Individually characteristic corncrake *Crex crex* song reveals long-distance movements within the breeding season

Individuelt karakteristisk sang av åkerrikse *Crex crex* avdekker langdistanse-forflytninger innen hekkesesongen

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Syngende åkerrikse like ved et område som ble satt av for åkerrikse på Stange, Karmøy, Rogaland. Bildet ble tatt av undertegnede 16. juli 2009.

Forord

Denne masteroppgaven i naturforvaltning er gjennomført ved Universitetet for miljø- og biovitenskap i perioden april 2009 til november 2010 etter forespørsel fra Fylkesmannen i Rogaland, som har forvaltningsansvaret for den rødlistede åkerriksa i Norge. Feltarbeidet ble utført fra ultimo mai til medio juli 2009; der jeg for det meste holdt til i Rogaland, mens min veileder, Svein Dale, og min medstudent, Thorstein Holtskog, for det meste samlet inn data i Akershus og Hedmark. Oppgaven er da også skrevet på vi-form siden den kun er gjort mulig gjennom dette samarbeidet. En stor takk til både Svein og Thorstein, både når det gjelder feltarbeidet og prosessen etterpå; for henholdsvis god og tålmodig veiledning, og tålmodig utveksling av data.

Denne masteroppgaven belyser nye sider ved åkerriksenes populasjonsøkologi i Norge, noe som forhåpentligvis vil komme forvaltningen til nytte. Arbeidet med masteroppgaven har gitt meg økt teoretisk kunnskap i biologi og statistikk, praktisk erfaring i hvordan man samler inn data i felt, samt kunnskap om hvordan et skriftlig, vitenskapelig arbeid blir til. Det har vært en positiv opplevelse, og det har vært rørende å se hvordan både bønder, fuglefolk og andre har latt seg engasjere i feltarbeidet vårt. Dette viser at selv om åkerriksa har vært en sjelden fugl i Norge lenge nå, så er den fortsatt en kjent og kjær fugl blant mange mennesker.

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Abstract

Due to modern agricultural practices, the corncrake is a species of global conservation concern. Mowing of meadows may cause corncrakes to make movements within one breeding season, but such movements are in general poorly understood. Previous studies have shown that corncrake calls are individually characteristic, and also that variation in individual song characteristics on a large geographic scale (>100 km) may occur. Song recordings were therefore used to identify both corncrake movements and possible differences between the corncrake populations of E and SW Norway. Observations of singing corncrakes were used to investigate corncrakes' disappearances from territories: 54 % of corncrakes (n = 80) were found to leave their territories probably or certainly due to mowing. In addition to song recording, telemetry and ringing were also, although to a lesser extent, used to document movements. A total of 32 movements (median = 129 km, range = 0.3 – 404 km) longer than 300 m were found, including 28 movements found by discriminant analyses of individual song characteristics (probability ≥ 0.85), and three movements found by telemetry. A total of 21 individuals were found to make the 32 movements, which included 22 long-distance movements longer than 17 km - all found by individual song characteristics, and 18 movements longer than 100 km. A total of six individuals were found to make more than one movement. A total of 18 movements, including ten long-distance movements, had a probability ≥ 0.95. Individual song characteristics showed no evidence for the two Norwegian corncrake populations to be different; and 13 movements between E and SW Norway also implies that the populations are functionally connected, even though they are about 300 km apart. Presumably 60 different corncrakes were recorded, but due to movements the actual number of corncrakes being recorded was found to be 36; we therefore suggest that the 2009 Norwegian corncrake population was strongly overestimated. To avoid such overestimation we suggest that future population estimates should be based on observations done prior to 16 June, where observations which are less than one km from each other and potentially the same individual, only should be used once in estimates. Using these restrictions, the 2009 Norwegian corncrake population estimate would have been about 123 individuals, which is 39 % lower than the official population estimate of 200 individuals. Our results show that recording of corncrake song might be an effective method to study corncrake movements; the method has shown that movements by Norwegian corncrakes seem to be a common phenomenon.

Sammendrag

På grunn av moderne landbruksmetoder er åkerriksa en art som krever et globalt bevaringshensyn. Slått av enger kan medføre at åkerrikser gjør forflytninger innen én hekkesesong, men slike forflytninger er generelt dårlig forstått. Foregående undersøkelser har vist at åkerriksesang er individuelt karakteristisk, og at variasjonen i individuelle sangkarakteristikker kan forekomme på stor geografisk skala (>100 km). Sangopptak ble derfor brukt til både å identifisere åkerrikseforflytninger, samt å finne eventuelle forskjeller mellom åkerriksepopulasjonene i Øst-Norge og Sørvest-Norge. Observasjoner av åkerriksesang ble brukt til å undersøke åkerriksenes forsvinninger fra territorier: 54 % av åkerriksene (n = 80) forlot sine territorier helt sikkert eller sannsynligvis på grunn av slått. I tillegg til sangopptak, ble telemetri og ringmerking, om enn i mindre grad, også brukt til å dokumentere forflytninger. Totalt 32 forflytninger (median = 129 km, variasjonsbredde = 0,3 – 404 km) lengre enn 300 m ble funnet, inklusiv 28 forflytninger funnet ved hjelp av diskriminante analyser av individuelle sangkarakteristikker (sannsynlighet ≥ 0.85), og tre forflytninger funnet ved hjelp av telemetri. Totalt 21 individer ble funnet å ha gjort de 32 forflytningene, som inkluderte 22 langdistanseforflytninger lengre enn 17 km - alle ble funnet ved bruk av individuelle sangkarakteristikker, og 18 forflytninger lengre enn 100 km. Totalt seks individer ble funnet å gjøre mer enn én forflytning. Totalt 18 forflytninger, inkludert ti langdistanseforflytninger, hadde sannsynlighet ≥ 0,95. Individuelle sangkarakteristikker viste ingen tegn til at de to norske åkerriksepopulasjonene er forskjellige. Funn av 13 forflytninger mellom Øst-Norge og Sørvest-Norge viser også at populasjonene er funksjonelt tilknyttet hverandre, selv om de er omtrent 300 km fra hverandre. Antall antatt ulike åkerrikser som det ble gjort opptak av var 60, men på grunn av forflytninger så ble det faktiske antallet anslått til 36. Vi foreslår derfor at den norske åkerriksepopulasjonen i 2009 var sterkt overestimert. For å unngå slik overestimering, foreslår vi at fremtidige populasjonsestimater baseres på observasjoner gjort før 16. juni, der observasjoner som er mindre enn én km fra hverandre og potensielt av samme individ, bare blir brukt én gang i estimatet. Ved å bruke disse restriksjonene ville estimatet av den norske åkerriksepopulasjonen i 2009 ha vært omtrent 123 individer, noe som er 39 % lavere enn det offisielle populasjonsestimatet på 200 individer. Våre resultater viser at opptak av åkerriksesang kan være en effektiv metode for å studere åkerrikseforflytninger; metoden har vist at forflytninger blant norske åkerrikser synes å være et vanlig fenomen.

Introduction

The corncrake is a species of global conservation concern, and it is listed as Near Threatened with a decreasing population trend on The IUCN Red List of Threatened Species (IUCN 2010). Meadows mown for silage or hay are the most common breeding habitats of the species (Green and Stowe 1993; Green et al. 1997b), but due to mechanization of agriculture, earlier mowing dates, and habitat loss, the species has been declining since around 1900, particularly in northern and western Europe (Green et al. 1997a). The corncrake population in Norway has been decreasing since the end of the 19^{th} century (Collett 1921), and the corncrake is listed as Critically Endangered on the 2006 Norwegian Red List (Kålås et al. 2006). In the mid 1990s, the number of singing corncrake males in Norway was estimated to about 50-75 (Folvik and Øien 1997); however, this number increased until 2003, when 231 singing males were reported (Folvik 2004). Due to a strong increase in corncrake observations in E Norway from the late 1990s (Eie 2005), Norway has now two main corncrake subpopulations; one in SW Norway and one in E Norway. An increase in the number of corncrake observations has also been reported from many other western European countries from the late 1990s and until the beginning of the 2000s (Birdlife International 2004; Koffijberg and Schäffer 2005 cited in Norwegian Directorate for Nature Management (hereafter referred to as DN) 2008). This increase is suggested to be due to high population densities in the species' central range, i.e. Eastern Europe and Russia (Koffijberg and Schäffer 2005 cited in DN 2008).

Corncrake movements within one breeding season are important to understand; both to make more realistic population estimates, and also to know what happens to corncrakes which disappear from their territories due to for instance mowing. However, such movements are in general poorly understood, although it is known that corncrakes may leave their territories due to mowing, heavy rains or floods (Schäffer and Koffijberg 2006). There is some evidence of long-distance movements within one breeding season, and it might also be a common phenomenon (Schäffer and Koffijberg 2006). A study of radio-tagged males in Poland showed that 85% of corncrakes moved away from original breeding site after disturbance by mowing, of which 70% were found to move more than 100 km (Hoffmann 1997 cited in Schäffer 1999). Movements during the breeding season are thought to be a common phenomenon in Norway due to for instance mowing (DN 2008). However, only five movements longer than ten kilometres (maximum 132 km), have previously been found in Norway from ring recaptures (unpublished data from Norwegian Bird Ringing Central).

