Norwegian University
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Population estimate, trend, and habitat preferences of breeding curlews *Numenius arquata* in Akershus, southeast Norway

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Preface

This master thesis concludes two years of study within general ecology at the Norwegian University of Life Sciences. Throughout this project, I acquired valuable knowledge about bird conservation and the problems that our modern agriculture brings to farmlands biodiversity.

I would like to thank my supervisor, Svein Dale, who guided me through every stage of this project, provided great advices and was always present when I needed help.

Norwegian University of Life Sciences

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Abstract

The Eurasian Curlew (*Numenius arquata*) is a species in decline, classified as near threatened (NT) worldwide, and vulnerable (VU) in Norway. In the region of Akershus (SE Norway), no recent update exists of the breeding population trend. I examined how curlews selected their habitats in Akershus, how the population size changed in the period 1971-2017, and how important natural bogs are for them. Curlews selected medium vegetation height (10-20 cm) and stubble and tended to avoid tilled fields. 28-30 pairs were recorded in Akershus in 2017, the population declining by 40% in the last 23 years. Curlews tended to decline less in lowlands territories than in uplands territories and on sites within 1 to 5 km from a bog. Curlews most likely preferred medium vegetation height as it provides shelter from predators and good foraging habitat and avoid dry tilled fields because of poor food availability and exposure to predators. Habitat changes in agricultural landscapes, agriculture intensification, and increase of predators such as corvids and foxes are possible causes of the decline.

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I. Introduction

Farmlands are a mosaic of diverse habitat types. Crop fields, grasslands, pastures, ponds, fallow lands and woodlands are all habitats composing agricultural landscapes. Crop fields and grasslands themselves represent a diverse component of agricultural landscape, as each field can be a different species, have a specific height and humidity. This habitat heterogeneity within farmlands allows a broad range of vertebrates to coexist (Krebs et al., 1999; Tews et al., 2004). More specifically, farmlands have a diverse bird community, comprising various groups such as birds of prey, passerines, gamebirds or waders. However, with the development of modern agriculture, many changes occurred in the agricultural landscapes. As Mazoyer and Roudart explains (2006), the second industrial revolution at the beginning of the twentieth century promoted a shift in agriculture by making powerful engines, large machineries and chemicals available. Farms became bigger and fewer and specialized in one or two products per farm which created specialized regions, where one type of production dominates (Mazoyer & Roudart, 2006). Nowadays, with a rising food demand, agriculture is expected to continue to intensify (Tilman et al., 2011). This loss of heterogeneity and changes in farmland practices negatively impact farmland biodiversity (Benton et al., 2003) and farmland bird populations (Donald et al., 2001; Krebs et al., 1999). Such changes are the increasing use of pesticides, land drainage, switch from spring to autumn sowing, improvement of pasture by use of fertilizers and mono-culture, silage harvest of grass and hedgerow removal (Geiger et al., 2010; Krebs et al., 1999). Different groups of birds are impacted by different changes. For instance, the survival rate of seed-eating birds decline mostly because of the increasing use of herbicide and the shift from spring to autumn sowing that reduces their food

supplies, while the reproductive rates of waders decline due to land-drainage and intensification of grassland management that reduce their food availability (Newton, 2004).

One group of farmland birds is particularly threatened by changing agricultural practices, namely waders. Waders are a group of birds wintering on coastal habitats such as beaches, rocky shores, mudflats and tidal wetlands and commonly found in freshwater wetlands during the breeding period. Most of them migrate, and some breed on farmlands such as the Eurasian Curlew (*Numenius arquata*), the Lapwing (*Vanellus vanellus*), and the Black-tailed Godwit (*Limosa limosa*). Different species of waders require different sward heights. Typically, a lapwing will prefer low sward heights while a godwit will prefer higher ones (Durant et al., 2008). Changes in sward heights can negatively impact waders in general (Bell & Calladine, 2017; Durant et al., 2008; van der Wal & Palmer, 2008). Bell & Calladine (2017) showed that a change of crop type led to a higher sward during spring, causing a decline of waders in Scottish farmlands. They also highlighted that habitats with bare soil help maintaining a wide community of waders. However, reduced sward heights can also impact negatively waders by exposing them to predators (Durant et al., 2008). The most common factor reducing swards height is grazing. Even though grazing can have a positive impact on breeding waders by creating heterogeneity within pastures, a high grazing pressure is detrimental (van der Wal & Palmer, 2008). In high numbers, grazers can disturb breeding birds, trample nests and reduce habitat heterogeneity (Durant et al., 2008; van der Wal & Palmer, 2008). In addition to grazing regime, the use of silage instead of hay also impacts breeding waders negatively. The use of silage creates more dense and uniform fields and destroys more nests due to its earlier spring cut (Wilson et al., 2004). To maintain a population, the habitat needs to fulfil the requirements of the species. However, to fully understand what drives the trend of a population, one should focus on both predation pressure and habitat requirement. As van der Wal and Palmer (2008)

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observed, if the predation pressure is low, the sward height does not matter. Inversely, if the predation pressure is high, the sward height requirement for each wader species matters a lot. As an example, curlews prefer tall vegetation, but they can still successfully breed in an environment with short vegetation and no predators. Mammals (foxes, badgers, stoats) but also birds (corvids and gulls) threaten waders by predating on nests and chicks (MacDonald & Bolton, 2008; Roodbergen et al., 2012).

Waders face several threats on their breeding sites and undergo a general decline. Categorized as near threatened (NT) worldwide by the IUCN red list of threatened species (Birdlife International, 2017), the Eurasian Curlew *Numenius arquata* is no exception. During the breeding season, curlews prefer grasslands with medium vegetation height (Berg, 1992a; Berg, 1992b; Berg, 1994; Durant et al., 2008; Valkama et al., 1998). Grasslands are especially important for their nest site, where breeding has a higher chance to succeed than on tillage because tall vegetation hides nests from predators (Berg, 1992a). As a result, curlews avoid nesting on tillage (Valkama et al., 1998). Tillage is also avoided for foraging (Berg, 1992b; Berg, 1993). Before breeding, curlews focus mainly on finding food. Thus, during that period curlews select the habitat with the best food availability. Earthworms (an important food source for curlews during the pre-breeding period) are more easily accessible in sown fields than in dry tillage, because ploughing destroys their burrow systems (Berg, 1993). Berg (1994), also showed that curlews thrive best in mixed farmlands with a high proportion of grasslands and more wetness than in arable sites. In addition, he showed that curlews produced too few young to maintain a stable population in habitats dominated by cereal crops. The decline of curlews results from habitat fragmentation, changes in land-use, predation and farming practices, all of which reduce their reproductive success (Berg, 1992a; Berg, 1992b; Grant et al., 1999; Valkama & Currie, 1999). Indeed, the low survival rate of young and even more of nests explain the

overall decline of the species (Grant et al., 1999; Valkama & Currie, 1999). By feeding on young and eggs, predators such as foxes and crows represent the largest cause of breeding failure for waders (MacDonald & Bolton, 2008). Increasing predators control can in some instances stabilize the decline of curlews (Douglas et al., 2014; Fletcher et al., 2010). The Norwegian population of curlews decline even more than the worldwide population. The national Norwegian red list of species categorized curlews as vulnerable (VU) in 2015 (Kålås et al., 2015). In Norway, curlews breed on farmlands, but also on open bogs both in forested areas and in agricultural areas. However, one third of Norwegian bogs have been drained in the last century (Lier-Hansen et al., 2013) adding one more possible threat to the species. In addition, Dale and Hardeng (2016) showed that the populations of breeding curlews on bogs in Akershus tended to decline.

