Landscape predictors of Bobolink presence in the Outaouais region

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BIO4009 Honours Research Project
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April 16th, 2021

Abstract

There have been marked population declines of field bird species in Canada starting in the 1970s. Most of these declines were caused by habitat loss and the use of increasingly toxic pesticides on nesting and wintering sites. The Bobolink (*Dolichonyx oryzivorus*) is one of the species that has suffered declines. A first step in protecting Bobolinks is to identify their critical habitat. To contribute to the conservation and management of the Bobolink, I tested which landscape variables were associated with the presence of Bobolinks in the Outaouais, a region rich in agricultural activities. I used five landscape variables, 581 records of Bobolink sightings (total of 2162 individuals) at 200 sites, and a spatial distribution model. The abundance of Bobolinks was highest at sites with higher road density and wetland coverage. Road density was most likely high at sites where Bobolinks were recorded because the observations were mostly collected at easy-to-access locations, thus along roads. Grassland and agriculture also predicted Bobolink presence, but their importance was lower than that of wetland coverage. My study shows the importance of preserving open habitats when planning conservation efforts for Bobolink populations in the Outaouais region.

Keywords: Agriculture, Bobolink, grassland, habitat, landscape, Outaouais

Résumé

Il y a eu d'importants déclins de population d'espèces d'oiseaux champêtres au Canada à partir des années 1970. La plupart de ces déclins ont été causés par la perte d'habitat et l'utilisation de pesticides de plus en plus toxiques sur les sites de nidification et d'hivernage. Le Goglu des prés (*Dolichonyx oryzivorus)* est l'une des espèces qui a subi des déclins. Une première étape de la protection des Goglu des prés consiste à identifier leur habitat essentiel. Pour contribuer à la conservation et à la gestion du Goglu des prés, j'ai testé quelles variables de couverture terrestre étaient associées à la présence de Goglu des prés en Outaouais, une région riche en activités agricoles. J'ai utilisé cinq variables paysagers, 581 registres d'observations de Goglu des prés (total de 2162 individus) sur 200 sites et un modèle de distribution spatiale. L'abondance de Goglu des prés était plus élevée dans les sites ayant une grande densité routière et couverture de milieu humide. La densité des routes était très fortement élevée aux sites où la présence de Goglu des prés a été noté parce que les observations ont principalement été prises à des endroits faciles d'accès, soit le long des routes. Les prairies et l'agriculture ont également prédit la présence de goglu des prés, mais leur importance était plus faible que celle de la couverture des milieux humides. Mon étude montre l'importance de préserver les habitats ouverts lors de la planification des efforts de conservation des populations de Goglu des prés de l'Outaouais.

Mots-clés: Agriculture, Goglu des prés, prairie, habitat, paysage, Outaouais

Acknowledgments

This project would not have been possible without the help of many amazing people. First, I would like to thank the University of Ottawa and Dr. Gabriel Blouin-Demers for allowing me to join his lab and to work on a project which stimulated my will to learn. I would also like to thank Audrey Turcotte for her greatly appreciated help with the statistical analyses and Catherine Čapkun-Huot for her help with the spatial analysis. I also give thanks to Hugo Crites and Pierre Leblanc from the team at the Geographic, Statistical, and Government Information Centre for helping me resolve my ArcMap technical difficulties.

I also would like to thank the National Capital Commission for helping me develop this project and make it possible. I would especially like to thank Catherine Verreault and Jean-François Gobeil for their efforts in facilitating this project and Daniel Pelletier for the collection of the data in Gatineau Park. I am also grateful for the contribution of QuébecOiseaux and eBird for providing me with a large dataset of observations, the bulk of my thesis.

Finally, I would like to thank my family for the continuous support throughout my academic years, Sophie Roy and Lydia Gauthier-Sauvé for their moral support and memes as well as everyone else who was there for supporting me during the realization of this project.

Table of Contents

Abstract 2

Résumé 3

Acknowledgments 4

Materials and Methods 11

Study area 11

Gatineau Park – National Capital Commission (NCC) 11

eBird – Cornell University 11

SOS-POP and ÉPOQ – QuébecOiseaux 12

Pseudo-absences 12

Data filtering 13

Landscape composition 15

Statistical analyses 16

Results 16

Discussion 17

Roads 17

Landscape predictors 18

Study limitations 19

Management implications 21

Conclusion 21

List of Tables

Table 1. Latitude and longitude of the 200 pseudo-absence points used in the spatial analysis. They were generated by creating background points in R…………..…28

Table 2. Negative binomial regression investigating the effects of landcover and road density on the abundance of Bobolinks (N = 400; 200 presence sites and 200 absence sites) observed in the Outaouais region, Québec. Significant *p* value for α = 0.05 are in bold. A buffer of 2000 m was used for each predictor (agriculture, grassland, wetland and road density). Dispersion parameter was equal to 0.8999 and residual deviance = 747.84 vs degrees of freedom = 776…..…………………………………31

Table 3. Merged landcover types used to split the 95 landcover types provided by the Agriculture and Agri-food Canada Annual Crop Inventory (ACI) 2019 and the 2020 Parcels and Reported Agricultural Productions Database (BDPPAD) of Québec……………………………………..…………..…………………………...32

List of Figures

Figure 1. Presence and absence points of Bobolinks in the Outaouais region. The blue triangles represent every 581 records of Bobolink presence. The orange triangles represent the 200 random background points generated in R which were used as absence data.…………………………………………………………………….....33

Figure 2. Number of Bobolinks observed for each of the 581 observation records in the Outaouais region.……………………………………………………………………36

Figure 3. Combined agriculture, forest, grassland and wetland landcover of the Outaouais region provided by Agriculture and Agri-food Canada Annual Crop Inventory (ACI) 2019 and the 2020 Parcels and Reported Agricultural Productions Database (BDPPAD) of Québec.………………………………………………………………37

Figure 4. Road density cover in the Outaouais region provided by DMTI CanMap Route Logistics (2019)…………………………………………………………………......38

Figure 5. Example of an observation and its six buffers. Buffers were created from 25 m, 50 m, 100 m, 250 m, 500 m, 1000 m and 2000 m of each record point.……………...39

Figure 6. Correlation between the number of Bobolinks observed and the proportion of the five landscape predictors at various buffer distances (25 m, 50 m, 100 m, 250 m, 500 m, 1000 m and 2000 m). The highest absolute variable is at 2000 m for each variable (Agriculture = 0.155097, grassland = 0.142383, forest = 0.23607, wetland = 0.155493 and Road density = 0.081296). Purple represents agriculture, orange represents grassland, grey represents forest, yellow represents wetland and blue represents road density………………………………………………………………40

Figure 7. Correlation matrix of all the measured variables for the landcover and road density analysis. Correlations above 0.6 or lower than - 0.6 are considered moderately high to high. Legend: coverage of agriculture (2000 m buffer) is represented by agri2000; coverage of grassland (2000 m buffer) is represented by grass2000; coverage of forest (2000 m buffer) is represented by forest2000; coverage of wetland (2000 m buffer) is represented by wet2000; road density (2000 m buffer) is represented by route2000……………………..……………………………………….........................41

Figure 8. Effect plots of the four predictors used in the statistical model. Maximum Bobolink abundance predicted in function of the coverage (%) of (A) agriculture, (B) wetland, (C) grassland and (D) road density with a 2000 m buffer. The light blue cloud around the plots represents the 95% confidence interval…...…………………………………………...42

Introduction

Human impact has caused the original biodiversity of terrestrial ecological communities worldwide to decline by an estimated mean of 20% (Hill et al., 2018). Since 1970, we have lost 1 out of 4 birds in North America (Rosenberg et al., 2019). Out of the 10 breeding biome groups, grassland birds showed the highest population loss, a proportion equivalent to 74% of the birds of North America (Rosenberg et al., 2019). The loss and degradation of native prairies are one of the most likely reasons for this strong decline (Herkert et al., 1996). Often, native prairies are converted to intense agricultural land or urban development. Some grassland birds have also been affected by the use of pesticides and the intensification of management in the agricultural fields where they breed (Renfrew and Saavedra, 2007; Martin & Gavin 1995). However, grassland birds are excellent allies for agriculture as the vast majority of farmland birds feed on insect pests. Grassland birds, therefore, contribute to the elimination of insects harmful to crops. It is estimated that, for a field with a high density of birds (158 individuals/ha), birds eliminate nearly 130,000 insects/day (CPVQ, 2000). In an agricultural context, this leads to a reduction in the costs associated with the purchase and application of insecticides. Grassland birds also include granivorous species which consume the seeds of weeds, thus reducing the need to use herbicides.

One important grassland bird which has been declining markedly is the Bobolink, *Dolichonyx oryzivorus*. Part of the Icterids, this large songbird is easily distinguished by its yellow patch on the head. It is usually found in agricultural lands and open fields and nests in Southern Canada and northcentral and northeastern USA (COSEWIC, 2010; Sibley, 2016). The Bobolink's main habitat is generally meadows and agricultural fields. On average, their territories vary from 0.33 – 2 ha depending on the local habitat conditions (COSEWIC, 2010; Ontario Ministry of Natural Resources and Forestry, 2019. The Bobolink's Canadian status was assessed as Threatened in April 2010 (Environment and Climate Change Canada, 2020). It is important to note that 25% of the global Bobolink population breeds in Canada and that their population has been drastically declining since the late 1960s, particularly in Eastern Canada (COSEWIC, 2010). According to the Recovery Strategy for the Bobolink in Canada, the main threats facing Bobolinks are the loss of annual and perennial crops of non-timber products due to increased intensification of agriculture, row monocultures, and mowing and hay harvesting activities (Environment and Climate Change Canada, 2020). The Bobolink has been considered an umbrella species for other declining grassland birds such as the Eastern Meadowlark, the Savannah Sparrow, and the Grasshopper sparrow (Renfrew et al., 2015). Thus, by protecting the Bobolink, it will aid in maintaining the breeding habitat of other prairie grassland birds which share similar habitat due to the Bobolink's wide distribution and presence in working agricultural landscapes (Powers et al., 2014).