Movements, especially long-distance movements, within the breeding season may lead to overestimated population size, and may therefore be particularly important to understand in small bird populations, such as the Norwegian corncrake populations. Methods which earlier have revealed long-distance movements among corncrakes are ringing and telemetry. Since ringing and telemetry are both labour- and time-consuming methods, the ability of individual song characteristics to provide information about long-distance movements was investigated in this study. Individual song characteristics is a common phenomenon in birds (Catchpole and Slater 1995), and Peake et al. (1998) demonstrated a high level of individuality in corncrake song characters. Individual song characteristics have also been used to investigate within-seasonal movements in a small study area (Peake and McGregor 2001). However, individual song characteristics have not prior to this study been used to investigate long-distance movements in or between corncrake populations. Geographical variation in individual song characteristics on a large geographic scale (>100 km) have previously been found to some extent (Peake and McGregor 1999, Budka et al. unpublished data); and individual song characteristics were therefore also used to try to determine how different the corncrake populations of E and SW Norway are.

The main aims of this study were to find out whether movements among corncrakes within one breeding season is a common phenomenon in Norway, the reasons for such movements, and whether individual song characteristics is an effective method to find out more about these movements. Thus we studied: 1) spatial and temporal distribution of corncrakes in Norway; 2) duration of stay in original territories, and reasons for disappearances from territories; 3) whether long-distance movements could be revealed by individual song characteristics; and finally 4) distances and time of movements, and reasons for movements. By knowing more about corncrake movements in Norway, one will have a better chance of making realistic population estimates, as well as knowing more about how separate the eastern and the south-western Norwegian corncrake populations are. The understanding of such movements will also be important for making effective management plans for the Norwegian corncrake population.

Methods

Study area

This study was conducted from May to July 2009 in eastern and south-western Norway, in the counties of Akershus, Hedmark, Oslo, Rogaland, Telemark and Vest-Agder. The main investigations of corncrakes in eastern Norway were done in the northern part of Akershus (approximate location 60°10'N, 11°30'E) and in the southern part of Hedmark (approximate location 60°10'N, 12°00'E). Akershus and Hedmark are important agricultural areas, where grain production is dominating. The grain is ususally harvested from the end of August to September. Other corncrakes in eastern Norway were studied further south in Akershus, further north in Hedmark, and in Oslo and Telemark. The counties Akershus, Oslo and Hedmark are together referred to as eastern Norway (E Norway).

The main investigation of corncrakes in south-western Norway was done in Jæren (approximate location 58°45'N, 5°35'E), a 1070 km^2 lowland area at the coast of the southern part of Rogaland. Jæren is an important area for agricultural production, and consists mainly of pastures and meadows; there are few grain fields here compared to E Norway. Meadows are mainly mowed 3-4 times; from the end of May to September. Other corncrakes in west and south Norway were studied in the northern part of Rogaland and in Vest-Agder. In the following, SW Norway corresponds to Rogaland, and S Norway corresponds to Vest-Agder.

Corncrake registrations

Other registrations of corncrakes than those we did ourselves were found using the websites www.artsobservasjoner.no (Artsdatabanken- the Norwegian Biodiversity Information Centre) and www.nofoa.no (the Norwegian Ornithological Society (NOF), Oslo and Akershus branch). Data on ringings, controls and recaptures of corncrakes from the period 1995-2009 were provided by Stavanger Museum, the Norwegian Bird Ringing Central. The corncrakes' sex is usually not specified throughout this study, since the vast majority of the registered corncrakes in Norway in 2009 were singing males.

Radiotagging and ringing

Male corncrakes in Akershus (n = 1) and Rogaland (n = 11) were caught in nets by playback of corncrake song from a loudspeaker. Of these were eleven corncrakes ringed with a numbered metal ring; one corncrake was a recapture. Radio transmitters (n = 12) were glued to the birds' lower back; mainly according to the method used by Green et al (1997b). Tagged birds were in most cases located once every night and once every day to determine any movements. However, in 83 % of the cases, the radio transmitters fell off before the corncrakes made any potential long-distance movements, possibly because the corncrakes removed them with their beak. These ten radio transmitters had a median operative time of 3.5 days (range 0 days – 13+ days).

Song recordings

Corncrake songs were recorded at close range, usually from approximately 00.00-04.00 hours. When observing and recording a male the first time at a new place, the position was recorded with a GPS or marked on a M711-map (scale 1:50.000), and the song was recorded for approximately 2-4 minutes with a Marantz PMD 620 digital recorder and a Sennheiser ME67 directional microphone. In total 83 recordings of corncrakes in 60 different territories were made in six different regions (number of recordings; number of territories): Hedmark (14; 12), Jæren (25; 14), N Rogaland (11; 5), Oslo & Akershus (28; 24), Telemark (2; 2) and Vest-Agder (3; 3). The criterion for considering corncrakes to be in different territories was that individuals were singing more than 300 m from each other, or closer if singing at the same time (see Materials and definitions). However, in three cases this criterion was not used, due to aberrations from the more official evaluation of Norwegian corncrakes in 2009 on www.artsobservasjoner.no. Of the official Norwegian corncrake estimate of 2009 (n = 200), 30 % were recorded.

Corncrakes have been found to call on 41.5 % of nights (Peake and McGregor 2001) and on 75-80 % of nights (Stowe and Hudson 1988) at a rate of 35-55 calls per min. for several hours (Peake et al. 1998). Each corncrake call consists of two syllables, hereafter referred to as syllable I and II, and two intervals. Each syllable consists of a number of pulses of sound (usually 14-22) (Peake et al. 1998). Average length of pulses is 3-5 ms, and they are separated by intervals of 4-8 ms (Peake et al. 1998). The time from the start of one pulse to the start of the next pulse has been defined as the pulse-to-pulse duration (Peake et al. 1998), and is hereafter referred to as PPD. Since Osiejuk et al. (2004) found that other song characters than PPD, such as syllable lengths and interval lengths, would vary seasonally within one breeding season, only PPD-values were used in this study for individual song recognition (see also Peake et al. 1998). However, since duration of syllable I (hereafter referred to as SYL-I) and duration of syllable II (hereafter referred to as SYL-II) seem to be more population specific than PPD-values (T. S. Osiejuk, personal communication), SYL-I and SYL-II were used in the analyses of vocal difference between the two Norwegian corncrake populations. All recordings were first calibrated to the same digital quality (22.05 kHz/16 bit sampling). Recordings were analyzed using Avisoft-SASLab Pro v. 4.3x software. Background noises were cut with a low-pass filter (0.5 kHz) before PPD measurement. The first ten calls without significant background noises were digitized from each bird for each recording session according to the method by Peak et al. 1998.

Material and definitions

The term locality is used in the analyses which involve arrival dates to new territories. A locality is in this study defined as an area with a radius of one km. This is much larger than male corncrake home-ranges, which in various investigations have been found to be 3 - 51 hectar (Schäffer and Koffijberg 2006), a variation which according to Sklíba and Fuchs (2004), mainly is due to different lengths of tracking periods. However, results from radio tracking have shown that males rarely move more than 250 m between calling sites (Stowe and Hudson 1988, 1991; Peake and McGregor 2001). In our analyses of duration of stay in one territory and reason for disappearance from territory, we have, due to generally low corncrake densities, considered a maximum distance of 300 m between calling sites to be the same individual within the same territory. Only movements longer than 300 m have therefore been studied and analysed statistically. Corncrakes which were recorded in different territories during the same night are in the results referred to as ‘different birds’. The reason for using localities, and not territories in the analyses of arrival dates, was to avoid errors from local movements by corncrakes. However, neither localities nor territories are used consistently on www.artsobservasjoner.no, which means that the total number of individuals used in the statistical analyses will differ slightly from the registered number of corncrakes on www.artsobservasjoner.no (also registrations in duplicate seem to occur on www.artsobservasjoner.no).

Reasons for disappearance and movements were categorized into two groups: One group consisting of individuals that surely or probably disappeared or made movements due to mowing (e.g. they disappeared the night after mowing; they probably disappeared the night after mowing; they stayed a while in edge vegetation after mowing, but left after some days); and another group consisting of individuals that surely or probably disappeared due to other reasons than mowing (e.g. they disappeared prior to mowing; they were found in grain fields which were not harvested during the study period). Corncrakes with unknown reason for disappearance were left out of the analyses. The main study area of SW Norway, Jæren, had a more concentrated population of corncrakes than what E Norway had, and therefore the knowledge about how long the corncrakes stayed in one territory, and the reason for their disappearance from territories, was generally better known and more accurate in SW Norway than in E Norway.

