Butler, S. J., Boccaccio, L., Gregory, R. D., Vorisek, P., & Norris, K. (2010). Quantifying the impact of land-use change to European farmland bird populations. Agriculture, Ecosystems & Environment, 137(3-4), 348-357. https://doi.org/10.1016/j.agee.2010.03.005

Chernetsov, N. (2012). Passerine migration: stopovers and flight. Springer Science & Business Media.

Coll, M., & Wajnberg, E. (Eds.). (2017). Environmental pest management: challenges for agronomists, ecologists, economists and policymakers. John Wiley & Sons, 385

Dušek, R., & Popelková, R. (2017). Theoretical view of the Shannon index in the evaluation of landscape diversity. AUC GEOGRAPHICA, 47(2), 5-13. https://doi.org/10.14712/23361980.2015.12

Eggenschwiler, L. (2003). Einfluss von Samenmischungen für Bunt- und Rotationsbrachen auf die Vegetationsentwicklung, den Samenvorrat und die N Dynamik im Boden (p. 102 S.) [ETH Zurich; Application/pdf]. https://doi.org/10.3929/ETHZ-A-004584038

Ellison, K. S., Ribic, C. A., Sample, D. W., Fawcett, M. J., & Dadisman, J. D. (2013). Impacts of Tree Rows on Grassland Birds and Potential Nest Predators : A Removal Experiment. PLoS ONE, 8(4), e59151. https://doi.org/10.1371/journal.pone.0059151

Erni, B., Liechti, F., & Bruderer, B. (2002). Stopover Strategies in Passerine Bird Migration : A Simulation Study. Journal of Theoretical Biology, 219(4), 479-493. https://doi.org/10.1006/jtbi.2002.3138

European Commission. Joint Research Centre. Institute for Prospective Technological Studies. (2012). The influence of the Common Agricultural Policy on agricultural landscapes. Publications Office. https://data.europa.eu/doi/10.2791/94269

Fehlberg, F. S. (2022). The role of ecological compensation areas and conspecific density for the persistence of the largest Swiss Corn Bunting population (BSc 3rd year Dissertation)

Gogtay, N. J., & Thatte, U. M. (2017). Principles of correlation analysis. Journal of the Association of Physicians of India, 65(3), 78-81.

Guerrero, I., Morales, M. B., Oñate, J. J., Geiger, F., Berendse, F., Snoo, G. D., Eggers, S., Pärt, T., Bengtsson, J., Clement, L. W., Weisser, W. W., Olszewski, A., Ceryngier, P., Hawro, V., Liira, J., Aavik, T., Fischer, C., Flohre, A., Thies, C., & Tscharntke, T. (2012). Response of ground-nesting farmland birds to agricultural intensification across Europe : Landscape and field level management factors. Biological Conservation, 152, 74-80. https://doi.org/10.1016/j.biocon.2012.04.001

Herzog, F., Jacot, K., Tschumi, M., & Walter, T. (2017). The Role of Pest Management in Driving Agri-environment Schemes in Switzerland. https://doi.org/10.1002/9781119255574.ch17

Hill, T. C. J., Walsh, K. A., Harris, J. A., & Moffett, B. F. (2003). Using ecological diversity measures with bacterial

communities. FEMS Microbiology Ecology, 43(1), 1-11. https://doi.org/10.1111/j.1574-6941.2003.tb01040.x

Hristov, J., Clough, Y., Sahlin, U., Smith, H. G., Stjernman, M., Olsson, O., Sahrbacher, A., & Brady, M. V. (2020). Impacts of the EU's Common Agricultural Policy "Greening" Reform on Agricultural Development, Biodiversity, and Ecosystem Services. Applied Economic Perspectives and Policy, 42(4), 716-738. https://doi.org/10.1002/aepp.13037

Julseth, M. G. (2019). The effect of arthropod availability on reproductive phenology and success in a multi-brooded passerine Passer domesticus (Master's thesis, NTNU).

Kormann, U. G., Scherber, C., Tscharntke, T., Batáry, P., & Rösch, V. (2019). Connectedness of habitat fragments boosts conservation benefits for butterflies, but only in landscapes with little cropland. Landscape Ecology, 34(5), 1045-1056. https://doi.org/10.1007/s10980-019-00835-6

Liste rouge des oiseaux nicheurs. Espèces menacées en Suisse. (2021). *www.bafu.admin.ch/uv-2124-f*

Lécuyer, L. et al. (2021): The Future of Agricultural Landscapes, Part III. Advances in Ecological Research (Vol 57).