In the region of Akershus (southeast Norway), the breeding population size of curlews was estimated to 50-60 pairs in 1982 (Olsen, 1982). In this study, I censused their breeding population in Akershus in 2017 and analyzed the population trend between 1971-2017. In addition, I tested the hypotheses that curlews prefer medium vegetation heights and avoid tillage. I also compared the population trend of curlews on forested areas with curlews on agricultural areas. For agricultural sites, I tested whether the distance of a site to the nearest bog had an impact on the population trend. By testing the habitat preferences of curlews and the importance of bogs for their survival, I aim to understand the causes of a possible decline in Akershus.

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II.   Methods

A.   Study species and study area

The Eurasian Curlew (*Numenius arquata*), is a large shorebird belonging to the Scolopacidae family. The curlew is distributed throughout Europe and Russia during the breeding season and spends the winter on the coasts of Africa and Eurasia (Birdlife International, 2017). It migrates to Norway in April to breed and leaves towards south in July and August. Parts of the Norwegian population breed inland, in agricultural areas. They build their nests on the ground, most of the time in open areas such as bogs or fields. Each pair possesses its own territory during the breeding season. The Eurasian Curlew is classified as near threatened worldwide (Birdlife International, 2017), and vulnerable in Norway (Kålås et al., 2015).

The study took place in Akershus counties, in South-Eastern Norway. The region has a continental climate, with an average daily temperature of -0.3°C in April, 4.9°C in Mai, and 9.1°C in June (Yr statistics). In total, 112 sites were visited in the municipalities Aurskog-Høland (42 sites), Nes (31 sites), Sørum (13 sites), Ullensaker (9 sites), Nannestad (7 sites), Hurdal (5 sites), Eidsvoll (3 sites), Enebakk (3 sites), Fet (2 sites), Skedsmo (1 site) and Gjerdrum (1 site). Selection of sites visited was based on previous records of curlew, originating from fieldwork done by Svein Dale during 1994-2016 supplemented by reports submitted to the bird reporting websites nofoa.no and artsobservasjoner.no, and records published in the local ornithological journal Toppdykker'n. The sites vary in size but are around 1km^2 and a few were located on two or three different municipalities. Some sites were bogs located in forested landscapes, whereas some were in agricultural areas in the lowlands.

For sites in the lowlands, we differentiated 5 main habitat types: stubble, tilled fields, sown fields, cereal fields, and grass fields (see appendix A1). Any other habitat types were

classified as "other" (potato, peas, broad beans, rapeseed, fallow field, onion and half-tilled stubble). We grouped vegetation height of cereal fields and stubble into 6 categories: 0-5 cm (0 cm includes sown and tilled fields), 5-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, and 40-50 cm. Our fieldwork began in spring (end of April). At that time, some fields were stubble, some tilled, and some were cereal fields with very low vegetation heights. Cereal fields in early spring were sown during autumn. The availability of each habitat changed with the progression of agricultural work. Farmers start with ploughing fields (tillage), and then sow seeds in the upper layer of the fields. As a result, tilled fields and sown fields are very common during spring. Tilled fields have an irregular surface whereas sown fields present a smooth surface. Cereal will then sprout out and grow height, increasing their availability during late spring and beginning of summer. We classified in "cereal fields" any crop fields such as wheat, oats, rye or barley. "Grass fields" consist of any crop raised to produce hay, straw or silage and are permanent from year to year (rarely ploughed). In late summer, the fields are harvested and tilled again for the next sowing. Harvested fields that have not been tilled yet were classified as stubble.

B.   Data collection

Data collection in the field (112 sites mentioned above) took place from late April to beginning of July. The spring arrivals of curlews in Norway can start as early as beginning of April, and the departures can start as early as mid-July. Thus, even though curlews are present in the area from April to August, we selected a shorter period to minimize the risk of including migrating birds in our observation period. We visited sites at least twice except for some bogs in the forested areas that we visited only once due to their difficulty to reach. On each visit, the presence or absence of birds was noted, as well as the number of birds present and the geographical coordinates of their position. The proportions of each habitat (habitat type and

vegetation height) within the whole site was noted for each agricultural site to analyze how habitat availability changed with time and to analyze habitat selection. In addition, if a bird was observed on an agricultural site, we noted the behavior of the bird, which habitat it used, and the proportions of each habitat within 300 meters around the bird. A visit typically consisted of scanning all the fields within the site with binoculars, which took 30-60 min depending on the size of the site.

The total number of curlews was used to estimate current breeding population size. To analyze the population trend, historical records of curlews from Akershus were compiled by searching through field observations of Svein Dale from extensive mapping of bird communities at nearly 2000 sites in Oslo and Akershus since 1995. In addition, we retrieved information from published literature such as a study by Dale and Hardeng from 2016, the journal of the Norwegian Ornithological Society, Oslo and Akershus branch (Toppdykker'n), the bird reporting websites of the Norwegian Ornithological Society, Oslo and Akershus branch (www.nofoa.no) and the Norwegian Biodiversity Information Centre (www.artsobservasjoner.no), as well as personal communications from several birdwatchers. All records of curlew during the period 15 April - 15 July were noted. To avoid observations that may concern curlews on migration, all sites that were in wetlands and farmland in the lowlands included only observations during 1 May - 30 June. The search for historical records identified some sites that were not visited during the field work in 2017. Single or few observations from 12 sites during early May or late June were regarded to concern migrating birds, and these sites were excluded from analyses. Thus, in total 320 year-records of curlews from 109 sites with indications of breeding were included in analyses (mean 2.9 years with curlews recorded for each site).

For all 109 sites with curlew records accepted as indicating breeding, all sources of

information were searched for negative reports, i.e. reports indicating that a site had been visited during the periods mentioned above, but no curlews were seen. There were 384 year-records of no curlews seen. Thus, there was a total of 704 year-records for the 109 sites, representing a mean of 6.5 year-records for each site (range 1-37 years). Records spanned 1971-2017 with a mean of 15.0 sites visited per year (range 0-95 sites). There was a clear change-point in amount of data from 1995, with a maximum of 6 sites visited per year during 1971-1994 (mean 2.8), and a minimum of 5 sites visited per year during 1995-2017 (mean 27.7). The observations from 2017 were plotted on a map to determine the number of pairs in Akershus. If birds were observed twice or more within a radius of 1 km, they were considered as being from the same pair (1 km criterion recommended by Robertson and Skoglund (1983) and used by Åke Berg (1994)). If two birds were observed on the same day more than 2 km apart, they were considered as two different pairs.

C.   Statistical analysis

To see how the availability of the different habitats changed during our study period, the study period was divided in 12 weeks (1 week in April, 5 weeks in May, 4 weeks in June and 1 week in July). The average proportion of one habitat type/vegetation height was calculated for each period. Spearman's rank correlation tests were used to analyze trends in habitat availability and vegetation height.

The observed and expected habitat use were compared with a chi² test to identify if birds selected or avoided a specific habitat. The proportion of each habitat within 300 meters around a bird or within the whole site (i.e. habitat availability) constituted the expected habitat use. If birds do not show preference for any habitat, the observed habitat use should equal the expected habitat use. For instance, for the habitat "stubble", we compared the number of time we saw

birds foraging on stubble with the expected number of time birds should have foraged on stubble according to habitat availability (i.e the overall proportion of stubble). If the observed habitat use is significantly higher or lower than the expected habitat use, the birds respectively select or avoid this habitat. As an alternative hypothesis, one could argue that the presence of one habitat around the bird matters more than its relative proportion. Thus, we ran the same comparisons, but using presence/absence of one habitat within 300 meters around the bird and within the whole site.