Habitat models can be used to determine species habitat requirements and to identify areas of special conservation need (Martin & Fahrig, 2012). These types of models use empirical data to fit relationships between species presence or abundance and various environmental predictors to define the species response and make predictions on habitat suitability (Martin & Fahrig, 2012). Understanding spatial use and variation in time are key, especially when dealing with fragmented habitats and declining populations, because landscape changes are dynamic and species behaviour is more likely to change in the disturbed areas (Fletcher & Fortin, 2018). When species navigate from one habitat to another, they often meet obstacles, landscape features that have been fragmented or that are riskier for them, and are forced to move through complex patchworks of suitable habitat. This can dramatically reduce their success (Collinge, 2010).

Bobolinks are year-round grassland obligates (Renfrew et al., 2015). However, they inhabit various habitats during different periods. Bobolinks can be found near various wetlands such as marshes and peatlands and in various types of grasslands. In Ontario, McCracken et al (2013) found that Bobolinks nested in large fields of oats, winter wheat, and rye. Bobolinks also rely on agricultural habitats such as pastures, hayfields, and other fields with a high yield of grass (Renfrew et al, 2015). However, the quantity and proportions of essential habitat needed to sustain Bobolink populations are not well documented (Environment and Climate Change Canada, 2020). More spatial use data of Bobolinks are needed to understand their critical habitat which is why local spatial analyses are important (Environment and Climate Change Canada, 2020). The critical habitat of the Bobolink has been evaluated at larger scales such as federally and provincially, but not as much locally. Baker et al. (2020) state that occupancy at smaller spatial scales is important for planning decisions which in this case is missing from many parts of Canada such as in the Outaouais, in Québec. This is because information on species' distributions gathered at the appropriate scale will facilitate decisions on management actions for species requiring legal protection (Baker et al, 2020). The purpose of my project was to determine which landscape predictors are linked to the presence of bobolinks in the Outaouais region during their breeding season. My project will help guide local conservation efforts and serve for other similar local scale spatial analyses. To accomplish this goal, I generated a spatial distribution model by performing a spatial analysis using ArcMap and R.

Materials and Methods

Study area – The study area was the Outaouais administrative region, situated in the southwest of Québec, Canada. This area covers around 30 800 km^2 of Québec and is home to many agricultural lands (Statistics Canada, 2017).

Data origin – I gathered observational data from three sources: NCC, eBird, and QuébecOiseaux, and combined them in one database. Data was not restricted to a specific seasonal timeframe. I considered all observations of Bobolinks to have been recorded during breeding season. Here is a brief description of each dataset used:

Gatineau Park – National Capital Commission (NCC) - An Eastern Meadowlark and Bobolink survey was done during the 2020 field season (May-August) by a team of NCC biologists. They gathered 141 Bobolink records amongst 51 stops in 9 sectors of Gatineau Parc. These data were collected by point surveys which lasted 5 minutes each and covered a 150 m radius.

eBird – Cornell University – Bobolink observation data were collected from raw eBird data for three regions, Gatineau, Collines-de-l'Outaouais, and Pontiac (Cornell Lab of Ornithology, 2020). These data were from March 2020. Due to technical problems and being unable to contact eBird, I was unable to get more recent data nor data from the other Outaouais MRCs (Vallée-de-la-Gatineau and Papineau). This data set contained observations dating from 1954. The following information was included: the number of observers, number of individuals observed, latitude and longitude, date observed, distance traveled (for some observations) and duration. A total of 2881 observations were contained in this dataset.

SOS-POP and ÉPOQ – QuébecOiseaux – Bobolink presence data from the SOS-POP (Suivi des populations d'oiseaux en péril) and ÉPOQ (Étude des Populations d'Oiseaux du Québec) was generously provided by QuébecOiseaux. The SOS-POP dataset contained 1003 Bobolink observations between 1997-2013. The data received included the number of observers, number of adults observed, latitude and longitude and the precision of the site (S = less than 150 m, M = less than 1.5 km, G = less than 8 km, U = more than 8 km). The ÉPOQ data contained observations between 1960-2020. This dataset contained 6114 Bobolink observations. The same information as the SOS-POP dataset was available.

Pseudo-absences

Habitat models require both presence and absence points to make predictions (MacKenzie, 2009. Obtaining presence data is a relatively simple task for species that are conspicuous. However, absence data are not always possible to acquire as easily as it requires certainty that the species has not been detected in the area being surveyed and detectability is highly variable between species and locations. An alternative to absence points is pseudo-absences (Hijmans, 2021). This type of data is inferred from the available presence data. Pseudo-absences provide a comparative data set used when running a spatial analysis (Barbet-Massin et al., 2012). Because I did not have absence data, I needed to generate pseudo-absences. To match the sample size of observations I randomly generated 200 points in R version 4.0.4, also known as background points, throughout the Outaouais region (R Core Studio, 2021) (Figure 1; Table 1).

Data filtering – Detectability is an important factor when using unstructured or semi-structured data (Strimas-Macket et al., 2020). This type of data is usually collected with community science projects such as eBird and the data collected by QuébecOiseaux. This means that the probability of a species being detected can vary due to the effort put in the record and needs to be given a more consistent structure to account for this large variation (Strimas-Macket et al., 2020). To reduce this variability in detectability and to account for this bias, I filtered observations based on the effort variables (Kelling et al, 2018; La Sorte et al, 2018).

To control for the rapid changes in landscape composition over time, I chose to keep a temporal measurement scale of 10 years which is realistic (Tang & Zhang, 2018). This ensured that there was less variation in the spatial data over time.

Because eBird records tracks (GPS track of the distance travelled), the longitude and latitude given per record are not always exact. To control for this and have more precision, I chose to only take observations that mentioned the trip length, and that was ≤ 1 km. In the case of ÉPOQ data, only data with a precision < 0.150 km (code S) were kept. In this case, the trip length was noted as 0.150 km.

According to Strimas-Mackey et al (2020), keeping only the presence points from trips shorter than 5 h with a maximum of 10 observers will reduce the variation in detectability. The more hours spent looking for birds, the more the chances of detecting a higher number of birds increase and the same goes when there are more observers, the chances of spotting birds are higher when more observers are alert. Since I am comparing the landscape composition of various sites, consistency is needed to not bias the abundance of Bobolinks present by predicting higher numbers of Bobolinks in certain areas whereas, in reality, there were only higher chances of detectability.

Data that did not meet one or more of these criteria were removed from my final observations. The distance traveled for "Stationary" (distance travelled under 30 m of the starting point) surveys under surveys was converted to 0 km if nothing was specified in the row. Also, since some data obtained were present in multiple databases, I had to remove duplicates manually to avoid pseudo-replication. Once all the records were filtered, I was left with 581 records of Bobolink which totaled 2162 individual Bobolinks observed (Figure 1; Figure 2). These observations were gathered in 200 locations. The sites were determined by creating a grid composed of 1 km squares in ArcMap to ensure Bobolink habitats did not overlap each other. According to Freemark & Rogers (1995), the standard minimum distance between counts should be 500 m or more (radius of 1 km), especially in open environments where detectability of birds is greater, which is why I chose to use a 1 km square grid. Observations grouped in the same square were counted as taken at the same site.

Landscape composition – With the final data set obtained, I was able to evaluate which landscape predictors were associated with the presence of Bobolinks using ArcMap and R version 4.0.4 to performing a spatial analysis (ESRI, 2018; R Core Team, 2021). Using the Agriculture and Agri-food Canada Annual Crop Inventory (ACI) 2019 and the 2020 Parcels and Reported Agricultural Productions Database (BDPPAD) of Québec, I created a unique landcover layer. Following this, I collapsed the 23 original land cover classes of the BDPPAD layer and the 73 classes of the ACI layer together (Table 3). I then collapsed them into 5 cover types (agriculture, grassland, wetland, forest) (Figure 3). Unlike the wetlands and forests, agricultural lands and grasslands are more difficult to distinguish, mostly because native grasslands in Québec are rare (Lamoureux & Dion, 2019; Plante et al., 2006). In my study, because the grassland habitat in the Outaouais region is mostly agricultural or "surrogate" grasslands, I defined my variable grasslands as a mix of perennial crops, which is predominantly grass such as pastures, small grains, fallows, and hayfields. In contrast, agricultural habitats were defined as areas with intensive row crop agriculture which are usually used to produce food for humans. I obtained road density by using a vector data file provided by DMTI Spatial Inc. (2019) and merged all types of roads such as expressways, major roads, and secondary roads (Figure 4). Buffers of 50, 100, 250, 500, 1000, and 2000 m were created for each presence and absence point (Figure 5). According to Guttery et al. (2017), habitat variables from scales of < 300 m to 3000 m were important to patch occupancy of Bobolinks in the Wisconsin grasslands which is why I chose the six buffers mentioned above. Landcover was calculated as a percentage of the total buffer area for each variable. To choose which buffer I would use to calculate coverage, I calculated correlations between the number of Bobolinks observed at each data point and the percentage of landcover type (including road density) for each buffer distance (Figure 6). I selected only the highest correlation buffer distance for each of the variables.

Statistical analyses

All statistical analyses were realized in R version 4.0.4 (R Core Team, 2021). To evaluate which landscape variables affected Bobolink abundance, I used a generalized linear model. I chose to use a negative binomial regression because my variables were over-dispersed as my data showed variation which was greater than the mean (Bruin, 2006). In contrast to a Poisson distribution, the binomial regression is more flexible and can adjust the variance independently from the mean (Bruin, 2006).