The proportion of individuals which we considered to have enough information about to include them in the analysis of duration of stay and in the analysis of reason for disappearance was 64 % for Oslo & Akershus (n = 55), 40 % for Hedmark (n = 40), and 67 % (analysis of duration of stay) and 63 % (analysis of reason for disappearance) for Rogaland (n = 48). Two individuals which were followed telemetrically after they had been exposed to mowing (Anda and Pollestad, both in Rogaland), made one and two short movements (approximately 310 – 440 m), respectively, before disappearance from territory; still, these individuals were only used once in the analyses of duration of stay and reason for disappearance from territory. Corncrakes with unknown reason for disappearance were not included in the statistical analyses; however, they were included in figure 4, but might have stayed longer in their territories than figure 4 shows. Three corncrakes which were observed in E Norway, were not included in the analyses and not in figure 4 because they possibly made several local movements (not documented), which made both duration of stay in one territory and reason for disappearance unclear. The corncrake at Pollestad/Lynghaug in Rogaland was only used once in the analysis of reasons for movements in relation to date of corncrake disappearances prior to movements, and also in the analysis of corncrake population in relation to date of corncrake disappearances prior to movements.

Statistical analyses

Statistical analyses were run in MiniTab. The similarity in song between different recordings was analysed using linear discriminant function analyses (see also Peake et al. 1998). Prior to the linear discriminant function analyses, the recordings were classified into two groups: One group with recordings from the same bird or presumably from the same bird (group hereafter referred to as 'same bird'), and another group with all other recordings (group hereafter referred to as 'other'). However, a few individuals were hard to classify due to long time between recordings and/or relatively long distance between recordings. These individuals were grouped as 'other' in one discriminant function analysis (hereafter referred to as the conservative classification), and 'same bird' in another discriminant function analysis (hereafter referred to as the liberal classification). The criteria for being 'same bird' in the conservative classification were set to maximum one week and maximum 250 m between recordings (distance according to Peake and McGregor 2001). The criteria for being 'same bird' in the liberal classification were set to maximum two weeks and maximum 600 m between recordings. Controlled, ringed bird was naturally classified as 'same bird' in both classifications. However, two exceptions were made: Due to several corncrakes in the same area, and therefore uncertainty about whether it was the same individual that had been recorded twice, two recordings (Store Brennengen 1 and 2, Oslo) were classified as 'same bird' only in the liberal classification, although they also fulfilled the criteria of the conservative classification; two other recordings (Pollestad 3 and Lynghaug, Rogaland) were classified as 'other', although it fulfilled the criteria of 'same bird' in the liberal classification; this classification was due to that the individual which was recorded first was ringed, whereas the corncrake which later was recorded, was possibly not ringed. Ten individuals were classified as 'same bird' in the conservative classification; of these were eight recorded on two different nights and two on four different nights. In the liberal classification, 15 individuals were classified as 'same bird'; of these were ten recorded on two different nights, two on three different nights and two on four different nights.

Two syllable characters were used for individual song recognition: PPD in syllable I (hereafter referred to as PPD-I) and PPD in syllable II (hereafter referred to as PPD-II). The numbers of PPDs used in the linear discriminant function analyses were determined by the minimum numbers of pulses in each of the two syllables (Peake et al. 1998; T. S. Osiejuk, personal communication); a minimum of 13 pulses in syllable I made twelve PPD-I values, and a minimum of 15 pulses in syllable II made 14 PPD-II values. In total, four linear discriminant function analyses were carried out; one with PPD-I values in the conservative classification (CONS-I), one with PPD-I values in the liberal classification (LIB-I), one with PPD-II values in the conservative classification (CONS-II), and the last one with PPD-II values in the liberal classification (LIB-II). Differences in values of PPD-I and PPD-II were calculated for all pairwise combinations of the 83 recorded calls, giving a total of 3403 pairwise comparisons of recordings. These pairs of recordings generated a linear discriminant function analysis based on the two groups 'same bird' and 'other', which then gave a probability (p-value) for pairs of recordings being the same individual, and also for movements to have happened if recordings were done at different sites. P-values further used in this study refer to average p-values; calculated from the p-values of the four different discriminant function analyses (CONS-I, LIB-I, CONS-II and LIB-II). Only the pair of recordings with the highest p-value was used where there were several recordings of one individual. Pearson correlation tests, based on the first twelve PPD-I values and the first 14 PPD-II values within each pair of recordings, were carried out to determine the correlation coefficient (r) of all presented movements (according to Peake et al. 1998).

Average values of ten SYL-I values and ten SYL-II values were used to try to determine whether there was a difference in song between corncrakes in E and SW Norway (Budka et al. unpublished data; T. S. Osiejuk, personal communication). Two methods were used for this purpose: SYL-I and SYL-II from E and SW Norway were compared (based on method by Budka et al. unpublished data), and secondly, discriminant function analyses were carried out to see whether corncrakes could be classified based on song characteristics to the population to which they belonged (method modified from Peake and McGregor 1999). Two different data selections were used in these two statistical methods: One selection contained recordings of all individuals except one outlier (only the first recording from each individual was used), and another selection tried to minimize the effect of movements on initial, potential differences in song between the two populations; this by excluding both recordings done after 15 June, and also recordings of four corncrakes which, based on our results on movements, were likely to have been recorded elsewhere earlier. Two discriminant function analyses based on the largest data selection, were carried out by splitting the data set in two halves; where the two halves were determined by listing recordings chronologically, and then assigning every other recording to one group, and the rest of the recordings to the other group.

The first group generated the linear discriminant function analysis based on SYL-I and SYL-II values of the two populations, and population membership was then predicted for the second group; and vice versa. Due to small sample size in the data set based on recordings done prior to 16 June (n = 25), a total of 25 different discriminant function analyses were carried out by putting all recordings except one in the group which generated the linear discriminant function analyses (also based on SYL-I and SYL-II values); population membership was then predicted for one recording at a time.

Results

Spatial and temporal distribution of corncrakes

Based on our own corncrake observations (where potentially same individuals within a radius of one km only were counted once) and on reported corncrakes on www.artsobservasjoner.no, we found that about 200 presumably different corncrakes were observed in Norway in 2009. The official population estimate was also 200 corncrakes, which is the third highest number since the Norwegian Ornithological Society (NOF) started their corncrake project in 1995 (County Governor of Rogaland 2009). Based on our own observations and on www.artsobservasjoner.no, 94 % of corncrakes in Norway in 2009 were observed in the counties south of Møre & Romsdal and Sør-Trøndelag (figure 1); and the spatial distribution of this majority of corncrake observations was relatively clearly separated into two populations; one in the eastern part of Norway (n = 134) and one in the southern and western parts of Norway (n = 52). However, one observation in Aust-Agder in September was between these two populations. In general, the two populations were separated by unfavourable habitats, such as mountains and forests.

Based on reported corncrakes on our own corncrake observations and on www.artsobservasjoner.no, the maximum number of presumably different corncrakes during one week in 2009 was 70 (1-7 June), which corresponds to 35 % of the official population estimate; and also, the number of corncrake observations in the southern and western part of Norway were found to reach a peak before the number of corncrake observations in the eastern part of Norway (figure 2). Many of the new corncrake observations were made late in the breeding season; and based on our own observations and www.artsobservasjoner.no, a total of 42 % of all new corncrake observations were reported after 15 June. For Hedmark (n = 38), Oslo & Akershus (n = 53) and Rogaland (n = 45) these numbers were 45 %, 50 % and 24 %, respectively.

Corncrakes in SW Norway arrived to new localities significantly earlier (median = 28.5 May, range = 16 May – 30 August, n = 40) than corncrakes in E Norway (median = 13 June, range = 16 May – 6 August, n = 86) (Mann-Whitney U-test, W = 1677.5, $p < 0.001$). To avoid effects of corncrakes' movements within Norway on arrival dates to new localities, later observations were kept out of the analyses. When only using arrival dates in May, corncrakes in SW Norway were still found to arrive to new localities significantly earlier (median = 26 May, n = 27) than corncrakes in E Norway (median = 30 May, n = 11) (W = 465.0, p = 0.05). A significant correlation was found between latitude and arrival dates of corncrakes to new localities within E and SW Norway as a whole (Spearman Rank correlation, $r_s = 0.41$, n = 126, $p < 0.01$), and also within Oslo & Akershus ($r_s = 0.37$, n = 49, p = 0.01); but no such correlation was found neither within E Norway ($r_s = 0.15$, n = 86, p = 0.15), within Hedmark ($r_s = 0.061$, n = 37, p = 0.71), nor within Rogaland ($r_s = -0.10$, n = 40, p = 0.54) (figure 3).

Corncrake disappearances from territories

Meadows with corncrake territories were mowed significantly earlier in SW Norway (median = 2 June, range = 28 May – approximately 17 June, n = 16) than in E Norway (n = 21, median = 26 June, range = 4 June – 30 June) (W = 557.5, $p < 0.001$). The proportion of corncrakes found in territories which at some point were likely to be mowed during the breeding season (i.e. meadows) was 70 % for E and SW Norway together (n = 101). The difference in this proportion between E Norway (35/62) and SW Norway (36/39) was significant (Chi-square, $\chi^2 = 14.74$, $p < 0.001$). The proportion of corncrakes actually disappearing or moving away from their territories certainly or probably due to mowing was 54 % for E and SW Norway together (n = 80). The difference in this proportion between E Norway (22/50) and SW Norway (21/30) was significant ($\chi^2 = 5.10$, p = 0.02).