For population trend, I used the package RTRIM using model 2 (assumes that populations vary across sites but show the same growth everywhere and that growth rates are constant during specified time intervals). Four different analyses were performed. First, an analysis was performed with data from 1995 to 2017 with data from 70 sites. Those 70 sites originated from merging some of the 109 original sites. Due to the proximity of some sites, it is possible that birds in two sites represented the same territory. To account for this, we merged some of these sites that were next to each other. Results from this analysis gave us an estimate for the population trend between 1995 and 2017. We ran the same analysis with all 109 sites, which gave us a second estimate for this period. We used data dating back until 1995 only because only a few amounts of data exist from the years before, and probably also an underrepresentation of zero observations. From 1995 zero observations are likely to have been reported due to the initiation of a project of systematic mapping of the bird communities all over Akershus (see Dale et al. 2001). The third and fourth analyses were performed using all years (1971-2017), with respectively 70 sites and 109 sites. In that case the 47 years were grouped into 10 periods of 5 years, except the last period which contained 3 years only (2015-2017), and the first period which contained 4 years only (1971- 1974).

To test the importance of bogs for curlews, I did two more analyses with TRIM using covariates. In the first one, a habitat covariate was added to the model to check if sites within

forested areas had a different population trend than sites on agricultural areas, using the data with 70 sites from 1995 to 2017. In the second one, the covariate was the distance to the nearest bogs expressed as a category: category 1 for sites on bogs or neighboring a bog, category 2 for sites within 1 to 5 km from a bog, and category 3 for sites further than 5 km from a bog. Only natural, non-harvested bogs with an open area larger or equal to 5 hectares were considered. The minimum of 5 hectares was chosen because it was the size of the smallest bog on which curlews were observed in the region. For this analysis, data with 70 sites from 1995 to 2017 was used, and only sites in agricultural areas with at least 3 survey visits.

III.   Results

A.   Temporal changes in availability of habitat types and vegetation heights

Stubble, tilled fields and sown fields decreased significantly over time while cereal fields significantly increased (table 1). The three first weeks of May, the study area was a mix of stubble, tilled, sown and cereal fields. From the fourth week of May, cereal fields dominated the landscape, their proportion above 60% (Fig. 1). Sown and tilled fields tended to disappear, their proportions constantly decreasing towards the end of the study period (Fig. 1). Stubble fields also tended to disappear towards the end of May (Fig. 1). Grass fields showed no significant trend through the study period, as expected (table 1).
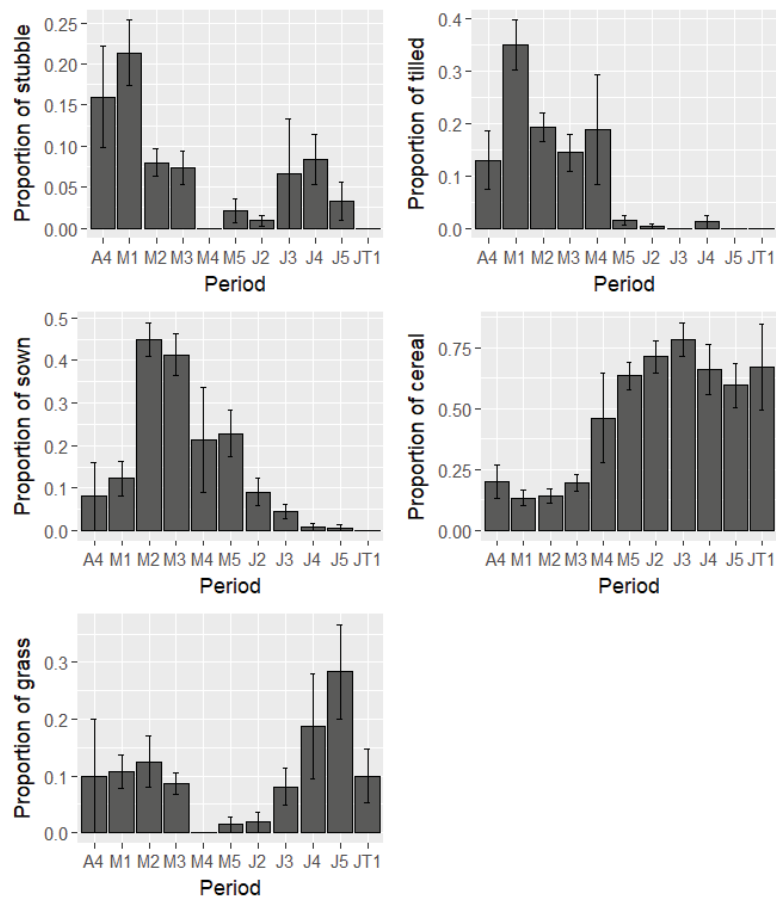
Figure 1: Changes in habitat availability in relation to time of breeding season.

A4: 17/04 to 21/04; M1: 01/05 to 05/05; M2: 08/05 to 14/05; M3: 15/05 to 19/05; M4: 22/05 to 26/05; M5: 29/05 to 02/06; J2: 05/06 to 09/06; J3: 12/06 to 16/06; J4: 19/06 to 23/06; J5: 26/06 to 30/06; JT1: 03/07 to 07/07.

Table 1: Results of the Spearman's rank correlation tests between week of breeding season and the proportion of each habitat available

	Rho	N	P-value
Stubble	-0.47	162	<0.001
Tilled	-0.70	156	<0.001
Sown	-0.32	159	<0.001
Cereal	0.60	158	<0.001
Grass	0.07	159	0.392

Very low vegetation heights (0-5 cm) significantly decreased over time, while vegetation heights above 20 cm significantly increased through the study period (Table 2). Vegetation heights between 5 and 20 cm showed no clear trend (Table 2). The four first weeks, low vegetation height dominated the landscape with 60 to 80% of the fields having a vegetation

height lower or equal to 5cm (Fig. 2). All the fields during that period had a vegetation height lower or equal to 30 cm (Fig. 2). After the fourth week of May, the very low vegetation heights constantly decreased. After the third week of June, at least 8% of the fields reached 40cm (Fig. 2).
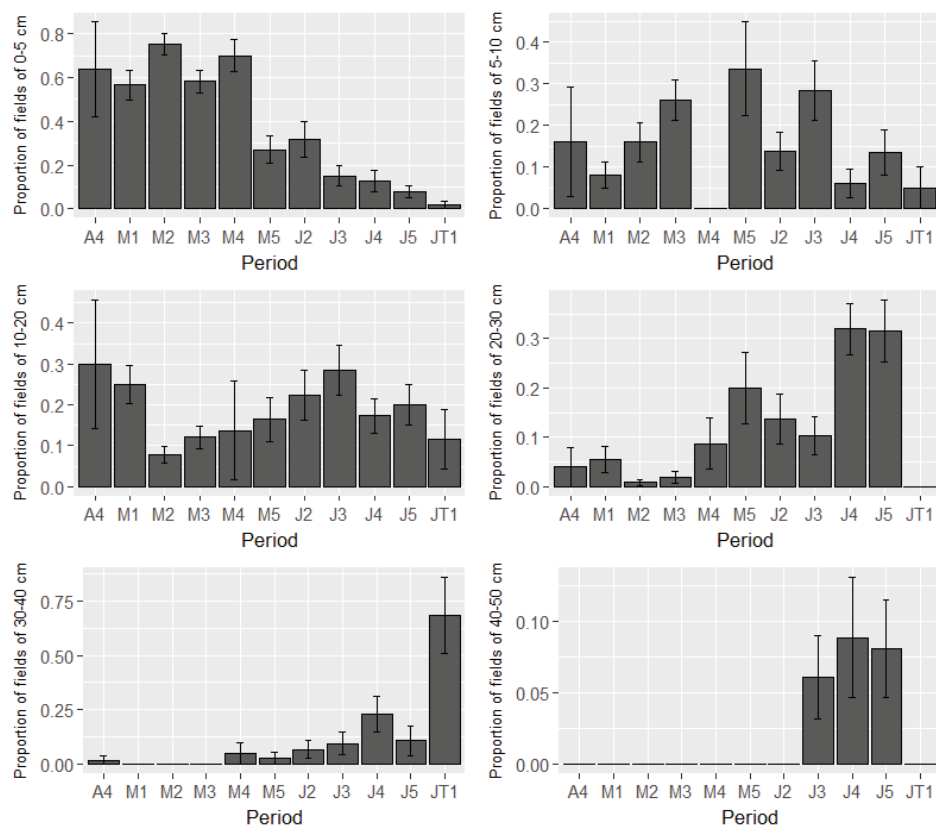

Figure 2: Changes in availability of vegetation heights in relation to time of breeding season.