Results

The maximum effect of each landcover variable between Bobolink abundance and landcover area was at 2000 m for all five covers: agriculture ($r = 0.16$), grassland ($r = 0.14$), forest ($r = -0.24$), wetland ($r = 0.16$) and roads ($r = 0.08$) (Figure 6). These buffer distances were added to my model. Because the correlation between forest and grassland ($r = 0.64$) was moderately high, I removed forest from the model as it caused multicollinearity (Figure 7) (Akoglu, 2018). This left me with four predictors in my model. My final model included all variables (NUMBER = Bobolink abundance, agri2000 = agriculture, grass2000 = grassland, wet2000 = wetland and route2000 = road density) except forest:

$$NUMBER \sim agri2000 + grass2000 + wet2000 + route2000$$

Road density was the strongest predictor of Bobolink abundance (coefficient = 0.29) followed by wetland coverage (coefficient = 0.15) (Table 2). Even with a smaller coverage available, the number of Bobolinks present in wetlands increased by 14.6% with coverage of wetland going from 0 to 15%. Grassland coverage and agriculture were also significant predictors in the model, but were not the best indicators of abundance. Grassland coverage (correlation = 0.027) was slightly more related to Bobolink abundance than agriculture coverage (correlation = 0.016). Grassland and agriculture landscape variables must be present in larger proportions than wetlands (at nearly 70% of coverage) to obtain maximal abundance (Figure 8). Road density increased Bobolink abundance by 29%, a high count of nearly 40 Bobolinks, when the density of roads increased from 0 to 12% (Table 2; Figure 8).

Discussion

Roads

The high correlation of Bobolinks with road density is surprising as the proximity to roads has been shown to reduce breeding success in birds (Bollinger & Gavin, 2004). Roads cause fragmentation and can have edge effects extending up to several kilometers beyond the road (Sliwinski & Koper, 2012). Londe et al. (2019) have found that some grassland birds were not as affected by roads as other grassland birds. However, this does not explain why it is a stronger predictor than the landscape cover variables. Bias in detectability is a more plausible explanation for this strong relationship with abundance. Roads make areas more accessible to observers and it is therefore more likely to detect birds where observers are going more. Wellicome et al (2014) found that roadside surveys tended to overestimate certain species. It is also unclear if there was a specific type of road which might have influenced the results.

In my study, I combined all types of roads and, therefore, combined roads with various intensities in usage. Because a large proportion of Bobolinks are found near farms and in agricultural habitats, the roads present might have less traffic and, therefore, could have less impacts on Bobolinks (Husby, 2017).

Landscape predictors

Wetlands are often in proximity to grasslands and offer some similar habitats features such as long grasses and open space areas. Bobolinks also use wetland habitats, especially in their wintering habitats, as it is their preferred habitat to molt which could be an explanation for their higher abundance in proximity to wetlands (American Bird Conservancy, 2021; Di Giacomo et al, 2005). However, this still indicates that wetland habitats are an important habitat for the migration of Bobolinks.

Bobolinks are described as year-round grassland obligates (Renfrew et al, 2019). However, grassland coverage did not have the highest effect on Bobolink abundance out of the five predictors tested. Because Bobolinks are area-sensitive birds, specific landscape mosaics may be preferred (Renfrew et al, 2019). Other criteria such as area size and type of grassland could affect their abundance. I used a simplified grassland variable that merged 5 classes from the BDDPAD layer and 16 classes from the AAFC ACI layer. Therefore, gaining map accuracy, I lost specific landcover detail as some subsets of landcover might not be preferred by Bobolinks (Marchand & Litvaitis, 2004). The primary land use replacing native and surrogate grasslands is cropped agriculture (Renfrew et al, 2019). Hayfields and non-intensive pastures are usually converted to corn, soybean, and alfalfa fields which have been associated with Bobolink declines in the past (Renfrew et al., 2019). However, I showed a positive relationship with agriculture. This could be due to the merger of the agriculture landcover variables (see *Study limitations*).

Bobolinks are more abundant in areas with low forest coverage. The coverage of forest was found to be declining at a similar rate than grassland coverage is increasing for the simple reason that a large forest has little grassland habitat and vice versa.

Study limitations

It is important to acknowledge that the absence points were generated randomly in R and do not represent verified absence points. However, it has been suggested that when lacking absence data, distribution models could be improved by generating random background points, as in this study, versus doing a presence-only approach (Brotons et al., 2004).

In my analysis, I used all 581 filtered records in 200 locations. This means that many sites that were considered in my analysis have more than one record per 1 km square site. By not choosing the highest counts for each site, the sites which have gotten more visits could create pseudo-replication in my results. Also, sites in the southern part of the Outaouais will more likely have higher detectability as it is near larger cities than the northern part of the Outaouais, increasing the potential for observations.

The merging of the landcover categories is also a factor to consider. Grasslands present in Québec are mostly surrogate grasslands which mean they are not native. Distinguishing grasslands from agriculture can be hard in this case. Native grasslands are usually composed of a variety of plant species such as forbs, clovers, grasses, small shrubs, and sometimes alfalfa. However, it is common for many of the mentioned plant species to be planted in monocultures, without variation in plant species (COSEWIC, 2010). This has been found to decrease the habitat suitability for Bobolinks as they prefer non-static fields (McCracken et al, 2013). This makes choosing which landcover to merge, in the case of agriculture and grassland, more complicated. Surrogate grasslands are harder to classify, especially when using geospatial data. This could affect the coverage of both variables calculated for each observation and change the results in my model.

Another possible issue is the high counts of Bobolink that were present in my data. Some of the observations totalled up to 150 individuals flocking together. These high counts were most likely taken once the breeding season was done. In fact, bobolinks flock together before leaving their breeding grounds to migrate South. Some of these flocks can exceed 10 000 individuals (Renfrew et al, 2019). Since I considered that all observations obtained were made during breeding season, it is possible that the high counts obtained in my data influenced the results by affecting the correlation between abundance and the various predictors studied.

My main goal was to find which landscape predictors could predict Bobolink abundance in the Outaouais region only. Because spatial predictors can vary at a small scale, more local studies in Canada would be useful to gather a better understanding of the spatial ecology of the Bobolink.

Management implications

It is important to conserve open habitats and to diminish fragmentation. Even at small spatial scales, fragmentation can be detrimental to a species population, especially when there is little of its habitat left. All things considered, spatial distribution frameworks should be integrated into ecological impact assessments as they provide support for biodiversity protection and provides insight for planning and management (Baker et al., 2020).

Active management of Bobolink habitats and changing agricultural practices could help boost their low populations. A common example of this is to modify the date of field mowing as this activity puts at risk the nests of Bobolinks. Currently, mowing is often done at the height of the nesting season. By mowing before and after the nesting period, nest loss can be reduced to about 4% whereas, without these changes, nest loss can be nearly 80% (Luscier & Thompson, 2009).

Conclusion

More detailed spatial analyses should be done to have a better picture of the landscape predictors of Bobolink habitat as various other factors could also be important. I found that Bobolinks are influenced by specific land covers, however, there is still much to learn. Using more specific landscape categories for agriculture and grassland would be useful to have a more detailed look into these habitat predictors. Adding size and area of the landcover parcels in the model could also be more informative as Diemer & Nocera (2014) found that Bobolink abundance could vary according to field size. The five predictors discussed in this paper will help identify areas of concern when trying to manage this important grassland bird and, hopefully, be of great aid in the future recovery plans for their population.

References

Akoglu H. 2018. User's guide to correlation coefficients. Turkish journal of emergency medicine, 18(3), 91–93.

American Bird Conservancy. 2021. Bobolink. American Bird Conservancy [Internet] https://abcbirds.org/bird/bobolink/ . Date consulted: April 11 2021.

Baker, D.J. 2020. Species distribution modelling is needed to support ecological impact assessments. Journal of Applied Ecology. 58(1): 21-26.

Barbet-Massin, M., Jiguet, F., Albert, C.H. & Thuiller, W. 2012. Selecting pseudo-absences for species distribution models: how, where and how many?. British Ecological Society, 3(2): 327-338.

Bollinger, E. K.& Gavin, T. A. 2004. Responses of nesting bobolinks (*Dolichonyx oryzivorus)* to habitat edges. Auk 121: 767–776.

Brotons, L., Thuiller, W., Araújo, M.B. & Hirzel, A.H. 2004. Presence-Absence versus Presence-Only Modelling Methods for Predicting Bird Habitat Suitability. Ecography, 27(4): 437-448.

Bruin, J. 2006. newtest: command to compute new test. UCLA: Statistical Consulting Group [Internet] https://stats.idre.ucla.edu/stata/dae/negative-binomial-regression/ . Date accessed: April 10 2021.

Conseil des productions végétales du Québec (CPVQ). 2000. Impacts sur les milieux agricoles de la fréquentation des oiseaux et de l'établissement de végétaux dans les haies brise-vent. Fiche technique, VU 039. 6 p.

COSEWIC. 2010. COSEWIC assessment and status report on the Bobolink *Dolichonyx orzivorous* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. Vi + 42 pp. (http://www.sararegistry.gc.ca/status/status_e.cfm)

Di Giacomo, A.S., Di Giacomo, A.G. & Contreras, J.R. 2005. Status and Conservation of the Bobolink (*Dolichonyx oryzivorus*) in Argentina. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191, 519-524.

Diemer, K.M & Nocera, J.J. 2014. Associations of bobolink territory size with habitat quality. Ann. Zool. Fennici, 51: 515-525.

DMTI CanMap Route Logistics [computer file]. Markham, Ontario: DMTI Spatial Inc. , [2019].

eBird Basic Dataset. Version: EBD_relMar-2020. Cornell Lab of Ornithology, Ithaca, New York. Mar 2020.

Environment and Climate Change Canada. 2020. Programme d rétablissement du Goglu des prés (Dolichonyx oryzivorus) au Canada [Version provisoire], Série de Programmes de rétablissement de la Loi sur les espèces en péril, Environment and Climate Change Canada, Ottawa, xx + XX p.