Corncrake median duration of stay in one territory was found to be four days (range = 1 – 28, n = 82) for E and SW Norway together. No significant difference in duration of stay (days) was found between E Norway (median = 3, range = 1 – 28, n = 50) and SW Norway (median = 5.5, range = 1 – 19, n = 32) (U-test, W = 1380.5, p = 0.62). Corncrakes in E and SW Norway which disappeared or moved away from their territories certainly or probably due to mowing, were found to stay significantly longer in their territories (median = 5.5 days, range = 1 – 24 days, n = 42) than corncrakes which disappeared or moved away due to other reasons than mowing (median = 3 days, range = 1 – 28 days, n = 37) (U-test, W = 1876.5, p = 0.05). No significant differences in date of disappearances from territories between corncrakes which certainly or probably disappeared due to mowing and corncrakes which disappeared due to other reasons than mowing, were found among corncrakes in E Norway (W = 702.5, p = 0.83, n = 50), SW Norway (W = 171.0, p = 0.49, n = 30) nor in E and SW Norway together (W = 1690.0, p = 0.15, n = 80).

Individual song identification

Probabilities (p-values) were determined by similarity in individual song characteristics, and refer to the probability of two song recordings (also referred to as pairs of recordings) being from the same individual. The total distribution of all p-values based on CONS-I (n = 3403) was uneven (figure 5). However, no peak in high p-values was found, which made it difficult to set a p-value limit between pairs of recordings being from the same individual and pairs of recordings being from two different individuals. By setting the limit at too high p-values, we would risk classifying some real movements as false; and opposite, by setting the limit too low, we would risk classifying some false movements as real.

No overlap in p-values of 'different bird' (range = 0.00 - 0.78, n = 79) and 'same bird' (range = 0.83 - 0.99, n = 20) was found in CONS-I (figure 6a). However, overlap in p-values of 'different bird' (range = 0.00 - 0.82, n = 79) and 'same bird' (range 0.32 - 0.99, n = 29) was found in LIB-I (figure 6b). This overlap was due to the different classification of individuals in the conservative and the liberal analyses of PPD-I values. Based on frequency distribution of p-values from these two analyses, we decided to further investigate potential movements with p-values ≥ 0.80. Potential movements with overlapping observation dates were considered to be false and are not presented in the results (n = 19). The proportion of such assumed false movements was found to increase as p-values decreased (logistic regression, g = 3.88, n = 93, p = 0.05 (figure 7). In a total of 29 cases, potential movements shared observation dates with other potential movements (due to difficulties of finding an exact number, this maximum number of different cases is presented); only the potential movement with the highest p-value was then chosen as a real movement. A total of 29 movements (median r = 0.97, range r = 0.88 – 1.00) found by individual song characteristics were considered real (figure 8), and for these 29 movements, significant correlations between p-values and average r in SYL-I (p-value: median = 0.941, range = 0.806 – 0.989, n = 29; r: median = 0.970, range = 0.916 – 0.999, n = 29) and SYL-II (p-value: median = 0.941, range = 0.787 – 0.991, n = 29; r: median = 0.972, range = 0.875 – 0.998, n = 29) were found

(Spearman Rank correlation; SYL-I: $r_s = 0.79$, $p < 0.001$; SYL-II: $r_s = 0.83$, $p < 0.001$) . Based on all 29 movements, the differences in p-values between conservative discriminant function analyses (CONS-I and CONS-II) and liberal discriminant function analyses (LIB-I and LIB-II) (median = 0.002, range = 0.000 – 0.055, n = 58) was significantly smaller than the differences in p-values between discriminant function analyses of PPD-I (CONS-I and LIB-I) and PPD-II (CONS-II and LIB-II) (median = 0.024, range = 0.001 – 0.171, n = 58) (W = 2263.0, $p < 0.001$).

A significant correlation was found between number of days between recordings of 'same bird' pairs and p-values of 'same bird' in LIB-I (Spearman Rank correlation, $r_s = -0.491$, $p = 0.009$), but not in CONS-I ($r_s = -0.242$, $p = 0.29$); suggesting that the reliability of song recording as a method to find movements, might be higher the closer recordings are in time. However, number of days between recordings of 'same bird' was generally low both in conservative function analyses (median = 3, range = 1 – 30, n = 20) and liberal function analyses (median = 5, range = 1 – 40, n = 29).

In addition to identifying movements among corncrakes, similarities in individual song characteristics (i.e. duration of SYL-I and SYL-II) were used to test whether the populations of E and SW Norway actually represented two different populations. One outlier was removed from SYL-II values from SW Norway (recorded after 15 June). No significant differences in SYL-I and SYL-II values between all recorded corncrakes in E Norway (n = 36) and SW Norway (SYL-1: n = 20; SYl-II: n = 19) were found, nor when only recordings prior to 16 June were used (E Norway: n = 14; SW Norway: n = 11) (four t-tests; all tests $p > 0.34$). Discriminant function analyses, based on song recordings from the whole breeding season in E Norway (n = 18) and SW Norway (n = 10 and n = 9) (where the individual which had an outlier SYL-II value was excluded from the material from SW Norway), in average correctly classified 39 % and 42 % of corncrakes in E Norway (n = 18) and SW Norway (n = 9 and n = 10), respectively; giving a total of 40 % correctly classified individuals. Discriminant function analyses based on recorded individuals prior to 16 June correctly classified 64 % of both corncrakes in E Norway (n = 14) and SW Norway (n = 11). If classification was done by chance, 50 % would have been classified to their 'right' population.

Movements

Prior to 2009, corncrake movements within the breeding season have only been documented by ringing in Norway (n = 11). The Norwegian corncrake ringing activity has been concentrated to Rogaland the recent decades (figure 9), where 78.7 % of all ringed corncrakes in the period 1990-2008 (n = 174) have been ringed. Corncrake ringing activity outside Rogaland has been scattered between ten other counties in the period 1990-2008: Vest-Agder (n = 8), Møre & Romsdal (n = 7), Sør-Trøndelag (n = 6), Aust-Agder (n = 3), Buskerud (n = 3), Nord-Trøndelag (n = 3), Telemark (n = 3), Hedmark (n = 2), Oslo & Akershus (n = 1) and Østfold (n = 1). All previously recorded movements within Norway have been within Rogaland, except one movement which was from Rogaland to Aust-Agder (132 km). We found one corncrake movement within Rogaland by ringing in 2009 (67 km), which was the second longest movement being recorded within Norway by ringing (longest recovery of living bird). However, movements based on individual song characteristics later showed that this corncrake had probably not moved directly from the site where it was ringed to the site where the recovery was made. Median travelling distance for all corncrakes which have been found by ringing in Norway was 14 km (range = 0 – 132 km, n = 12), with half of the movements being less than 10 km. Figure 10 shows all movements ≥ 5 km by adult corncrakes found by ringing in Norway within the breeding season (n = 10).

A total of 21 individuals were found to make altogether 32 movements longer than 300 m (median = 129 km, range = 0.3 – 404 km) in 2009. The movements were found by song identification (median = 318 km, range = 0.3 – 404 km, n = 29) and telemetry (median = 0.4 km, range = 0.3 – 0.4 km, n = 3) (figure 11). A total of six individuals were found to make more than one movement. No movements were found between 2 km and 17 km, and movements longer than 17 km are therefore referred to as long-distance movements, while movements shorter than two km are referred to as short movements. Of all movements found, 22 (69 %) were long-distance movements, and were all found by song identification; and 18 movements (56 %) were longer than 100 km. Of all movements found by song identification, 15 (52 %) had a p-value ≥ 0.95. No significant difference was found between p-values of long-distance movements (median = 0.93, range = 0.85 – 0.99, n = 22) and p-values of short movements (p-value = 0.97, p-value = 0.85 – 0.99, n = 7) (U-test, W = 135.0, n = 29, p = 0.13); nor between average *r* of long-distance movements (median = 0.96, range = 0.90 –

1.00, n = 22) and average *r* of short movements (median = 0.99, range = 0.93 – 0.99, n = 7) (U-test, W = 137.0, n = 29, p = 0.11). Long-distance movements with p-values ≥ 0.95 (median *r* = 0.99, range *r* = 0.88 – 1.00, n = 20 r-values from 10 individuals) are shown geographically in figure 12, while long-distance movements with p-values 0.85 – 0.94 (median *r* = 0.94, range *r* = 0.88 – 0.99, n = 24 r-values from 12 individuals) are shown geographically in figure 13. No movements with p-values 0.80 – 0.84 were found.