A4: *17/04 to 21/04;* ***M1***: *01/05 to 05/05;* ***M2***: *08/05 to 14/05;* ***M3***: *15/05 to 19/05;* ***M4***: *22/05 to 26/05;* ***M5***: *29/05 to 02/06;* ***J2***: *05/06 to 09/06;* ***J3***: *12/06 to 16/06;* ***J4***: *19/06 to 23/06;* ***J5***: *26/06 to 30/06;* ***JT1***: *03/07 to 07/07. Vegetation height was recorded for both cereal fields, stubble and grass.*

Table 2: Results of the Spearman's rank correlation tests between the week of breeding season and the proportion of each vegetation height available.

	Rho	N	P-value
0-5 cm	-0.54	159	<0.001
5-10 cm	0.10	155	0.202
10-20 cm	0.008	155	0.922
20-30 cm	0.49	154	<0.001
30-40 cm	0.46	157	<0.001
40-50 cm	0.41	157	<0.001

B. Habitat selection

When considering habitats within 300 meters around the bird, tilled fields seem to be chosen less often than expected, and stubble more often than expected (Fig. 3a). Specifically, curlews chose tilled fields 2 times, while they were expected to choose this habitat 5 times. Stubble was chosen 15 times, while only expected to be chosen 10 times. However, these differences were not significant (Table 3). For the other habitats, the observed habitat uses did not differ significantly from the expected habitat uses (Table 3). When using presence/absence data instead of proportions for the expected habitat use, the tendency to avoid tilled fields was confirmed (Table 4), but the tendency to prefer stubble was not. Fields with vegetation height between 10 and 20 cm were chosen significantly more often than expected (Fig. 3c; Table 3). Curlews chose this vegetation height 18 times when it was expected that they would only chose this vegetation height 12 times by chance. Fields with a vegetation height between 0 and 10 cm seems to be randomly chosen, as their observed distribution is close to the expected one (Fig. 3c). Vegetation heights above 20 cm had too small sample sizes and were excluded from analyses

When accounting for the habitats within the whole site, Curlews seem to avoid tilled fields (Fig. 3b). However, it did not differ significantly neither with proportions nor with presence/absence (Table 3, Table 4). Stubble was selected significantly more often than expected, with Curlews selecting this habitat 12 times against the 5 times expected (Fig. 3b, Table 3). Cereal, grass and sown fields seemed to be randomly chosen, as their expected distribution almost equaled the observed one (Fig. 3b). Curlews selected for vegetation heights between 10 and 20 cm (Fig. 3d, Table 2). This vegetation height was selected 14 times but was expected to be selected only 7 times. Vegetation heights between 0 and 10 cm were randomly selected (Fig. 3d). Curlews seemed to avoid vegetation heights between 20 and 30 cm (Fig. 3d). Indeed, the chi-square test showed a significant difference between observed and expected distribution, but since the expected value was under 5, this result is not reliable and does not appear in Table 2.
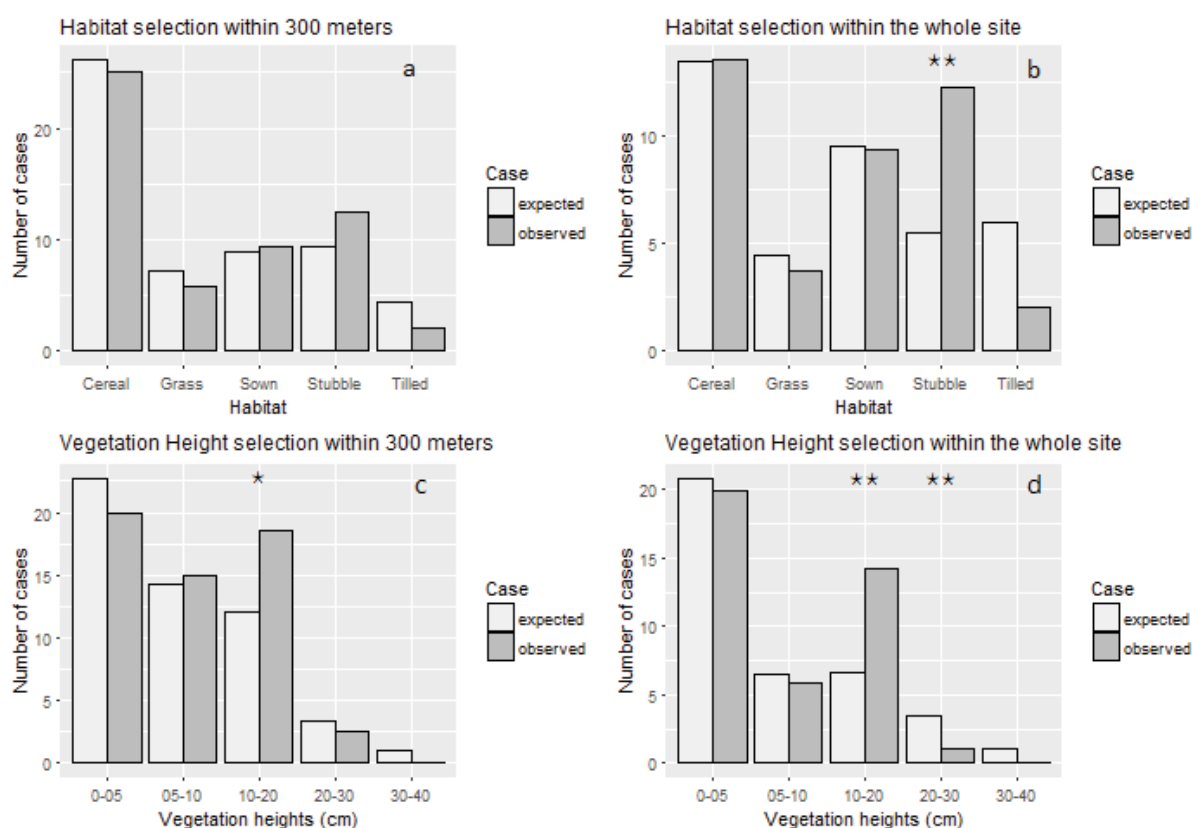

Figure 3: Number of times curlews were recorded in a habitat/vegetation height versus expected numbers calculated from the proportional availability of habitats within 300 m from birds (a and c) or within the whole site (b and d).

Table 3: Results of the chi-square tests for habitat selection. Observed and expected values were based on proportions.