ESRI. 2018. ArcGIS Desktop: Release 10.6.1. Redlands, CA: Environmental Systems Research Institute.

Fletcher, R.J & Fortin, M. 2018. Introduction to Spatial Ecology and Its Relevance for Conservation Applications with R. Spatial Ecology and Conservation Modeling: Applications with R, pp.1-13. Springer International Publishing

Freemark, K. & Rogers, C. 1995. Modification of Point Counts for Surveying Cropland Birds. USDA Forest Service - General Technical Report. PSW-GTR-149. 69-74.

Guttery, M.R., Ribic, C.A., Sample, D.W, Paulios, A., Trosen, C., Dadisman, J., Schneider, D. & Horton, A.H. 2017. Scale-specific habitat relationships influence patch occupancy: defining neighborhoods to optimize the effectiveness of landscape-scale grassland bird conservation. Landscape Ecology, 32:515-529.

Hijmans, R.J. 2021. Absence and background points, RSpatial [Internet] https://rspatial.org/raster/sdm/3_sdm_absence-background.html . Date accessed: March 27 2021.

Jones, R.1942. French-Canadian Agriculture in the St. Lawrence Valley, 1815-1850. Agricultural History, 16(3), 137-148.

Herkert, J.,Sample, D.W., Warner, R.E. 1996. Management of Midwestern Grassland Landscapes for the Conservation of Migtratory Birds. USDA Forest Service - General Technical Report PNW. NC-187. 89-116.

Hill, S.L.L., Ricardo, G., Sanchez-Ortiz,K., Caton, E., Espinoza, F., Newbold, T., Tylianakis, J., Scharleman, J.P.W, De Palma, A. & Purvis, A. 2018. Worldwide impacts of past and projected future land-use change on local species richness and the Biodiversity Intactness Index, bioRxiv, 12p.

Husby, M. 2017. Traffic Influence on Roadside Bird Abundance and Behaviour. Acta Ornithologica, 52(1): 93-103.

Kelling, S., Johnston, A., Fink, D., Ruiz-Gutierrez, V., Bonney, R., Bonn, A., Fernandez, M., Hochachka, W.M., Julliard, R., Kraemer, R. & Guralnick, R. 2018. Using

Semistructured Surveys to Improve Citizen Science Data for Monitoring Biodiversity. BioScience, 69(3):170-179.

Rosenberg, K.V., Dokter, A.D, Blancher, P.J., Sauer, J.R., Smith, A.C., Smith, P.A., Stanton, J.C., Panjabi, A., Helft, L., Parr, & Marra, P.P. 2019. Decline of the North American avifauna. Science 366(6461): 120-124.

Lamoureux, S. et C. Dion. 2019. Guide de recommandations – Aménagements et pratiques favorisant la protection des oiseaux champêtres - 2e édition. Regroupement QuébecOiseaux, Montréal, 198 p.

La Sorte, F.A., Lepczyk, C.A., Burnett, J.L., Hurlbert, A.H., Tingley, M.W. & Zuckerberg, B. 2018. Opportunities and Challenges for Big Data Ornithology. The Condor 120 (2): 414–26.

Londe, D.W., Fuhlendorf, S.D., Elmore, R.D. & Davis, C.A. 2019. Landscape heterogeneity influences the response of grassland birds to energy development. Wildlife Biology, 1:1-11.

Luscier, J.D. & Thompson, W.L. 2009. Short-Term Responses of Breeding Birds of Grassland and Early Successional Habitat to Timing of Haying in Northwestern Arkansas. The Condor, 111(3): 538-544.

MacKenzie, D. 2009. What are the issues with Presence-Absence data for wildlife managers?. Journal of Wildlife Management. 69(3): 849-860.

Marchand, M.N. & Litvaitis, J.A. 2004. Effects of Habitat Features and Landscape Composition on the Population Structure of a Common Aquatic Turtle in a Region Undergoing Rapid Development. Conservation Biology, 18: 758-767.

Martin A.E., Fahrig, L. (2012) Measuring and selecting scales ofeffect for landscape predictors in species-habitat models. Ecol Appl 22:2277–2292

Martin, S. G., & Gavin, T.A.. 1995. Bobolink (*Dolichonyx oryzivorous*) in A. Poole and F. Gills, editors. The Birds of North America. The Birds of North America, Inc., Philadelphia, PA.

McCracken, J.D., R.A. Reid, R.B. Renfrew, B. Frei, J.V. Jalava, A. Cowie, & A.R. Couturier. (2013). Recovery Strategy for the Bobolink (Dolichonyx oryzivorus) and Eastern Meadowlark (Sturnella magna) in Ontario. Ontario Recovery Strategy Series. Prepared for the Ontario Ministry of Natural Resources, Peterborough, Ontario. viii + 88 pp.

Ontario Ministry of Natural Resources and Forestry. 2019. General Habitat Description for the Bobolink (*Dolichonyx oryzivorus*). 4p. (https://www.ontario.ca/page/bobolink-general-habitat-description#section-0)

Plante, C., Hatvany, M. et N. Bhiry. 2006. Le haut marais de l'Isle-aux-Grues : un exemple d'exploitation et de développement durable. Revue d'histoire de l'Amérique française 60: 37-60.

Powers, N.,M. Brouder, S. Blomquist, B. Potter, J. Dingledine, C. Deloria, G., Soulliere, T. Kerr, & K. Steiger-Meister. 2014. Selecting surrogate species for Strategic Habitat Conservation in the Upper Midwest Great Lakes geography. U.S. Fish and Wildlife Service, Bloomington, Minnesota, USA. 27p.

Renfrew, R.B., K.A. Peters, J.R. Herkert, K.R. VanBeek, and T. Will. 2019. A full life cycle conservation plan for Bobolink (Dolichonyx oryzivorus). U.S. Fish & Wildlife Service. 216p.

R Core Team. 2021. R: A Language and Environment for Statistical Computing. Vienna, Austria.

Renfrew, R.B. & Saavedra, A.M. 2007. Ecology and conservation of Bobolinks (*Dolichonyx oryzivorus)* in rice production regions of Bolivia. Ornitologia Neotropical 18: 61–73.

Renfrew, R., A. M. Strong, N. G. Perlut, S. G. Martin, and T. A. Gavin. 2015. Bobolink (Dolichonyx oryzivorus), The Birds of North America Online in P. G. Rodewald, editor. Cornell Lab of Ornithology, Ithaca, USA.

Sibley, D.A. 2016. The Sibley Field Guide to Birds of Eastern North America: Second Edition Paperback – Illustrated, pp. 406. Knopf, New York.

Sliwinski, M. and Koper, N. 2012. Grassland bird responses to three edge types in a fragmented mixed-grass prairie. Avian Conserv. Ecol. 7: 6.

Statistics Canada. 2017. Outaouais [Economic region], Québec and Québec [Province] (table). Census Profile. 2016 Census. Statistics Canada Catalogue no. 98-316-X2016001. Ottawa. Released November 29, 2017. [Internet] https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E . Date accessed: April 2, 2021.

Strimas-Mackey, M., W.M. Hochachka, V. Ruiz-Gutierrez, O.J. Robinson, E.T. Miller, T. Auer, S. Kelling, D. Fink, A. Johnston. 2020. Best Practices for Using eBird Data. Version 1.0. https://cornelllabofornithology.github.io/ebird-best-practices/. Cornell Lab of Ornithology, Ithaca, New York. https://doi.org/10.5281/zenodo.3620739

Tang, t. & Zhang, J. 2018. Time-scale sensitive sensor applications in collecting and analyzing geographic event data. Annals of GIS, 24(4): 241-253.

Wellicome, T. I., K. J. Kardynal, R. J. Franken, and C. S. Gillies. 2014. Off-road sampling reveals a different grassland bird community than roadside sampling: implications for survey design and estimates to guide conservation. Avian Conservation and Ecology 9(1): 4.

Table 1. Latitude and longitude of the 200 pseudo-absence points used in the spatial analysis. They were generated by creating background points in R.

Pseudo absence ID	Latitude	Longitude	Pseudo absence ID	Latitude	Longitude
1	46.8064	-76.213	101	46.9072	-76.213
2	45.8488	-76.5898	102	47.0584	-76.3386
3	46.3024	-76.9666	103	46.6552	-76.7154
4	45.4456	-75.8362	104	45.7984	-75.585
5	47.1088	-76.9038	105	45.6976	-75.6478
6	46.2016	-76.0246	106	46.3024	-76.0874
7	47.5624	-76.2758	107	46.0504	-76.3386
8	46.6048	-77.3434	108	47.1592	-76.7154
9	46.3528	-77.5946	109	45.5968	-75.7734
10	46.3024	-76.6526	110	46.8064	-76.527
11	46.8568	-77.6574	111	47.008	-76.4014
12	46.1008	-76.5898	112	46.3528	-76.7782
13	46.3024	-76.0246	113	46.6552	-76.2758
14	46.3024	-77.2178	114	46	-75.8362
15	45.6472	-75.899	115	46.3528	-76.7154
16	45.5464	-75.7106	116	47.0584	-76.7782
17	46.2016	-76.7154	117	46.756	-76.4014
18	45.8992	-76.3386	118	46.1512	-76.841
19	45.6976	-76.6526	119	46.4032	-77.5318
20	47.6128	-76.0246	120	45.6472	-76.0246
21	46.7056	-75.9618	121	46.1008	-77.2178
22	47.4616	-76.4014	122	46.504	-75.899
23	46.7056	-76.841	123	45.5464	-76.4014
24	47.2096	-76.1502	124	46.504	-77.2806
25	46.0504	-75.0198	125	46.6048	-77.469
26	46.5544	-76.213	126	45.7984	-76.2758
27	46.3024	-77.2806	127	46.1512	-77.0294
28	46.5544	-77.4062	128	45.748	-75.0826
29	47.1088	-76.2758	129	46.4032	-77.2806
30	46.504	-76.2758	130	46.2016	-76.841
31	46	-76.6526	131	46.5544	-76.0246
32	46.4032	-76.841	132	47.1592	-76.5898
33	47.2096	-76.213	133	45.748	-76.2758
34	46.4032	-76.527	134	46.3024	-77.6574
35	46	-76.4014	135	47.6632	-75.9618
36	45.6976	-75.0198	136	45.9496	-76.0874
37	46.756	-75.899	137	46	-74.8942
38	46.6552	-76.4642	138	47.6632	-76.1502
39	45.6976	-74.8942	139	46.3024	-76.527
40	47.4112	-76.213	140	45.6976	-75.5222