Median travelling distance for corncrakes which made long-distance movements was 331 km (range = 18 – 404 km). No significant difference in travelling distance between corncrakes in E Norway (median = 318 km, range = 18 km - 404 km, n = 13) and SW Norway (median = 350 km, range = 328 km – 373 km, n = 6) was found (U-test, W = 110.5, p = 0.10). Of all movements found with certain or probable reasons for movements (n = 31), 58 % were certainly or probably due to mowing; no significant difference between E Norway (8/18) and SW Norway (7/10) was found (Chi-square, χ^2 = 1.69, p = 0.19). Of long-distance movements with certain or probable reasons for movements (n = 21), 57 % were certainly or probably due to mowing; no significant difference between E Norway (6/13) and SW Norway (3/5) was found (χ^2 = 0.28, p = 0.60). Length of corncrake movements which were made certainly or probably due to mowing (median = 65 km, range = 0.3 – 404 km, n = 18) was not significantly different from corncrake movements which were due to other reasons than mowing (median = 318 km, range = 0.5 – 372 km, n = 13) (U-test, W = 267.0, p = 0.41). Of all movements which certainly or probably were made due to mowing, 67 % were long-distance movements, and 50 % were longer than 100 km.

Based on movements found, corncrakes in SW Norway were found to leave territories significantly earlier (median = 1 June, range = 29 May – 23 June, n = 9) than corncrakes in E Norway (median = 24.5 June, range = 8 June – 30 June, n = 18) (W = 65.5, p = 0.002). Corncrakes which made movements certainly or probably due to mowing were found to leave territories significantly earlier (median = 17.5 June, range = 29 May – 27 June, n = 16) than corncrakes which made movements due to other reasons than mowing (median = 23 June, range = 8 June – 30 June, n = 13) (W = 184.5, p = 0.02). Figure 14 shows the distribution of arrival dates after movements ≥ 1 km, grouped in reasons for movements. A correlation was found between distances of movements made and time between observation dates for territories prior to and after movements (Spearman Rank correlation, r_s = 0.36, n = 32, p =

0.05) (figure 15), but no such correlation was found when excluding individuals which were found to have used less than two days on their movements ($r_s = 0.14$, $n = 29$, $p = 0.45$).

Case studies of movements

In the following, four different corncrakes which made movements in 2009 will be presented. This is to give the reader an impression of how corncrake movements may occur.

Anda - Telemetric observations of a corncrake during mowing

This individual was first observed 29 May in a meadow at Anda, Rogaland. On 30 May the corncrake was radio tagged. At about 21.30 h on 2 June, the edge (about five metres) of the meadow, were it had stayed at least the last four nights, was already mowed, and the rest of the meadow was then going to be mowed. The farmer then agreed to mow slowly towards the middle of the meadow, close to where the radio signals from the corncrake came from. The mowing speed was about 3 km/h; which was, according to the farmer, about one third of normal speed when mowing. The corncrake then flew up about four metres to the side of the tractor, and landed about 170 m away, on the neighbouring meadow. It was radio tracked for about 30 minutes in the 'new' meadow, where it seemed to wander around. This meadow was then mowed the same night, from about 00.45 h (3 June). The same procedure was followed as during the previous mowing: First the edge vegetation was mowed, and then it was mowed slowly towards where the corncrake was thought to be. Possibly because it was dark, and therefore harder to point out where exactly the corncrake was sitting, it did not fly up as soon as it did at the previous meadow. However, after some mowing, it also escaped from this meadow, and then flew to another meadow about 350 m away. It was radio tracked at this last meadow at 6.30 h and at 20.50 h the following day, but had disappeared at 2.45 am on 4 June. The surrounding area was searched telemetrically later the same day, but with negative result.

Pollestad – Registrations by telemetry and individual song characteristics after mowing

This individual was first observed 26 May in a meadow at Pollestad, Rogaland. The corncrake was ringed and radio tagged on 29 May. Mowing was completed on 30 May, and the following night it was radio tracked and recorded in a meadow about 250 m away from the first site. The following two nights we found that it had moved about 310 m and about 440 m, respectively. Probably on 2 June the corncrake lost its radio transmitter. A corncrake (probably the same individual) was heard in the same area on 3 June, but on 4 June no corncrake was heard. On 5 June a corncrake was found and recorded about 330 m away from where the corncrake at Pollestad last had been heard, and song analysis showed that this also probably was the same individual as was earlier found in the area (p-value = 0.97). Apparently the same corncrake was heard until 9 June. However, on 9 June a corncrake was ringed and radio tagged in the same area, and it could therefore not have been the same corncrake which earlier had been ringed (and radio tagged) at Pollestad. Perhaps there were two corncrakes in the same area around 5 - 9 June, or perhaps the corncrake which was recorded on 5 June was not the same as the first one recorded at Pollestad after all, even though individual song characteristics showed a high probability for them being the same individual. Even though only the first movement was a probable direct result of mowing, we have also grouped the two later movements (> 300 m) as a probable result of mowing in the analyses; this since mowing was thought to be the ultimate reason also for these later movements.

Leanuten – Probably found in four different territories – two in E Norway and two in SW Norway: Total travelling distance of 729 km

This individual was first observed 28 May in a meadow at Leanuten, Rogaland. The corncrake was recorded on 30 May. The locality was not checked the following two nights, but on 2 June, the meadow was found mowed, and the corncrake was not found. On 7 June a corncrake was found 344 km from Leanuten, in a meadow in Leikvoll, Akershus. Analysis of this corncrake's song, which was recorded on 9 June, showed that this probably was the same individual as the one at Leanuten (p-value = 0.92). The corncrake was heard until 15 June, and it disappeared some time between 15 June and 28 June, probably because of mowing. On 27 June two corncrakes were found and recorded 19 km from Leikvoll, in an oat field in Esval, Akershus. Song analysis from one of the corncrakes showed that this probably was the same individual as the one in Leikvoll (p-value = 0.98). The two corncrakes were also heard in Esval two nights later (29 June), and they disappeared some time betweeen 29 June and 7 July, even though the meadow was still not mown on 7 July. On 14 July a corncrake was found and recorded 366 km from Esval, in a meadow (or possibly an overgrown pasture) at

Ualand, Rogaland. Song analysis showed that this probably was the same individual as in Esval (p-value = 0.96). On 15 July the corncrake was found and recorded about 240 m away from the site where it had been the previous night (p-value = 0.98), sitting in 30 – 40 cm tall edge vegetation between two meadows. The corncrake's further movements were not known.

Nugguren – Probably travelling 404 km in one or two nights

This individual was first observed 30 May, in a meadow at Nugguren, Hedmark. On 8 June the corncrake's song was recorded, and it disappeared some time between 8 June and 13 June, probably due to mowing. On 13 June a corncrake was found and recorded 23 km from Nugguren, in a meadow in Bråta, Hedmark. Analysis of this corncrake's song showed that it probably was the same individual as the one at Nugguren (p-value = 0.99). The corncrake stayed until the meadow was started mown, on 26 June. Only two nights later a corncrake was found 404 km away, at Reve, Rogaland (p-value = 0.97). This corncrake was recorded on 3 July in edge vegetation between a meadow and a natural meadow; this was the last observation of the corncrake, even though the habitat was intact also after 3 July.

Overestimation rate of the Norwegian corncrake population

Individual song characteristics showed that the Norwegian corncrake population of 2009 was less than estimated. The number of what was thought to be different corncrakes (n = 60) and the actual number of different corncrakes (n = 36) was used in calculating an overestimation rate for the population; an overestimation rate which was found to be 67 %. When applying this overestimation rate on the whole 2009 Norwegian corncrake population, the actual population number would have been 120 individuals instead of 200 individuals. Only in one case individual song characteristics showed that two corncrake observations which was thought to be of the same individual, actually might have been of two different individuals (Store Brennengen, Oslo).

Discussion

Territory use and mowing

We found that the maximum number of corncrakes observed within one week (1-7 June) was low compared to the total number of corncrakes observed in Norway in 2009. We also found that a relatively high proportion of new corncrake observations was done after 15 June; such arrivals from mid-June onwards are thought to mainly involve displacements from first broods, or birds that have been disturbed elsewhere (Schäffer and Koffijberg 2006). These findings, together with the generally short period of time that corncrakes were found in one territory, suggest that there is a high rate of movements in the Norwegian corncrake population. Disturbance, such as mowing, is thought to be an important reason for corncrake movements (Schäffer and Koffijberg 2006; DN 2008), and we found that 54 % of the corncrakes in Norway in 2009 disappeared from their territories certainly or probably due to mowing. However, this proportion might also be higher as our results from telemetry show that mowing at one site may trigger a corncrake to make several movements (see case studies of Anda and Pollestad). A larger proportion of corncrakes disappeared or moved away from their territories certainly or probably due to mowing in SW Norway than in E Norway. This might be due to both that mowing was earlier in SW Norway than in E Norway, and that a larger proportion of corncrakes in SW Norway than in E Norway had their territories in meadows which were likely to be mown some time during the breeding season, which in turn probably is related to the difference in habitat availability between E and SW Norway. Corncrakes which disappeared or moved away from their territories certainly or probably due to mowing, were found to stay longer in their territories than corncrakes which disappeared due to other reasons than mowing; which may suggest that corncrakes move around before they settle in one territory, in which they then may stay until they are disturbed.