Within 300m	χ^2	p-value	Within the whole site	χ^2	p-value
Stubble	1.22	0.27	**Stubble**	**8.96**	**0.0028**
Tilled	1.05	0.31	**Tilled**	2.73	0.10
Sown	0.00	1.00	**Sown**	0.00	1.00
Cereal	0.04	0.84	**Cereal**	0.00	1.00
Grass	0.16	0.69	**Grass**	0.01	0.92
0-5 cm	0.51	0.48	**0-5 cm**	0.02	0.89
5-10 cm	0.00	1.00	**5-10 cm**	0.00	1.00
10-20 cm	**4.68**	**0.03**	**10-20 cm**	**9.88**	**0.0071**

Table 4: Results of the chi-square tests for habitat selection. Observed and expected values were based on presence/absence.

Within 300 m	χ^2	p-value	Within the whole site	χ^2	p-value
Stubble	2.89	0.09	**Stubble**	**4.26**	**0.039**
Tilled	**4.06**	**0.04**	**Tilled**	2.71	0.10
Sown	0.29	0.59	**Sown**	1.66	0.20
Cereal	1.76	0.19	**Cereal**	3.42	0.06
Grass	1.35	0.25	**Grass**	2.97	0.08
0-5 cm	0.3	0.59	**0-5 cm**	1.98	0.16
5-10 cm	3.2	0.07	**5-10 cm**	0.58	0.45
10-20 cm	2.63	0.11	**10-20 cm**	0.27	0.60

C.   Population size

During the fieldwork, 25 to 27 pairs were recorded (Fig. 4 & 5). To this number, we added one pair that was recorded on Midtfjellmosen (Aurskog-Høland) in 2014, but this site was not visited in 2017, plus two pairs breeding in Nordre Øyeren (information given by Nordre

Øyeren bird station). Thus, the population size in Akershus in 2017 was estimated to 28-30 pairs.
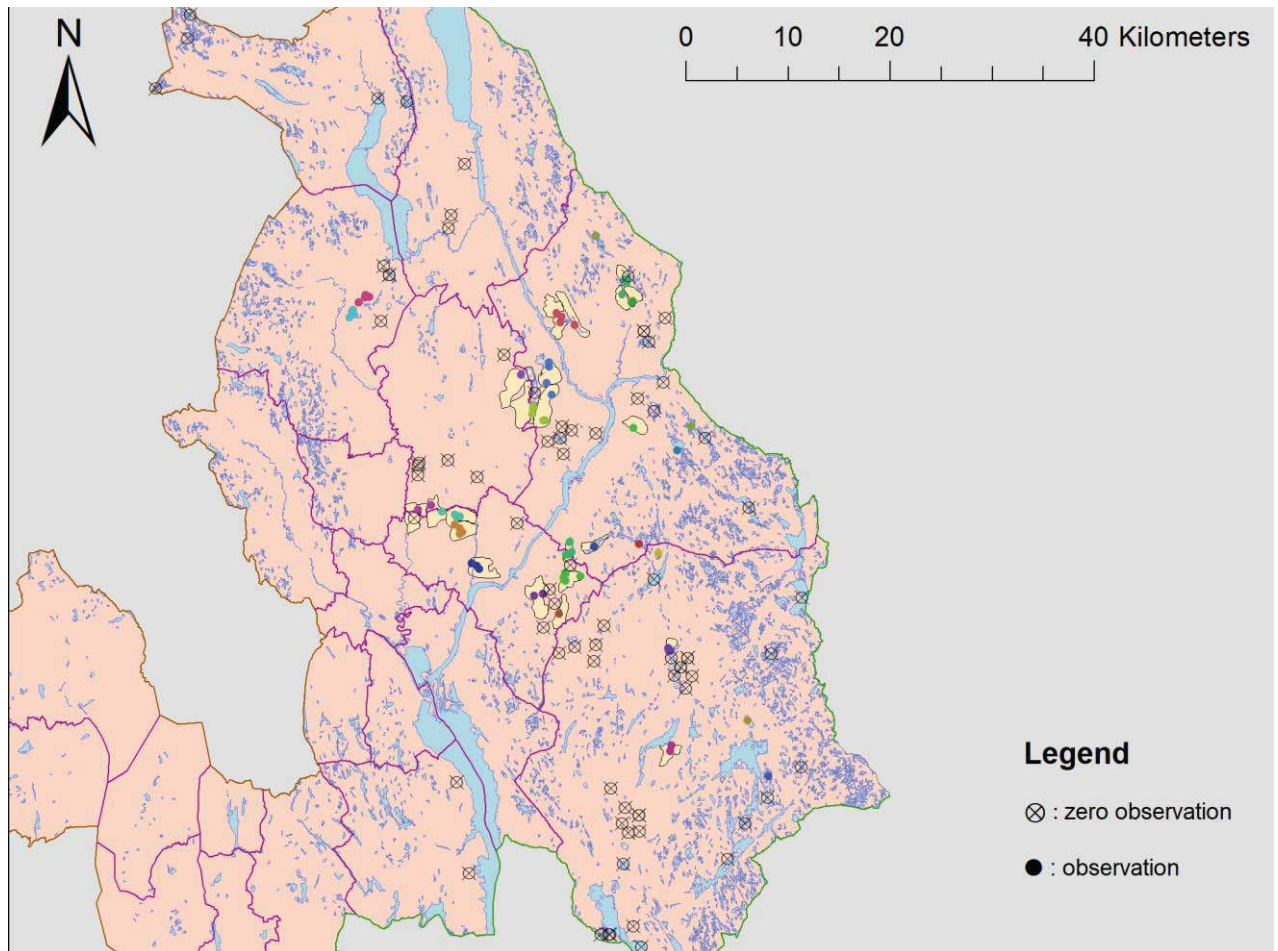

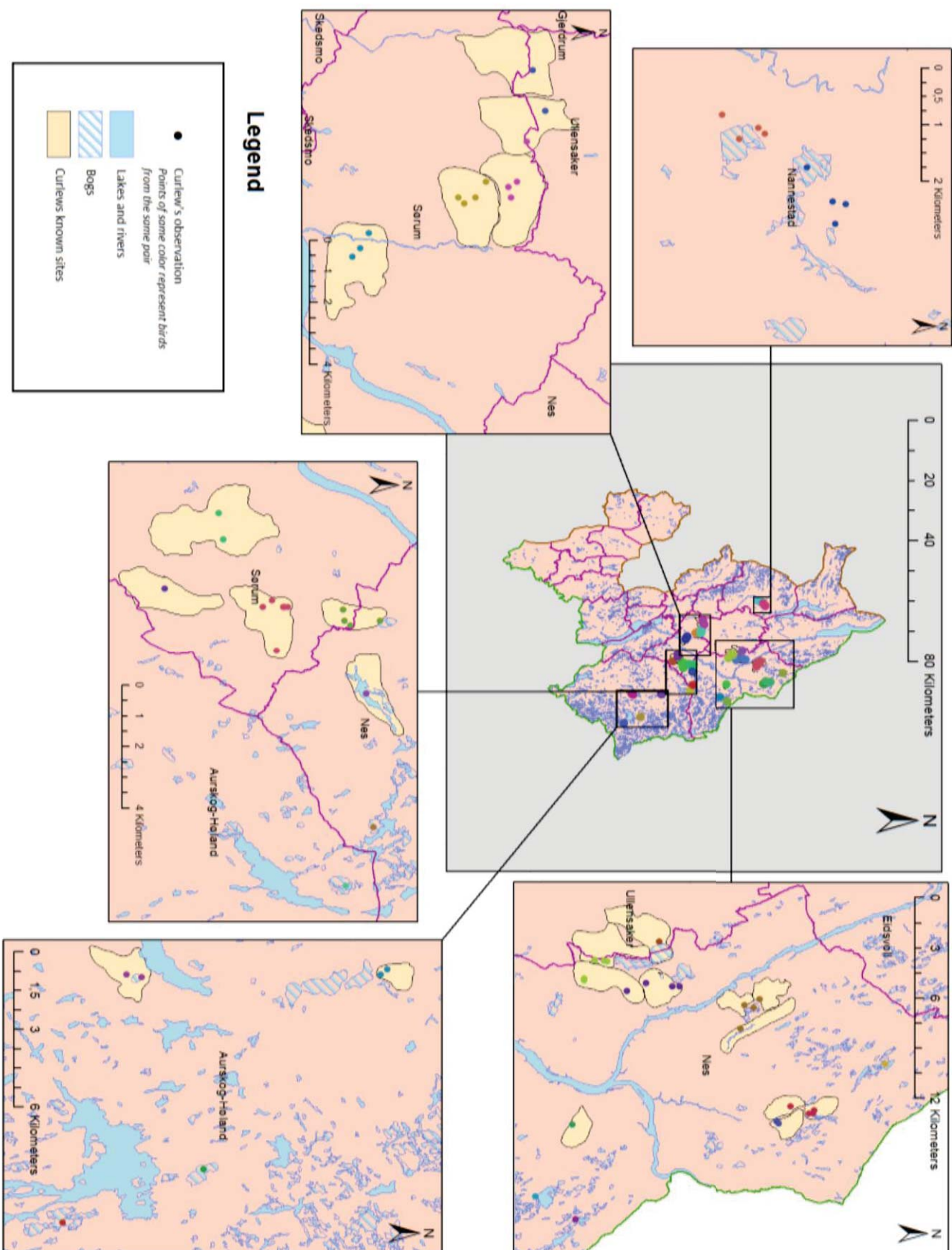*Figure 4: Map of Curlews observations and zero observations in 2017*