41	45.9496	-76.7154	141	45.9496	-75.3338
42	46.252	-76.0246	142	45.748	-75.3338
43	46.504	-77.5946	143	45.7984	-75.0198
44	46.1512	-76.6526	144	46.4536	-76.4642
45	46.504	-76.841	145	46.756	-76.9666
46	45.6976	-75.4594	146	46.4536	-77.3434
47	47.1088	-76.7154	147	45.6472	-76.4642
48	45.748	-75.9618	148	45.6976	-76.1502
49	46.7056	-76.4014	149	46.5544	-77.0294
50	46.8568	-76.9038	150	45.9496	-76.6526
51	46.504	-77.6574	151	45.9496	-76.213
52	46	-76.9666	152	46	-74.957
53	46.4536	-76.0874	153	46.7056	-76.4642
54	47.3608	-75.899	154	46.4536	-75.9618
55	46.1512	-77.2806	155	46.1008	-77.0294
56	46.6048	-77.0294	156	47.0584	-77.2806
57	46.5544	-77.155	157	47.4616	-76.4642
58	46.7056	-77.3434	158	47.0584	-77.2178
59	47.3608	-76.1502	159	45.8992	-76.7782
60	46.1008	-76.0874	160	46.6048	-76.4642
61	46.4536	-76.7154	161	45.6472	-75.7734
62	45.748	-75.585	162	45.8992	-75.271
63	45.6976	-76.0246	163	45.6976	-75.899
64	47.1592	-77.783	164	46.6552	-77.0922
65	46.9072	-77.5946	165	46.3528	-75.899
66	47.3608	-75.9618	166	47.008	-77.0922
67	47.008	-77.3434	167	46.252	-76.213
68	46.504	-76.1502	168	47.008	-76.3386
69	46.4536	-76.4014	169	46.0504	-76.7154
70	45.5464	-76.2758	170	47.0584	-77.0294
71	46.2016	-76.213	171	47.5624	-76.0874
72	45.7984	-75.6478	172	46.9072	-76.7782
73	46.4536	-76.2758	173	45.748	-76.3386
74	46.5544	-77.5318	174	47.512	-75.899
75	46.8568	-77.469	175	47.0584	-77.6574
76	47.4616	-75.7734	176	46.6552	-76.6526
77	45.7984	-75.3338	177	45.6472	-75.5222
78	47.3104	-76.2758	178	47.512	-76.3386
79	45.4456	-75.7734	179	45.748	-75.899
80	45.9496	-75.0826	180	47.26	-76.1502
81	45.9496	-77.155	181	46.504	-76.3386
82	45.748	-75.7106	182	47.008	-77.5318
83	45.5968	-76.4642	183	46.8064	-77.6574
84	46.1512	-76.7782	184	45.7984	-76.5898
85	46.1008	-76.841	185	45.6976	-76.213

86	46.1008	-76.3386	186	46.6048	-77.6574
87	46.5544	-76.9666	187	45.8488	-75.2082
88	45.6976	-75.1454	188	47.0584	-77.5318
89	47.512	-76.0246	189	47.0584	-76.2758
90	45.5464	-76.527	190	46.7056	-77.2178
91	46.756	-77.155	191	46.756	-76.1502
92	45.8488	-76.0246	192	47.3104	-75.899
93	46.3024	-77.0922	193	46.6552	-77.3434
94	46.4032	-76.0246	194	46.8064	-77.5946
95	45.6976	-75.9618	195	46.4032	-75.8362
96	47.0584	-76.7154	196	46.7056	-76.1502
97	46.9576	-76.527	197	46.0504	-77.0294
98	45.6976	-75.2082	198	45.6472	-76.1502
99	47.4112	-76.4014	199	46.756	-76.0246
100	46.6552	-77.155	200	46.3528	-76.213

Table 2. Negative binomial regression investigating the effects of landcover and road density on the abundance of Bobolinks (N = 400; 200 presence sites and 200 absence sites) observed in the Outaouais region, Québec. Significant *p* value for α = 0.05 are in bold. A buffer of 2000 m was used for each predictor (agriculture, grassland, wetland and road density). Dispersion parameter was equal to 0.8999 and residual deviance = 747.84 vs degrees of freedom = 776.

Variables	Coefficient estimate	Standard error	Z	*p* value
Intercept	-0.7231	-0.1165	6.205	**5.47e-10**
Agriculture	0.0157	0.0040	3.971	**7.15e-05**
Grassland	0.0271	0.0031	8.846	**< 2e-16**
Wetland	0.1463	0.0170	8.614	**< 2e-16**
Road density	0.2907	0.0327	8.886	**< 2e-16**

Table 3. Merged landcover types used to split the 95 landcover types provided by the Agriculture and Agri-food Canada Annual Crop Inventory (ACI) 2019 and the 2020 Parcels and Reported Agricultural Productions Database (BDPPAD) of Québec.

Final landcover name	Source	Original landcover name
1. Agriculture	1.1 BDDPAD	1.1.1 Autres
		1.1.2 Blé, triticale, épeautre
		1.1.3 CMA-Multiples
		1.1.4 CMA-Légumes divers
		1.1.5 CMA-Feuillus
		1.1.6 CMA-Fruits
		1.1.7 Inconnu
		1.1.8 Légumes de transformation
		1.1.9 Maïs fourrager
		1.1.10 Maïs-grain
		1.1.11 Pommes de terre
		1.1.12 Pommes
		1.1.13 Protéagineuses
		1.1.14 Petits fruits
		1.1.15 CMA-Racines
		1.1.16 Soya
		1.1.17 CMA-Vivaces
		1.1.18 Cultures émergeantes
	1.2 ACI	1.2.1 Greenhouses
		1.2.2 Agriculture (undiferentiated)
		1.2.3 Pasture/ Forages
		1.2.4 Cereals
		1.2.5 Other Grains
		1.2.6 Switchgrass
		1.2.7 Quinoa
		1.2.8 Corn
		1.2.9 Tobacco
		1.2.10 Ginseng

	1.2.11 Oilseeds
	1.2.12 Borage
	1.2.13 Camelina
	1.2.14Flaxseed
	1.2.15 Safflower
	1.2.16 Sunflower
	1.2.17 Soybeans
	1.2.18 Pulses
	1.2.19 Other Pulses
	1.2.20 Peas
	1.2.21 Chickpeas
	1.2.22 Beans
	1.2.23 Fababeans
	1.2.24 Lentils
	1.2.25 Vegetables
	1.2.26 Tomatoes
	1.2.27 Potatoes
	1.2.28 Sugarbeets
	1.2.29 Other Vegetables
	1.2.30 Fruits
	1.2.31 Berries
	1.2.32 Blueberry
	1.2.33 Cranberry
	1.2.34 Other Berry
	1.2.35 Orchards
	1.2.36 Other Fruits
	1.2.37 Vineyards
	1.2.38 Hops
	1.2.39 Sod
	1.2.40 Herbs
	1.2.41 Nursery
	1.2.42 Canaryseed

		1.2.43 Hemp
		1.2.44 Vetch
		1.2.45 Other Crops
2. Forest	2.1 ACI	2.1.1 Forest (undifferentiated)
		2.1.2 Coniferous
		2.1.3 Broadleaf
		2.1.4 Mixedwood
3. Grassland	3.1 BDDPAD	3.1.1 Avoine
		3.1.2 Canola
		3.1.3 Foin
		3.1.4 Orge
		3.1.5 Seigle
	3.2 ACI	3.2.1 Shrubland
		3.2.2 Grassland
		3.2.3 Fallow
		3.2.4 Barley
		3.2.5 Millet
		3.2.6 Oats
		3.2.7 Rye
		3.2.8 Spelt
		3.2.9 Triticale
		3.2.10 Wheat
		3.2.11 Sorghum
		3.2.12 Winter Wheat
		3.2.13 Spring Wheat
		3.2.14 Canola / Rapeseed
		3.2.15 Mustard
		3.2.16 Buckwheat
4. Wetland	4.1. ACI	4.1.1 Wetland
		4.1.2 Peatland