Individual song identification

Previous methods for documenting long-distance movements among corncrakes within one breeding season have been ringing and telemetry. Song recording is a less labour- and time-consuming method than ringing and telemetry, where for instance the capture of the birds might fail; and most movements presented in this study are indeed based on individual song characteristics. Still, vocal individuality based on individual song characteristics may show some false movements, and also fail to find some real movements, this because two different corncrakes in some cases have as similar songs as one single corncrake has in two different recordings. Movements found by individual song characteristics are therefore not as certain as movements documented by ringing and telemetry. Since p-value ≥ 0.80 was set as the criterion for potential movements, the correlation coefficient (r) was not found for all pairs of recordings, which implies that we have probably not found all the real movements (according to Peake et al. 1998); but also, since all presented movements had $r > 0.7$, it is likely that the number of false movements presented in this study is lower than if we had presented all potential movements with $r > 0.7$ (according to Peake et al. 1998). Based on this, our method for finding movements is more conservative than the method described by Peake et al. (1998); and Peake et al. (1998) also found a lower median r for 'same-bird dyads' than the median r we found for movements presented in this study, which together with the significant correlation found between p-values and r, suggest that most of the movements presented in this study are real. Relatively many of the potential movements found were not considered as real, either due to overlapping observation dates within one potential movement – a proportion which was found to increase with increasing p-value interval (figure 7); or due to overlapping observation dates between two potential movements. This is an important point, and it implies that this method must be used carefully when studying corncrake movements, and probably also that the number of corncrake movements is more correct than for instance the movements' lengths and reasons. It is possible that r rather than p-values should be used as a measure when choosing one real movement from two potential movements with overlapping observation dates; however, r and p-value did nearly give the same movements in this study regarding such cases. Arriving corncrake males have been found to take over or use nearly same singing sites as of males already present (Schäffer and Koffijberg 2006), which may lead to corncrake individuals being confused in surveys (Peake and McGregor 2001); this implies that some movements which we have considered as false, actually might have been real. However, the Norwegian corncrake population is not dense, so this is not likely to be a common phenomenon in Norway; our results based on individual song characteristics only showed one such possible confusion of individuals (Store Brennengen, Oslo).

In general, only small differences were found between the conservative and the liberal discriminant function analyses (see also Appendix for details), and these differences were also found to be significantly smaller than the differences in p-values due to different syllables, which suggests that perfect categorization of individuals in discriminant function analyses is not crucial when using this method. The correlation which was found between the number of days between recordings of 'same bird' and p-value in LIB-I, is not supported by Peake et al. (1998), who suggest that call structure remain constant over one year. Nevertheless, our findings might suggest that recordings which are done further from each other in time, should be treated more carefully than recordings which are done closer in time. Summarized, song recording of corncrakes does not require a lot of time or labour, nor does it involve handling of birds; it proved to be an effective method for documenting both short and long-distance corncrake movements, at least in such a small population as the Norwegian corncrake population.

Movements

Ringing has shown that corncrakes may travel several hundred km within one breeding season on the European continent (Schäffer and Koffijberg 2006), but due to few recoveries it is not known how common such long-distance movements are. Ringing in Norway has mainly found relatively short movements, with only one movement longer than 100 km (ringed bird found dead after mowing in 2002) (unpublished data from Norwegian Bird Ringing Central), which probably is due to that Norwegian corncrake ringing activity mostly has been concentrated to Rogaland. A telemetry study in a part of Poland which was affected by large-scale mowing, showed that 85 % of corncrakes moved away from original breeding sites after disturbance by mowing, of which 70 % were found to move more than 100 km (Hoffmann 1997 cited in Schäffer 1999). These findings indicate that long-distance movements within one breeding season may be a common phenomenon, at least when corncrakes are disturbed. Based on the movements we found in this study, we suggest that movements of various distances are common among corncrakes in Norway, and that mowing is the reason for about half of these movements. Telemetry studies of Anda and Pollestad (case studies) also show that corncrakes may make several movements after being disturbed once by mowing.

Corncrakes which made movements certainly or probably due to mowing were found to leave territories earlier than corncrakes which made movements due to seemingly other reasons than mowing; seemingly - because movements which are thought to be due to other reasons than mowing, actually may have had mowing as an underlying cause. An explanation for this difference in leaving time could be that mowing happens quite early in the breeding season at many localities, and corncrakes in SW Norway, where most corncrake territories were mown in the end of May or beginning of June, were indeed found to leave territories (prior to movements) significantly earlier than corncrakes in E Norway. Another possible explanation could be that corncrakes have a higher probability of making movements later in the breeding season, independently of mowing. However, these findings were not supported by the analyses of time of disappearances from territories in relation to reasons for disappearances from territories. There was a trend that corncrakes in S and SW Norway made a larger proportion of their movements due to mowing than corncrakes in E Norway, which is likely, as a larger proportion of corncrakes inhabit meadows in S and SW Norway than in E Norway. There was also a trend that corncrakes in SW Norway made longer movements than corncrakes in E Norway, which may be due to less available habitat in SW Norway than in E Norway, after the large-scale mowing at Jæren in the end of May and beginning of June 2009. Peake and McGregor (2001) studied corncrake movements at a smaller scale than we did, but found a negative correlation between distance of corncrake movements and the percentage of usable habitat in the area surrounding the abandoned site.

Four of the presented movements in this study are surprising, because they describe corncrakes moving from SW Norway (Hauge and Tornesvatnet) to E Norway (both p-values = 0.86) and back to SW Norway to respectively the same locality (Stange, p-value = 0.85) and same territory (Tornesvatnet, p-value = 0.95) in SW Norway. However, such movements back and forth between two localities within one breeding season have also been documented previously among other bird species; Dale et al. (2006) found that a male ortolan bunting (*Emberiza hortulana*) moved three times between two localities which were 34 km apart, all during one breeding season (S. Dale, personal communication).

There is often a larger proportion of males than females in small and isolated bird populations, probably particularly within migratory species (Dale 2001; Donald 2007), and Dale et al. (2005) suggest that a long breeding dispersal within the breeding season may occur if there is a lack of females in bird populations. A large proportion of singing corncrake males in Norway are indeed thought not to mate during their stay in Norway (DN 2008), and a possible lack of females in the Norwegian corncrake population may therefore be one reason for corncrakes to make movements. Other possible reasons for movements which are not due to mowing, are low habitat quality, breeding failure, or less likely, the fact that males move away after succeeded mating (Schäfffer and Koffijberg 2006). However, no corncrake breedings were documented in Norway in 2009.

Population estimates

The seemingly high mobility (supported by movements and short duration of stay in territories) in the Norwegian corncrake population affects population estimates directly, as corncrake movements entail that one individual will be counted more than once in the population estimate. Since the song of only 30 % of the official population estimate was recorded, it is likely that we have not identified all corncrake movements in 2009. If so, the overestimation rate which we calculated to be 67 % for the recorded corncrakes, is likely to be even higher when applied on the 2009 Norwegian corncrake population as a whole.

To avoid such a high overestimation of the Norwegian corncrake population, we suggest two restrictions for future population estimates: Firstly, based on the distribution of length of movements (figure 11), observations which are less than 1 km from each other and potentially of the same individual, should only be used once in estimates; and secondly, based on the distribution of arrivals to first territories and the distribution of arrivals to new territories after movements made (figure 14), only observations done prior to a certain date should be used in estimates. Folvik (2004) states that most corncrakes arrive to Norway in the period 20 May – 1 June, and Green et al (1997a) found, based on questionnaires, that mean date of main arrival time for corncrakes to Great Britain was 21 May (range 30 April – 15 June), which leads to the conclusion that corncrake arrivals in Great Britain from mid-June onwards mainly involve displacements from first broods, or birds that have been disturbed elsewhere (Schäffer and Koffijberg 2006). From figure 14, two alternative date limits seem to be useful; if assumed first territories actually are first territories, a limit set at 8 June would imply a correct estimation of the population (still based on figure 14), whereas a limit set at 15 June would imply an overestimation rate of 19 %. Still, to avoid underestimation of the population (e.g. in years with later mowing dates and presumably later movements), we suggest setting the date limit at 15 June, which means that only corncrake observations done prior to 16 June should be used in future estimates. However, a date limit at 10 June should also be considered. Using these two restrictions ('1 km + 15 June – rule'), the 2009 Norwegian corncrake population estimate would have been about 123 individuals (which is only three individuals higher than the population estimate found when using the previously calculated overestimation rate of 67 %), and 39 % lower than the official population estimate of 200 individuals. As a minimum population estimate, we also suggest that the highest number of presumably different corncrake observations (using the '1 km – rule') made within one week is presented as a part of future population estimates. In 2009 this number was 70 corncrakes (observed 1 – 7 June), which was 65 % lower than the official population estimate.