Figure 5: Distribution map of Curlews in Akershus in 2017

D. Population trend

When some small sites were merged together (70 sites in total), the number of territories dropped by 40% in 23 years (Fig.6.a) The total number of territories went from around 50 in 1995 (95% CI [46,63]), to 30 in 2017 (95% CI [25,39]), showing a significant decrease of 1.7% every year (±1%) (Wald test for significance of slope parameter: Wald = 8.57, df = 1, p < 0.01). This model was validated by a Chi² test for goodness of fit (p = 1.00, χ^2 = 277.25, df = 431).

When using all sites (109), the number of territories dropped by almost 50% in 23 years (Fig.6.b). The total number of territories declined from 88 in 1995 (95% CI [70,100) to 45 in 2017 (95% CI [38,50], showing a significant decrease of 2.2% every year (±1%) (Wald test for significance of slope parameter: Wald = 9.15, df = 1, p < 0.01). This was validated by a Chi² test for goodness of fit (p = 1.00, χ^2 = 337.97, df = 492).

When using merged sites (70), the number of territories dropped by 50% in 47 years (Fig.6.c) The total number of territories declined from around 120 in the period 1971-1974 (95% CI [100,140]) to 60 in the period 2015-2017 (95% CI [50,70]), showing a significant decrease of 1.1% every year (±2.4%) (Wald test for significance of slope parameter: Wald = 4.75, df = 1.00, p = 0.03). This model was validated by a Chi² test for goodness of fit (p= 0.08, χ^2 = 254.21, df = 222).

When using all sites (109), the number of territories dropped by almost 70% in 47 years (Fig.6.d). The total number of territories went from 190 in the period 1971-1974 (95% CI [150,225]) to 60 in the period 2015-2017 (95% CI [50,65]), showing a significant decrease of 1.45% every year (±2.5%) (Wald test for significance of slope parameter: Wald = 13.89, df = 1, p < 0.001). This model was validated by a Chi² test for goodness of fit (p = 0.41, χ^2 = 274.42, df = 270).

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The number of territories tended to decrease less in the lowlands than in forested areas. In the lowlands, the number of territories decreased by 28% (±12%) in 23 years, while in forested areas it decreased by 67% (±17%) (Fig.7.a). However, this habitat covariate was not significant (Wald test for significance of covariates: W = 3.08, df = 1.00, p = 0.079). In the lowlands, there was a non-significant trend for curlews to decline less on sites within 5km from a bog (Fig.7.b)
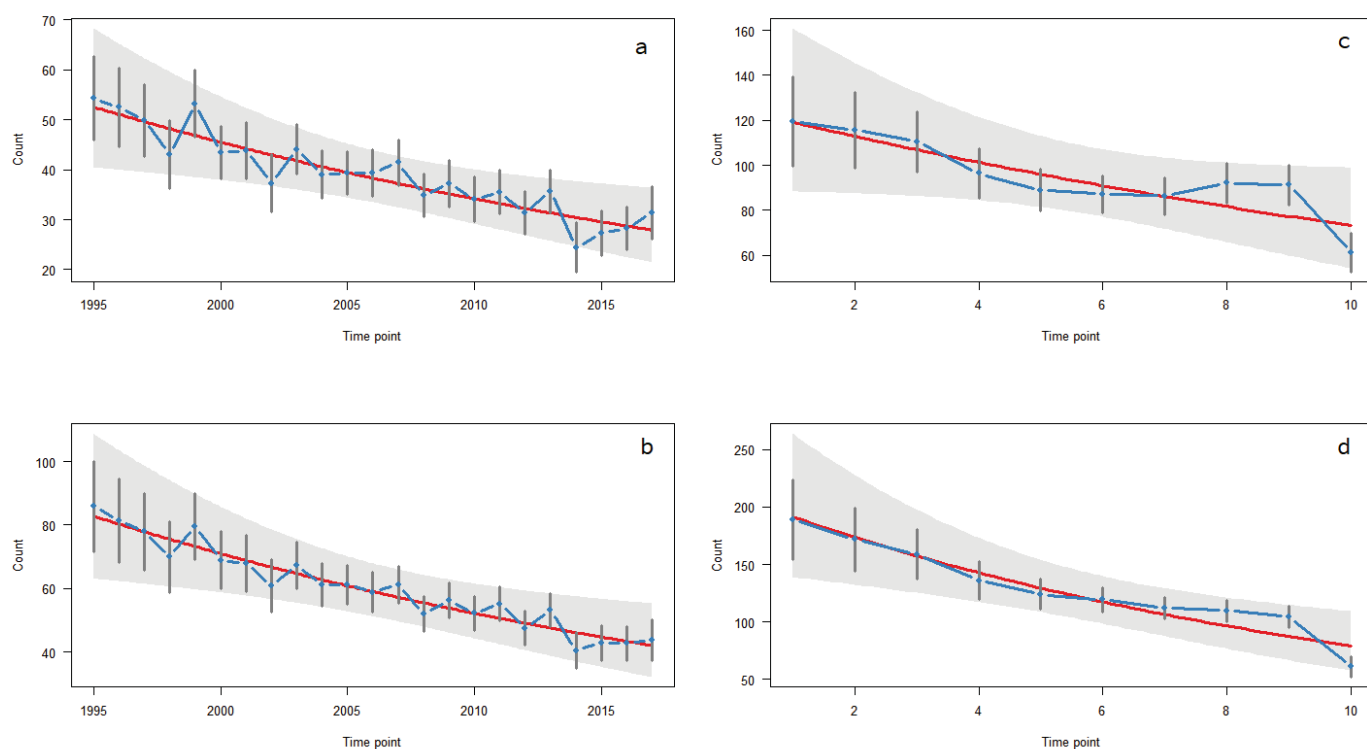