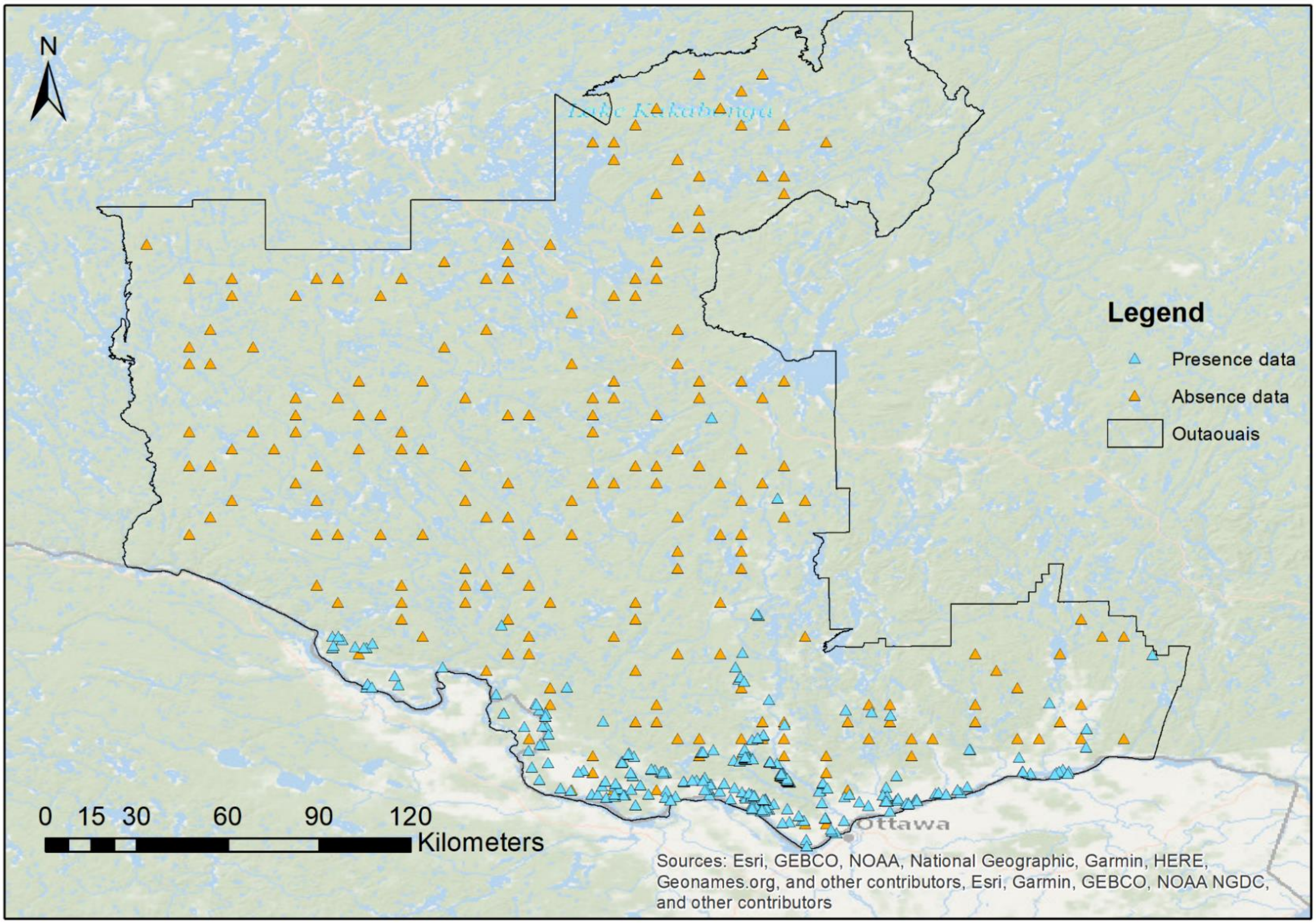


Figure 1. Presence and absence points of Bobolinks in the Outaouais region. The blue triangles represent every 581 records of Bobolink presence. The orange triangles represent the 200 random background points generated in R which were used as absence data.

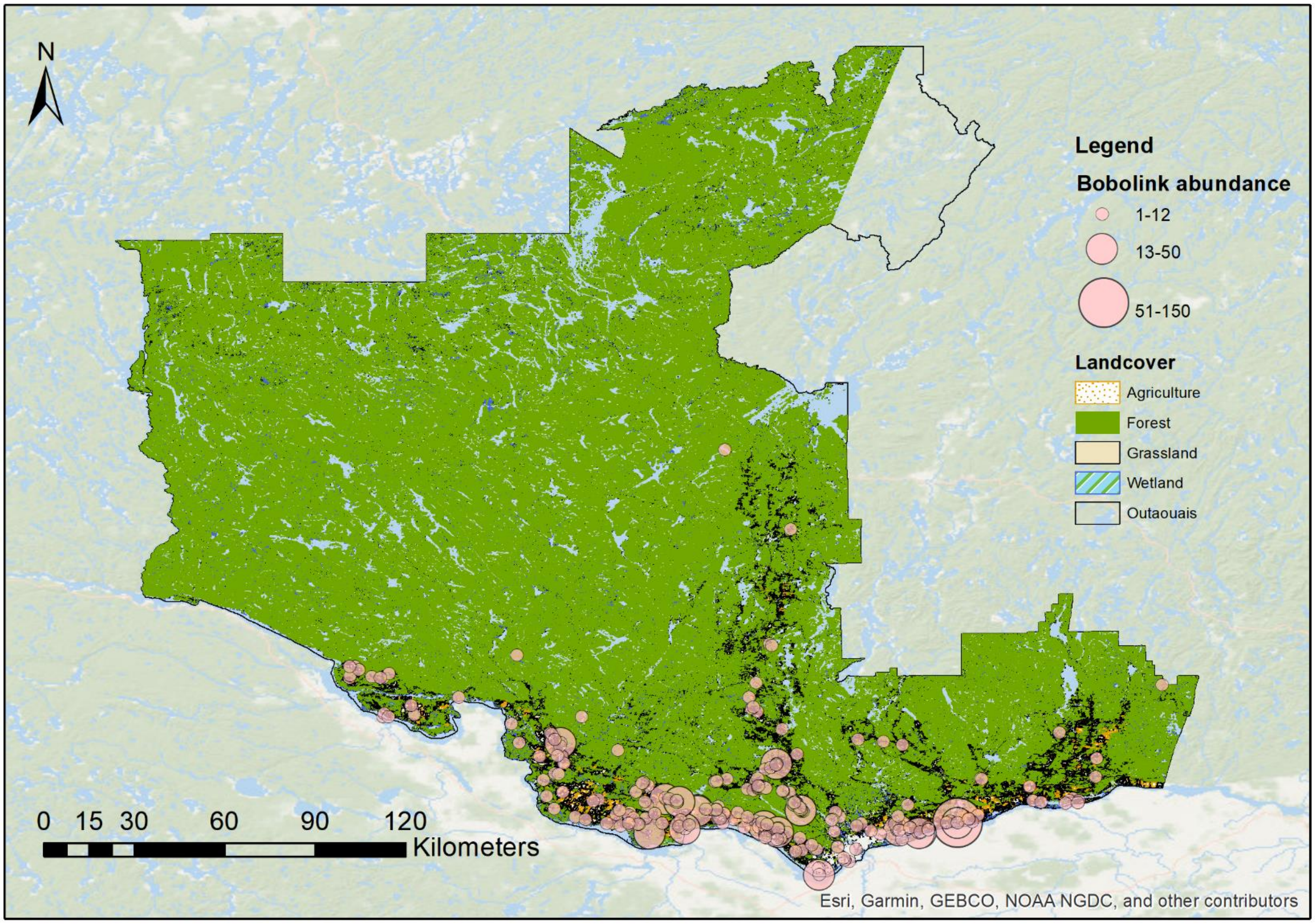


Figure 2. Number of Bobolinks observed for each of the 581 observation records in the Outaouais region.

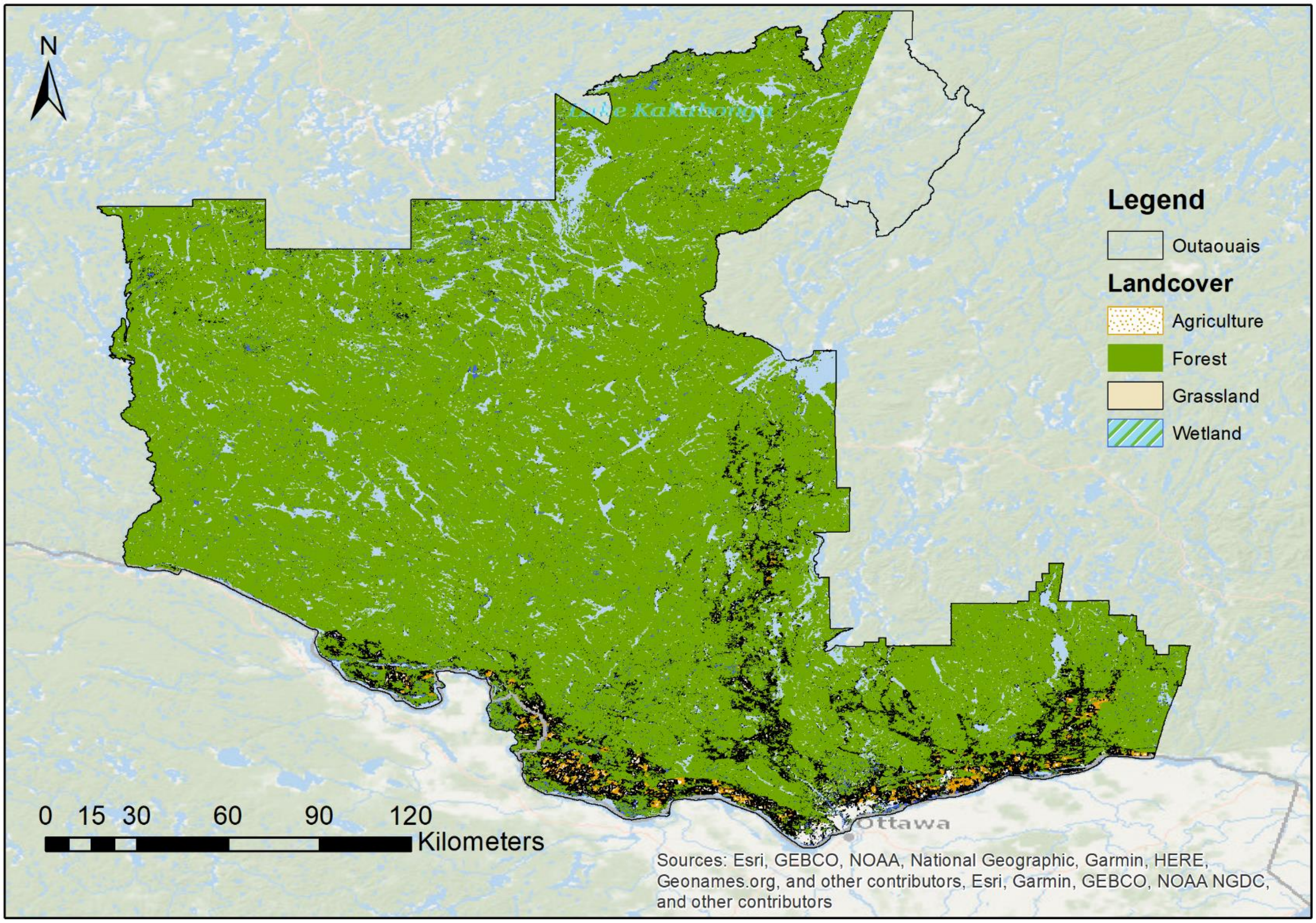


Figure 3. Combined agriculture, forest, grassland and wetland landcover of the Outaouais region provided by Agriculture and Agri-food Canada Annual Crop Inventory (ACI) 2019 and the 2020 Parcels and Reported Agricultural Productions Database (BDPPAD) of Québec.