Although the use of individual song identification in this study was found to decrease corncrake population estimates, individual song identification has previously been found to increase corncrake population estimates (Peake and McGregor 2001); however, this latter finding was from a smaller area (400 hectars) than our study area, and also in a denser corncrake population than the Norwegian corncrake population (Peake and McGregor 2001).

Norwegian corncrakes: One or two populations?

SW Norway has for decades been considered as one of the core areas for corncrakes in Norway, and in the 1990s more than 50 % of the singing corncrake males in Norway were reported from this part of Norway (Gjershaug et al. 1994; DN 2008). From the 1950s and until the 1990s, relatively few corncrake observations were made in the eastern part of Norway (Myrberget 1963; Haftorn 1971; Gjershaug et al. 1994); however, the reported numbers of singing corncrake males from this area increased rapidly from the late 1990s (Eie 2005), and in 2002 twice as many singing corncrakes were reported from Akershus as from Rogaland (Folvik 2004). The two Norwegian corncrake populations (E and SW Norway) may have different origin; the newer population of E Norway is thought to be a direct result of immigration (DN 2008); whereas it is suggested that the population of SW Norway, at least partly, has been a more original population (Folvik and Øien 1997).

It has been suggested that corncrake song varies geographically on a large scale (Peake and McGregor 1999; Budka et al. unpublished data); however, based on individual song characteristics (i.e. SYL-values), we found no evidence for the two Norwegian corncrake populations to be different, although differences in results of discriminant function analyses possibly due to different selections of corncrakes (one selection from the whole breeding season and another selection prior to 16 June) may suggest that the two populations are more different in the beginning of the breeding season than later in the breeding season . Budka et al. (unpublished data) did also not find any significant differences in SYL-I and SYL-II values between corncrakes in E and SW Norway, but average values of SYL-I and SYL-II from E Norway compared to values from SW Norway were closer to values from Poland and N Czech Republic. Based on the long-distance movements found in this study, we suggest that the two Norwegian corncrake populations are functionally connected, even though they are about 300 km apart. Corncrakes in SW Norway were found to arrive to territories significantly earlier than corncrakes in E Norway, which either might be due to more field activity early in the season in SW Norway than in E Norway, or a result (at least partly) of two different populations with different migration routes. Still, due to small sample size and risk of misclassification because of possible movements between the two populations, we suggest that further investigation (e.g. analyses of DNA, song, body size) is necessary to find out whether the two Norwegian corncrake populations actually have different origin or not. However, such investigations should be made as early in the breeding season as possible since the two populations seem to be functionally connected.

As a result of both probable low breeding success and a large proportion of unmated males, in addition to few reported breedings, DN (2008) states that the Norwegian corncrake population is probably not able to sustain itself, and that the population is largely dependent on immigrants from the species' more central range. Based on this, our own findings on movements and similarities in song characteristics between the two populations, and also corncrakes' relatively low annual survival rate (Green 2004), we suggest that corncrakes in Norway belong to one population, consisting mainly of immigrating individuals from the species' more central range, and also that this population has a high proportion of new individuals every year. Due to the early, large-scale and relatively simultaneous mowing in SW Norway, we consider the chances for re-establishing a self-sustainable population in SW Norway as low, at least unless large areas are set aside.

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Figures

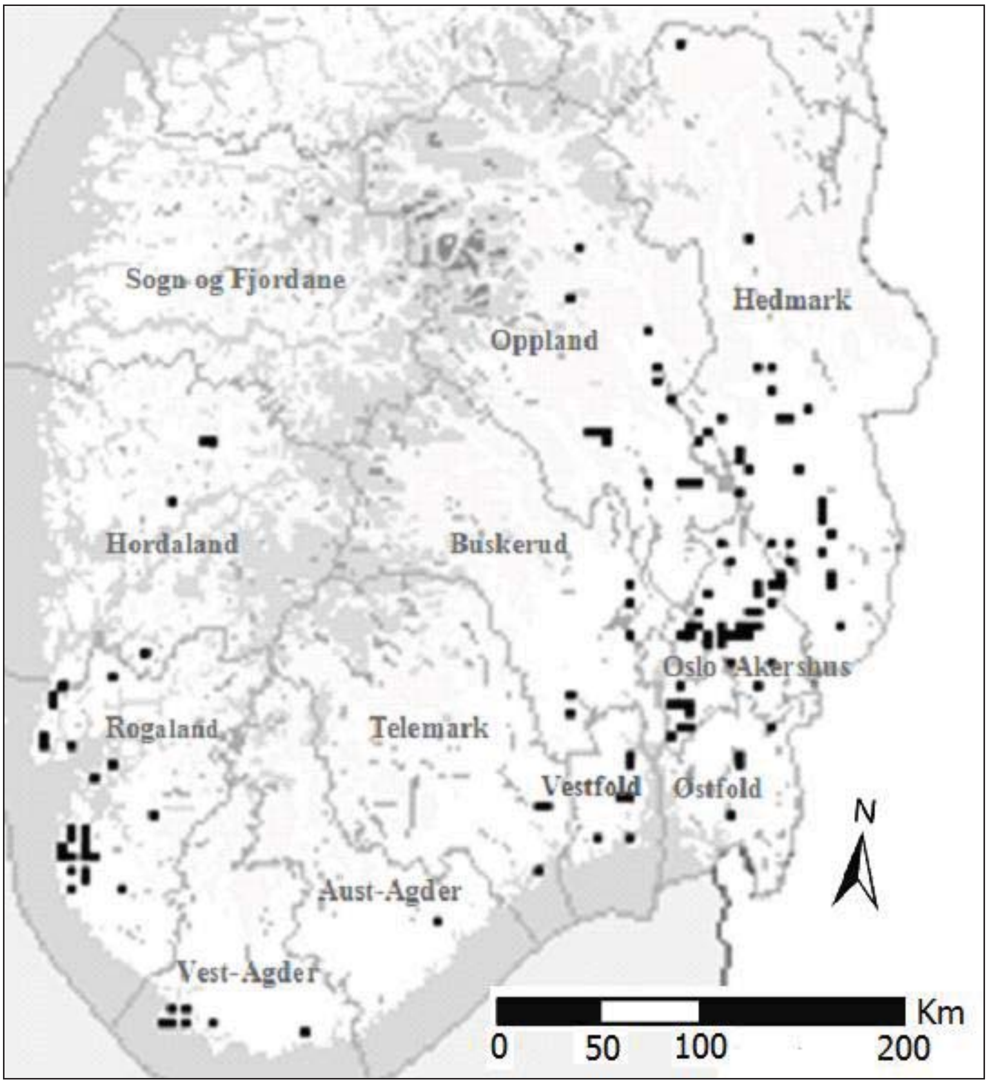


Figure 1. Spatial distribution of corncrake observations in Norway south of Møre & Romsdal and Sør-Trøndelag reported on www.artsobservasjoner.no in 2009 (n = 191). Map is printed from www.artsobservasjoner.no, and modified.