Figure 4: Number of territories of curlews from 1995 to 2017 (a and b) and from 1971 to 2017 (c and d) with 95% CI. In the graphics c and d, time points are expressed as periods. Period 1: 1971-1975; Period 2: 1975-1980; Period 3: 1980-1985; Period 4: 1985-1990; Period 5: 1990-1995; Period 6: 1995-2000; Period 7: 2000-2005; Period 8: 2005-2010; Period 9: 2010-2015; Period 10: 2015-2017. The graphics a. and c. have been made using 70 different sites, while graphics b. and d. have been made using 109 sites. The red line is the overall slope
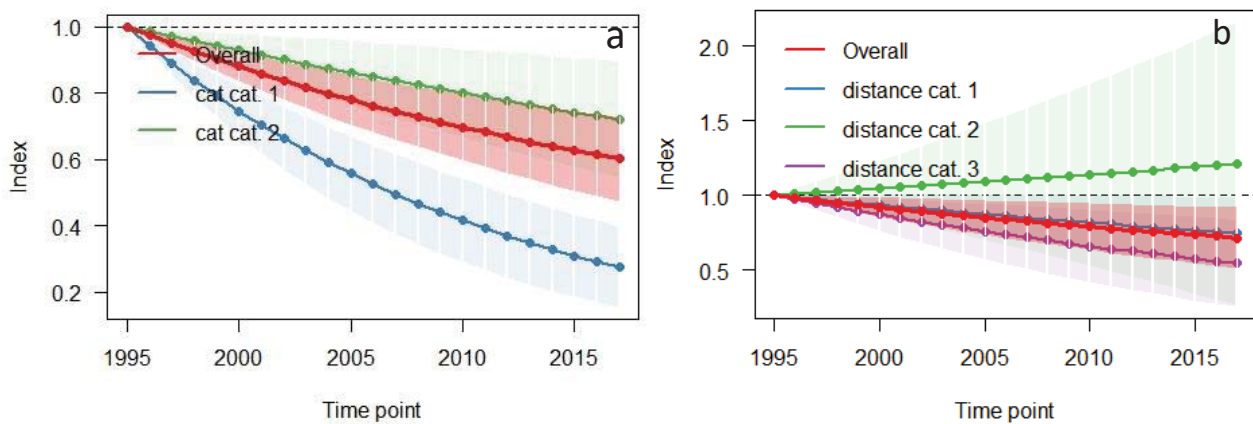
Figure 5: a) Population trend of curlews from 1995 to 2017 overall, in agricultural areas (cat. 2) and in forested areas (cat. 1). b) Population trend of curlews in agricultural areas in sites on bogs (cat. 1), within 5 km of a bog (cat. 2) and farther than 5 km from a bog (cat. 3). The light blue area shows the standard errors.

IV. Discussion

A. Habitat preferences

In May, stubble, tilled fields and sown fields made up about 70% of the agricultural landscape in Akershus. Later in the season, those habitat types got gradually replaced by swards of grass or cereals, dividing our study in two main periods. The first period of fieldwork contributed to get data on habitat selection, while the second period contributed to get data on vegetation heights selection.

The hypothesis that curlews prefer medium sward heights (10-20 cm) was verified. The preference for medium vegetation heights was also confirmed by many studies (Berg, 1992a; Berg, 1992b; Berg, 1994; Durant et al., 2008; Valkama et al., 1998). We saw a trend for curlews to avoid high sward heights (higher than 20cm), that could not be confirmed due to the very low number of observations on fields with high vegetations. It is possible that a bias exists there, as birds foraging in high vegetation are difficult to detect. However, other studies showed that

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waders and other birds foraging on soil invertebrates avoid tall swards during summer because they have a lower food accessibility and a higher predation risk as birds lose the ability to detect predators (Atkinson et al., 2004; Bell & Calladine, 2017). Bare fields (tilled and sown) and very low swards (<5cm) were grouped together in my analysis. Curlews might avoid tilled fields, but not necessarily very low vegetation heights. Thus, grouping those together might have hidden a possible preference for very low vegetation heights. However, if curlews preferred low to medium vegetation heights, swards between 5 and 10 cm would have been selected, which did not happen.

Even though curlews tended to avoid tilled fields, the trend was not significant when using percentage of each habitat because we had too few observations with significant proportions of tilled fields within the site. Indeed, the start of our fieldwork in early May corresponded with the time of sowing for many sites. Several studies also found that curlews avoid tilled fields because they do not provide a good foraging habitat nor a good nesting site (exposure to predators and to destruction of nests by farming practices) (Berg, 1992b; Berg, 1993; Valkama et al., 1998). In our study, all tilled fields were dry, which even increase the unsuitability of this habitat for curlews (Berg, 1993). However, when using presence/absence instead of proportions to compare observed and expected habitat use, the trend to avoid tilled fields became significant near the birds (300m). Curlews selected for stubble, which indicates that it might be a better foraging habitat than tilled fields. Since tilled fields and stubble were both present at the beginning of the season, stubble was the main alternative to tilled fields. Thus, curlews might have selected preferentially stubble only to avoid tilled fields. However, this alternative represented only about 10% of the total landscape during the 5 first weeks of the fieldwork, while tilled fields represented 20% of the landscape at the same period. In that case, a possible management solution to preserve curlews would be to reduce tillage by turning to direct drilling of spring crops. No till farming increased worldwide from 45 million ha in

1999 to 111 million ha in 2009, and suits any type of crop in any type of soil (Derpsch et al., 2010). In south-east Norway most farmers plough their fields in autumn, because they believe it is the best way to control weed and produce a high and stable yield (Lundekvam et al., 2003). By reducing tillage practices, farmers can reduce soil erosion, avoid destroying nests and preserve soil biodiversity which would provide a better foraging habitat for curlews.

To use presence/absence might be more advised when considering the habitats present near the birds. In that case, the percentage of each habitat matters less than when using a larger scale. In addition, we found that curlews selected for stubble when considering the habitats within the whole site, but not when considering only the habitats within 300 m around the birds. The selection for medium vegetation heights was significant when using proportions of each habitat, but not when using presence/absence, while the selection for stubble was significant in both cases. This could mean that using presence/absence makes more sense when considering habitat types than sward heights. Indeed, medium and high swards benefits curlews by, among other things, providing a shelter from predators (Berg, 1992a). However, this protection is limited if the high sward is present in very low proportions.

B.   Population size and trend

28 to 30 pairs of curlews bred in Akershus in 2017. The population trend analysis showed a 40% decline since 1995 when considering 70 sites instead of 109. This result is probably the most accurate one. Indeed, when using the initial number of sites (109), the TRIM software evaluated that 45 pairs of curlews were present in Akershus in 2017. When we manually defined this number by using the distribution map and the 1km rule described in the methods, we ended up with 28 to 30 pairs, which corresponds to what the TRIM software evaluated when using 70 sites. Thus, the 109 sites were not accurate, and we avoided double

counting by merging some of those sites. With 70 sites, the analysis showed a decrease of 50% in 47 years. However, the limited amounts of data before 1995 makes this result less reliable than the result from 1995 to 2017.