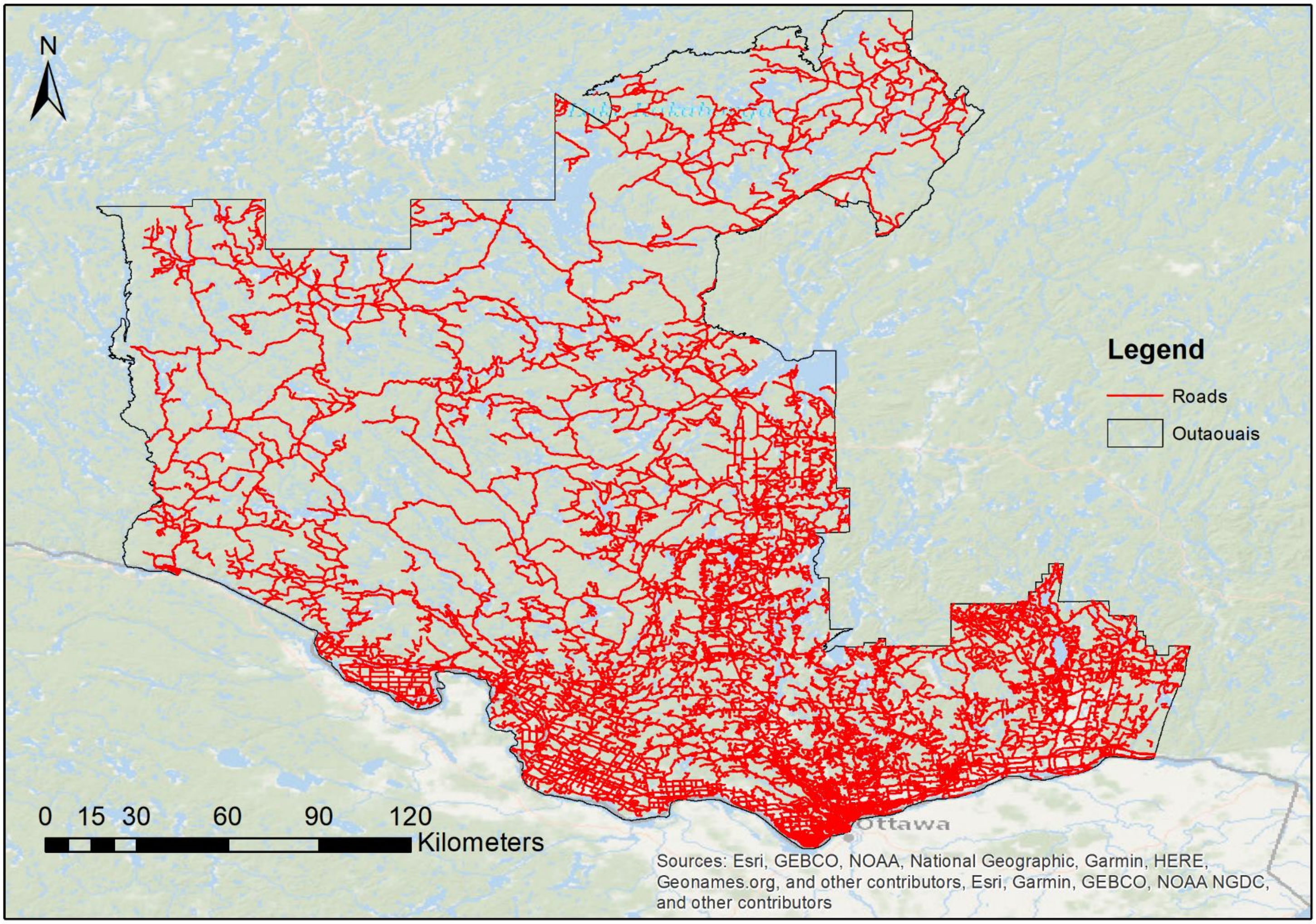


Figure 4. Road density cover in the Outaouais region provided by DMTI CanMap Route Logistics (2019).

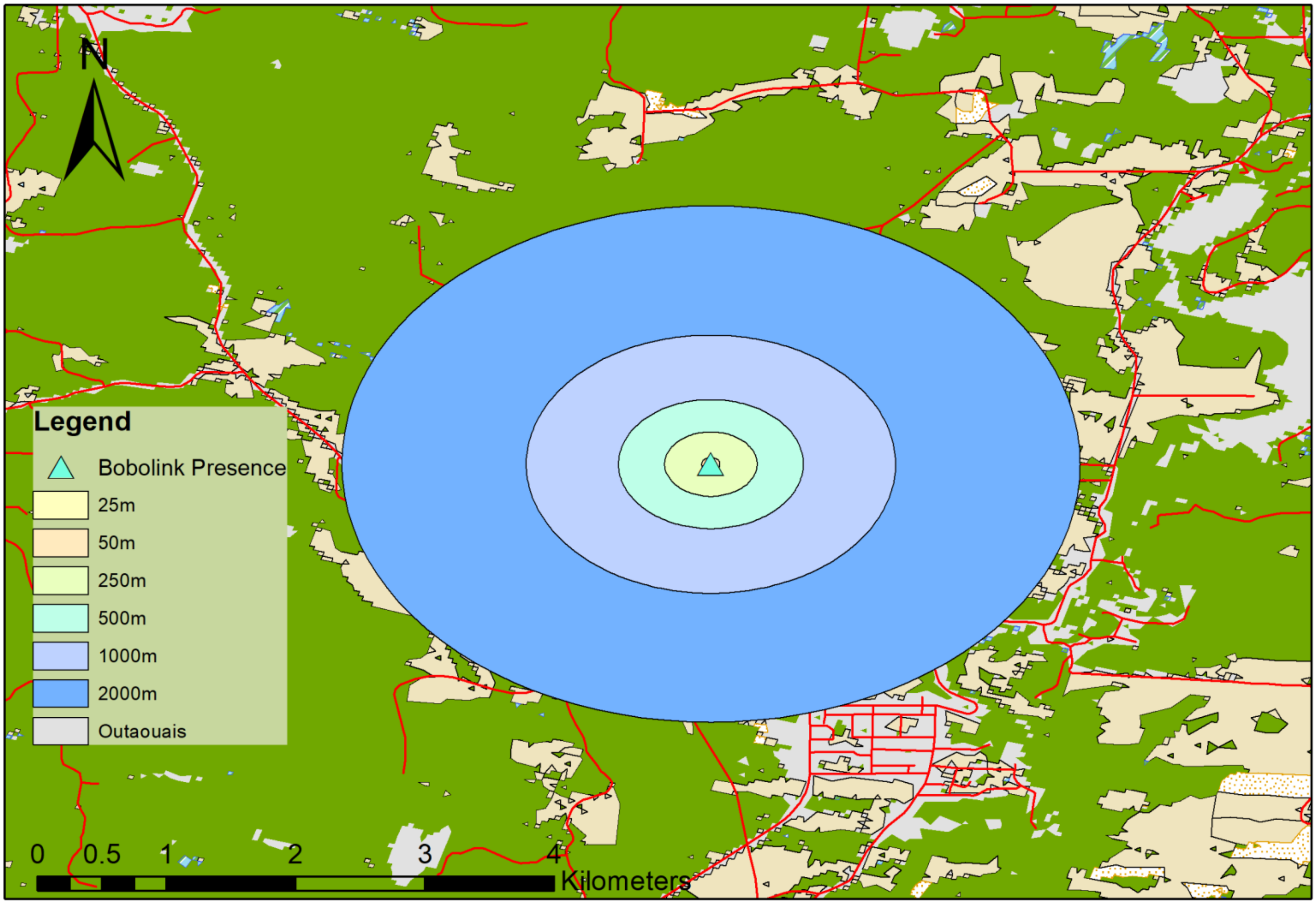
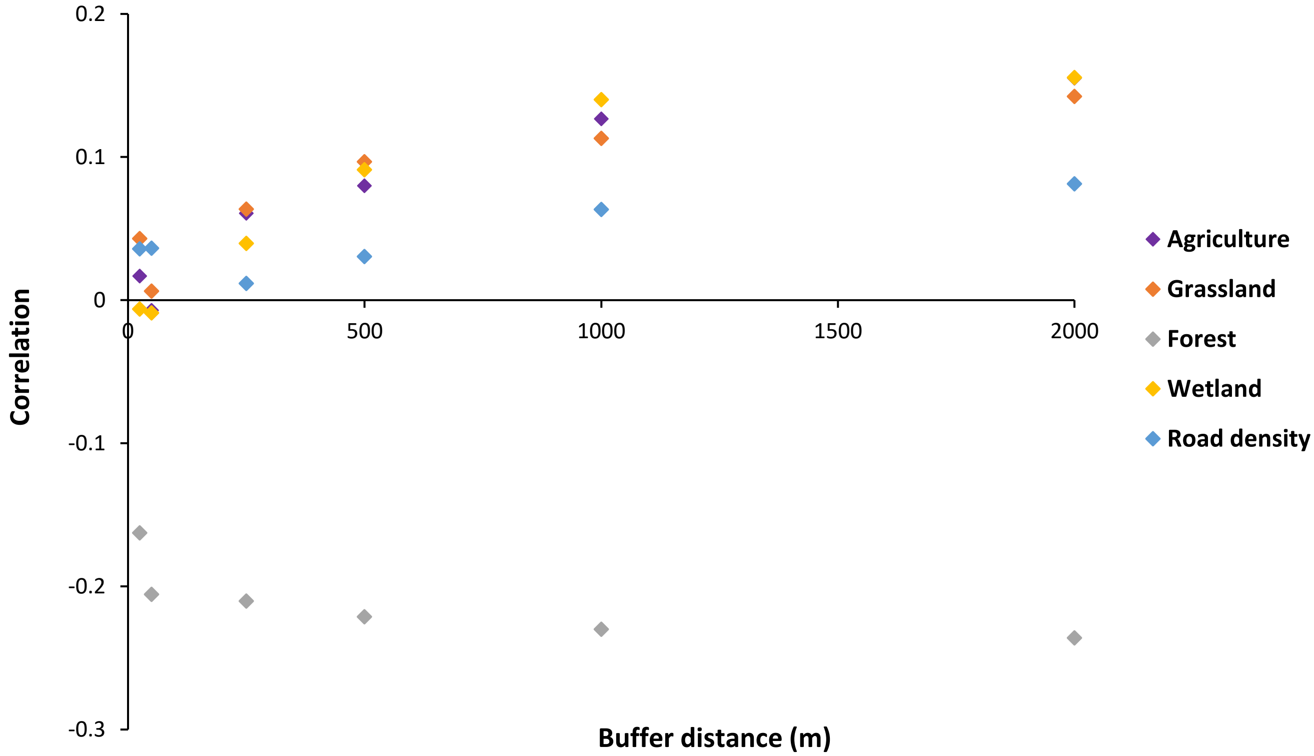