Lüscher, A. (2005). Grosses Moos : Eine Kulturlandschaft im Seeland [Text/html,application/pdf,text/html]. https://doi.org/10.5169/SEALS-108548

Moller, A. P. (1983). Song Activity and Territory Quality in the Corn Bunting Miliaria calandra; With Comments on Mate Selection. Ornis Scandinavica, 14(2), 81. https://doi.org/10.2307/3676010

Nucera, E., Lonati, M., RAVETTO ENRI, S., Pier, F. A., & Probo, M. (2018). The Surfaces for the Promotion of Biodiversity as an effective political tool to preserve plant diversity in the permanent grasslands of the southern Swiss Alps. In Adapting Innovation in Grassland Management (pp. 97-97). Vibeke Lind, Grete Meisfjord Jørgensen, Ellen Schei Pongo, Giampiero Lombardi.

Perkins, A. J., Maggs, H. E., Watson, A., & Wilson, J. D. (2011). Adaptive management and targeting of agri-environment schemes does benefit biodiversity : A case study of the corn Bunting Emberiza calandra: Effectiveness of agri-environment management. Journal of Applied Ecology, 48(3), 514-522. https://doi.org/10.1111/j.1365-2664.2011.01958.x

Perkins, A. J., Maggs, H. E., Wilson, J. D., & Watson, A. (2013). Delayed mowing increases corn Bunting Emberiza calandra nest success in an agri-environment scheme trial. Agriculture, Ecosystems & Environment, 181, 80-89. https://doi.org/10.1016/j.agee.2013.09.010

Perkins, A. J., Maggs, H. E., & Wilson, J. D. (2015). Crop sward structure explains seasonal variation in nest site selection and informs agri-environment scheme design for a species of high conservation concern : The Corn Bunting Emberiza calandra. Bird Study, 62(4), 474-485. https://doi.org/10.1080/00063657.2015.1076763

Perkins, A.J., Maggs, H., Stephan, Y., Corrigan, A. & Wilson, J.D. (2017). Effectiveness of SRDP in corn Bunting conservation: assessing the impact of six years of targeted agri-environment schemes. Scottish Natural Heritage Commissioned Report No. 941.

Setchfield, R. P., Mucklow, C., Davey, A., Bradter, U., & Anderson, G. Q. A. (2012). An agri-environment option boosts productivity of Corn Buntings Emberiza calandra in the UK : AES improves Corn Bunting productivity. Ibis, 154(2), 235-247. https://doi.org/10.1111/j.1474-919X.2011.01207.x

Stoate, C., Borralho, R., & Araújo, M. (2000). Factors affecting corn Bunting Miliaria calandra abundance in a Portuguese agricultural landscape. Agriculture, Ecosystems & Environment, 77(3), 219-226. https://doi.org/10.1016/S0167-8809(99)00101-2

Taylor, A. J., & O'Halloran, J. (2002). The decline of the corn Bunting, Miliaria calandra, in the Republic of Ireland. In Biology and Environment: Proceedings of the Royal Irish Academy (Vol. 102, No. 3, pp. 165-175). Royal Irish Academy. https://doi.org/10.3318/BIOE.2002.102.3.165

Tscharntke, T., & Batáry, P. (2023). Agriculture, urbanization, climate, and forest change drive bird declines. Proceedings of the National Academy of Sciences, 120(22), e2305216120. https://doi.org/10.1073/pnas.2305216120

Visser, M. E., Holleman, L. J. M., & Gienapp, P. (2006). Shifts in caterpillar biomass phenology due to climate change and its impact on the breeding biology of an insectivorous bird. Oecologia, 147(1), 164-172. https://doi.org/10.1007/s00442-005-0299-6

Vogelwarte (2024). Code international de l'atlas. https://www.vogelwarte.ch/wp-content/uploads/2024/05/internationaler-atlascode-f-2024.pdf

Wat, A., & Rae, S. (1997). Preliminary results from a study of habitat selection and population size of corn Buntings Miliaria calandra in north-east Scotland. Ξ \f, 115.

Wilson, J. D., Morris, A. J., Arroyo, B. E., Clark, S. C., & Bradbury, R. B. (1999). A review of the abundance and diversity of invertebrate and plant foods of granivorous birds in northern Europe in relation to agricultural change. Agriculture, ecosystems & environment, 75(1-2), 13-30. https://doi.org/10.1016/S0167-8809(99)00064-X