Breeding curlews showed a similar decline nationally, with 43% reduction of the population in the last 17 years (Kålås et al., 2014). The population might have halved since 1981, going from 5000 to 2500 pairs in Norway (Shimmings & Øien, 2015). In Europe, curlews declined by 45% in the past 32 years and by 13% in the past 10 years (EBCC, 2014). Thus, it seems that curlews in Akershus decline in a similar way to the rest of Norway and more widely, the rest of Europe. In Norway, agriculture intensifies since 1950, probably leading curlews to decline. In southeastern Norway, the grain production increased by 50% between 1950 and 1975, resulting in a similar decline of grass production, and farmers turned to silage instead of hay (Lundekvam et al., 2003). Lundekvam (2003) and his colleagues also explain that since 1975 the number of farms decreased, and the size of each farm increased to enhance productivity. Berg (1994) showed that grasslands were particularly important for curlews, and that they thrive best in mixed farmlands, making those changes in the Norwegian agriculture highly negative for curlews. In addition to threats on their breeding sites, curlews also face many threats on their wintering lands and during their migration. The main activities that negatively impact non-breeding curlews are aquaculture, transport (e.g. collision with vehicles), fishing and human disturbances (Pearce-Higgins et al., 2017). More precisely, shellfisheries, sea level rise, oil and gas drilling can all disturb wintering curlews in Europe and Africa (Brown et al., 2014).

Since nest destruction by farming practices is one of the main causes of curlew's decline (Berg, 1992a; Valkama & Currie, 1999), postponing grass or crop harvesting represents a good management measure. In France, postponing grass harvesting to either 1 or 15 July increased significantly the number of breeding curlews over the years (Broyer et al., 2014). In addition,

a phenological mismatch exists between the nesting time of curlews and the sowing time of farmers, which exposes nests to destruction (Santangeli et al., 2018). Because of climate change, curlews nest earlier, but the time at which farmers sow their fields did not change as fast, and curlews end up nesting on unsown fields more and more. During our fieldwork, a nest was spotted in a stubble field, but on the second visit to this site, the field had been tilled and sown and the nest was gone, most likely destroyed. Thus, another management measure could be to start sowing fields earlier to avoid nest destruction. The other main cause of decline of curlews is predation of nests and young (Berg, 1992a; Douglas et al., 2014; Grant et al., 1999; Valkama & Currie, 1999). Thus, a third management measure could be to implement or increase predator control. This management measure has been successful before in the UK by controlling predators through the presence of gamekeepers (Douglas et al., 2014; Fletcher et al., 2010). Another strategy to prevent further decline of the curlews in Akershus is to involve farmers in the conservation of the species by informing them about the species and by teaching them how to recognize and protect them. In the county of Møre og Romsdal, western Norway, such measures have been implemented to protect curlews and lapwings (Bondelaget, 2018). In that county, farmers have the ability to spot nests on their fields, and will be informed of the observations made by the public.

In addition to farming practices and predators, another threat for curlews in Akershus is the destruction of bogs.

C.   Importance of bogs

Curlews nesting on bogs in forested areas tended to decline more than curlews nesting in agricultural areas. Waders living on bogs in the south of Scandinavia undergo a higher predation pressure than waders living on bogs in the north of Scandinavia (Berg et al., 1992).

The harsh living conditions in the north does not allow many generalist predators to survive, creating a lower predation pressure for birds nesting on bogs in the north than in the south. Similarly, predation pressure could be higher on bogs in forested areas than in farmlands, but this has not been experimented yet. In addition, farmland areas also include bogs which makes them more diverse than forested areas and thus more suitable for the survival of curlews. However, there is no documented evidence of this, and the trend we found for curlews to do better in agricultural areas being non-significant, we cannot confirm it. Moreover, most sites on forested areas were visited only once in 2017, which increases the uncertainty of this trend.

Within agricultural areas, a non-significant trend existed for pairs within 5km of a bog to have a smaller population decline than pairs further away from a bog. Bogs represent an important habitat for curlews, where their reproductive success is higher than on arable lands (Berg, 1992a; Berg, 1994; Johnstone et al., 2017). Curlews do better on bogs because this habitat provide a damp terrain with standing water, where invertebrate are abundant and accessible (Henderson et al., 2002). However, several bogs in Akershus are being harvested or have been harvested to extract peat. Harvested bogs most likely do not suit curlews needs, as they lack the vegetation and wetness composing a natural bog. In our study area, out of 15 bog sites within farmlands, 6 were totally or partially harvested. In other words, at least 40% of bogs area in the lowlands were spoiled.

V.   Conclusion

Curlews in Akershus declined by 40% in 23 years, similarly to the rest of Norway and Europe. 28 to 30 pairs were recorded in the region in 2017. They selected for medium vegetation heights and for stubble which was the main alternative to stubble in the beginning of the season. The selection for stubble and the trend to avoid tilled fields brings some evidences that tillage is not ideal for curlews. Curlews face threats both on their breeding grounds and their wintering grounds in Europe and Africa. Agricultural intensification causes most of the threats that breeding curlews face, such as increased predation pressure, habitat degradation and nest destruction that all negatively impact their breeding success. Their decline could be reversed by educating and involving farmers, by adapting timing of farming practices to the life cycle of curlews, and by controlling predators when predator pressure is too high. In addition, curlews in Akershus breeding in the lowlands face the destruction of bogs, which represents an important breeding habitat for the species. Thus, restoring harvested bogs in Akershus and stopping harvesting more would benefits breeding curlews in the region. More studies could be done to compare the breeding success of curlews in lowlands and in uplands, and to try to identify the causes of poor breeding success in Akershus.

VI.   References

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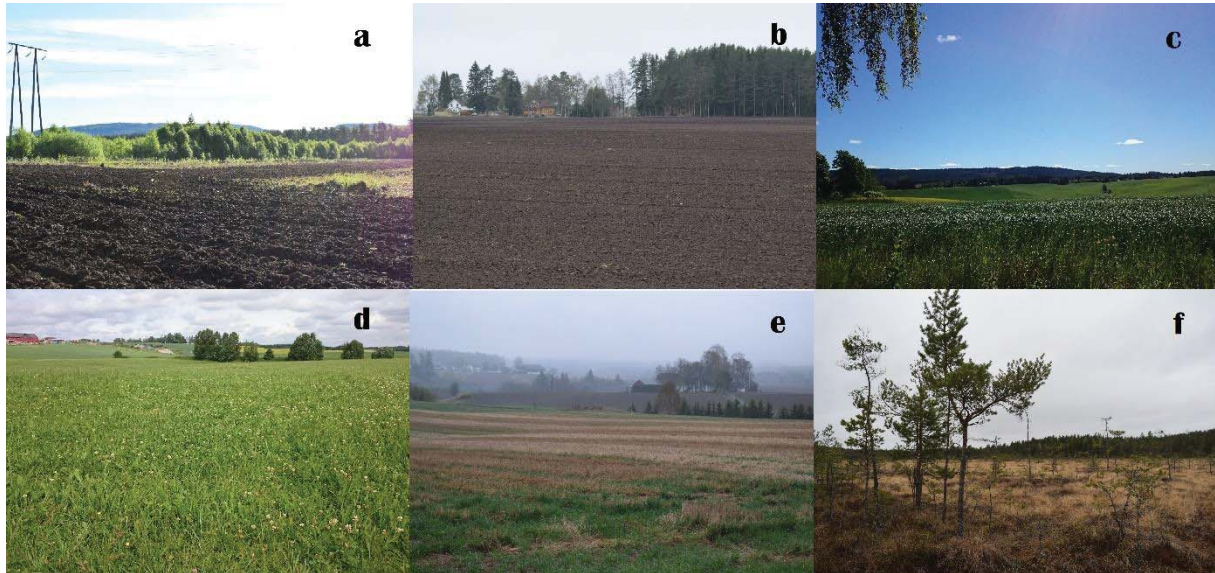
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VII. Appendix

A. A1.

The five main habitat types found during fieldwork. a) tilled field; b) sown field; c) cereal field; d) grass; e) stubble; f) natural bog