Figure 5. Example of an observation and its six buffers. Buffers were created from 25 m, 50 m, 100 m, 250 m, 500 m, 1000 m and 2000 m of each record point.

Figure 6. Correlation between the number of Bobolinks observed and the proportion of the five landscape predictors at various buffer distances (25 m, 50 m, 100 m, 250 m, 500 m, 1000 m and 2000 m). The highest absolute variable is at 2000 m for each variable (Agriculture = 0.155097, grassland = 0.142383, forest = 0.23607, wetland = 0.155493 and Road density = 0.081296). Purple represents agriculture, orange represents grassland, grey represents forest, yellow represents wetland and blue represents road density.



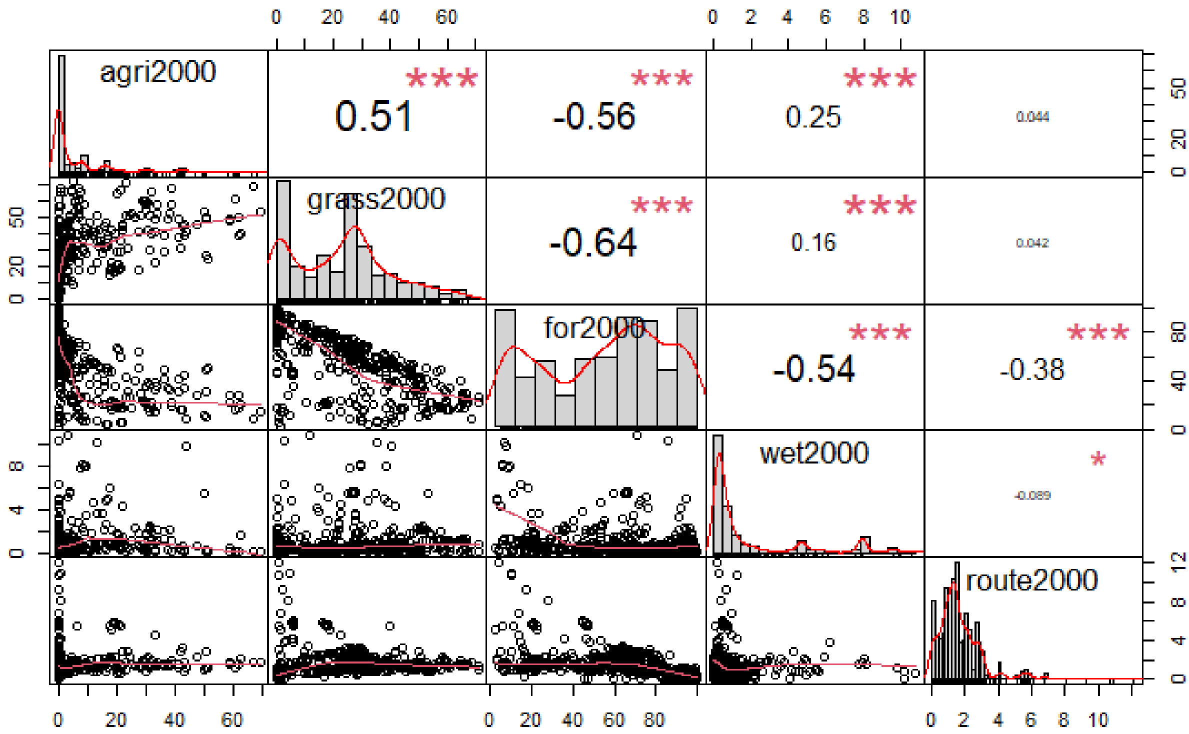


Figure 7. Correlation matrix of all the measured variables for the landcover and road density analysis. Correlations above 0.6 or lower than - 0.6 are considered moderately high to high. Legend: coverage of agriculture (2000 m buffer) is represented by agri2000; coverage of grassland (2000 m buffer) is represented by grass2000; coverage of forest (2000 m buffer) is represented by forest2000; coverage of wetland (2000 m buffer) is represented by wet2000; road density (2000 m buffer) is represented by route2000.

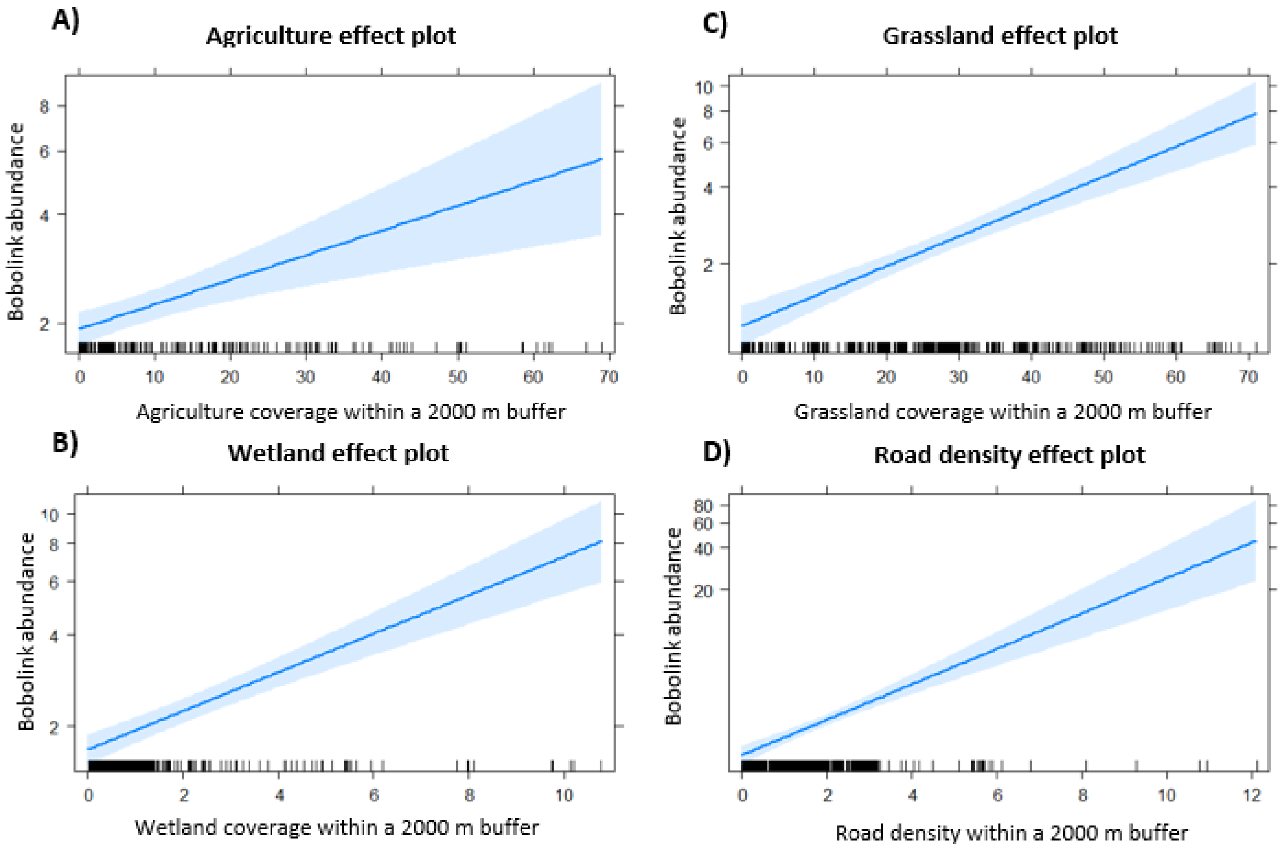


Figure 8. Effect plots of the four predictors used in the statistical model. Maximum Bobolink abundance predicted in function of the coverage (%) of (A) agriculture, (B) wetland, (C) grassland and (D) road density with a 2000 m buffer. The light blue cloud around the plots represents the 95% confidence interval.