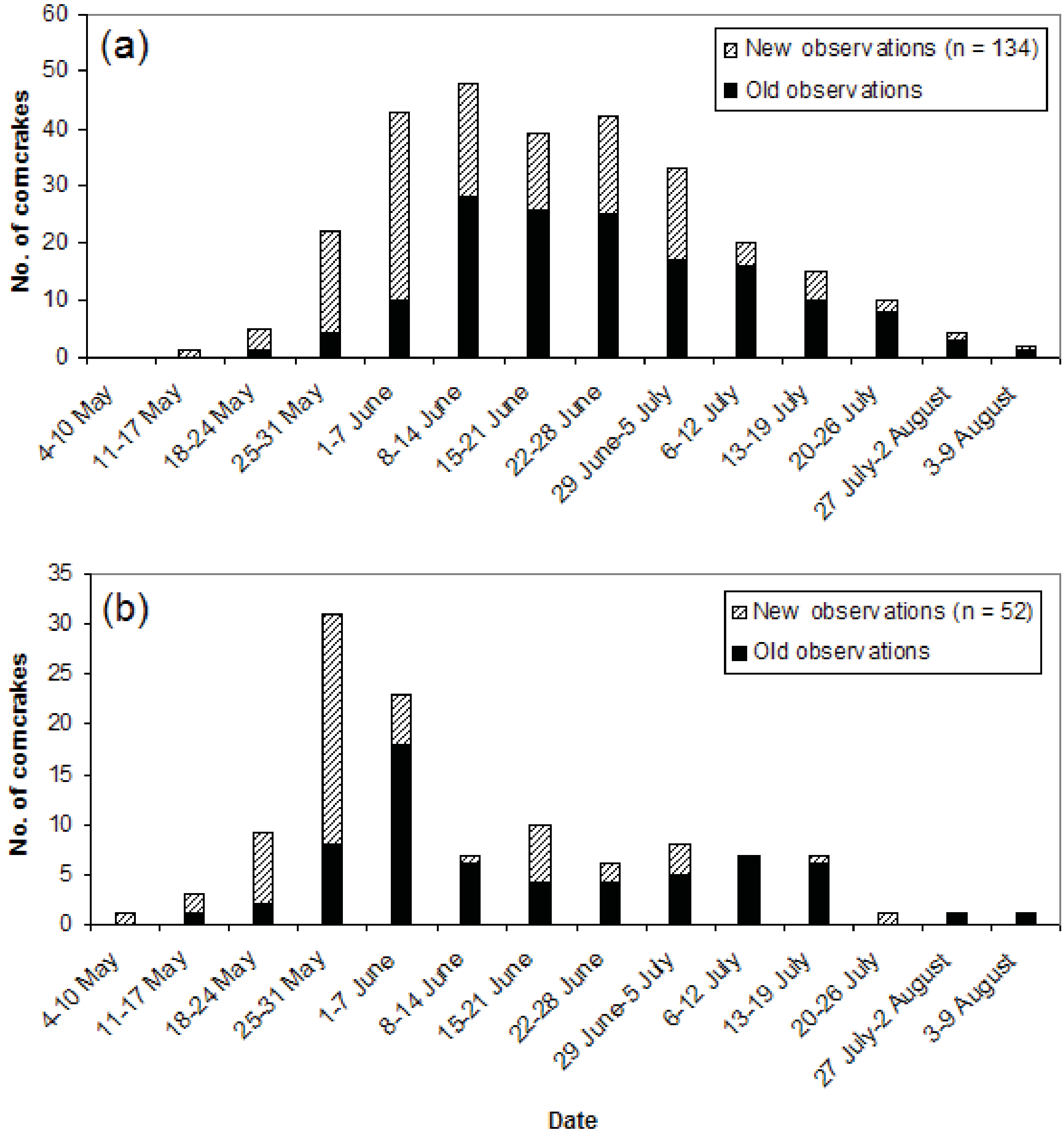


Figure 2. New and old weekly numbers of corncrake observations from (a) the eastern part of Norway and (b) the southern and western part of Norway; period 4 May – 9 August.

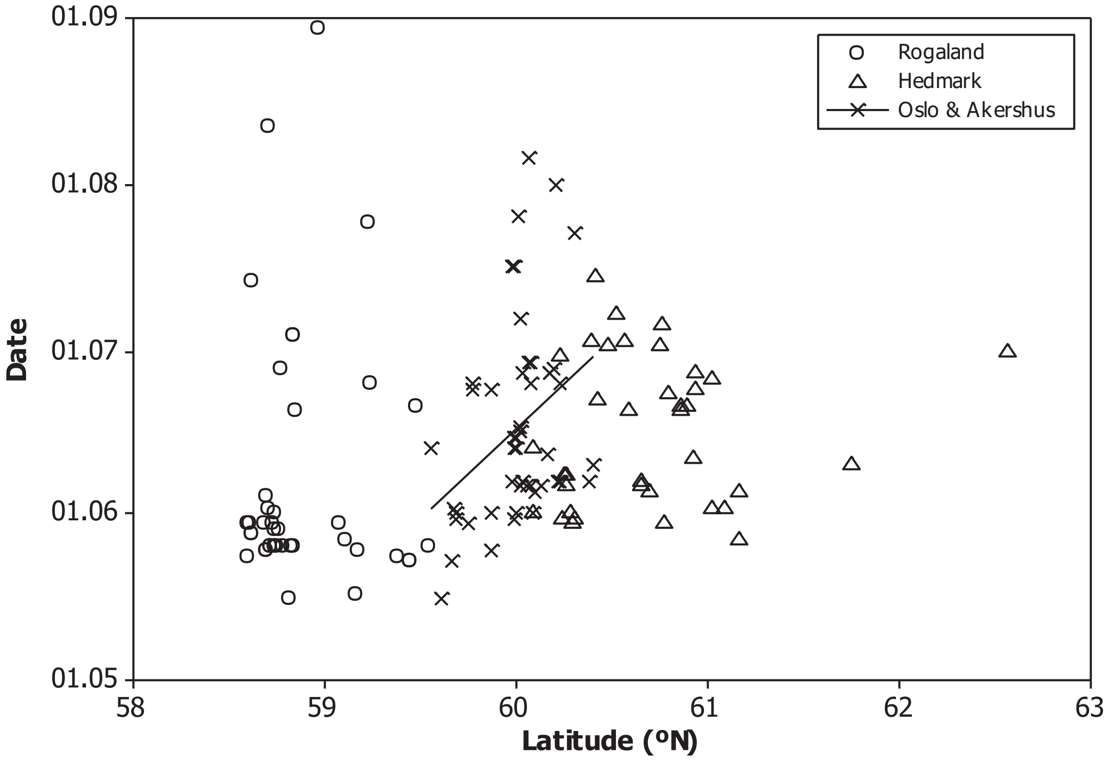


Figure 3. Arrival dates of corncrakes to new localities (radius 1 km) in relation to latitude for localities in Hedmark (n = 37), Oslo & Akershus (n = 49) and Rogaland (n = 40). Line is regression line for Oslo & Akershus.

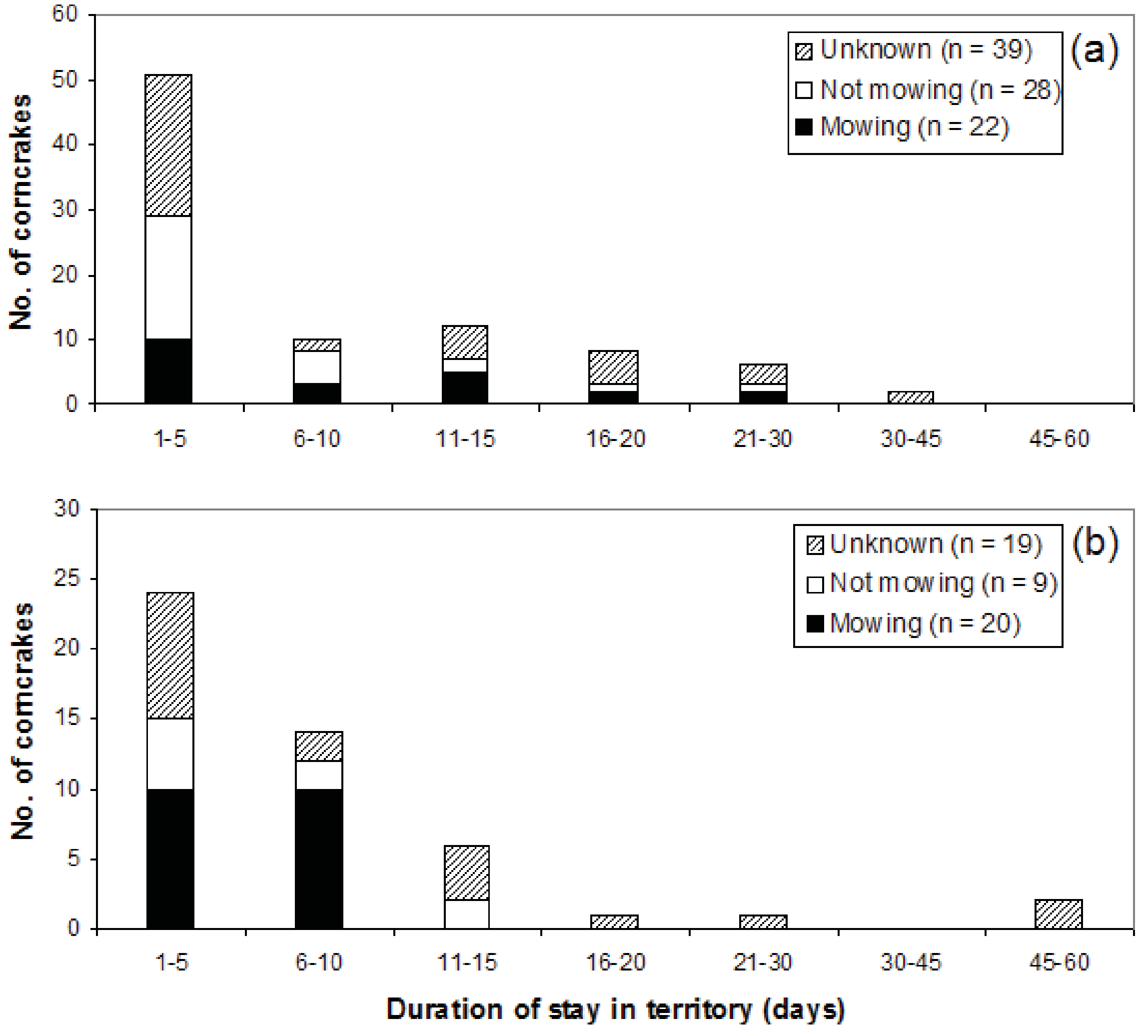


Figure 4. Frequency distribution of corncrakes' duration of stay in territories in (a) E Norway (n = 89) and (b) SW Norway (n = 48); with reasons for disappearance from territories.

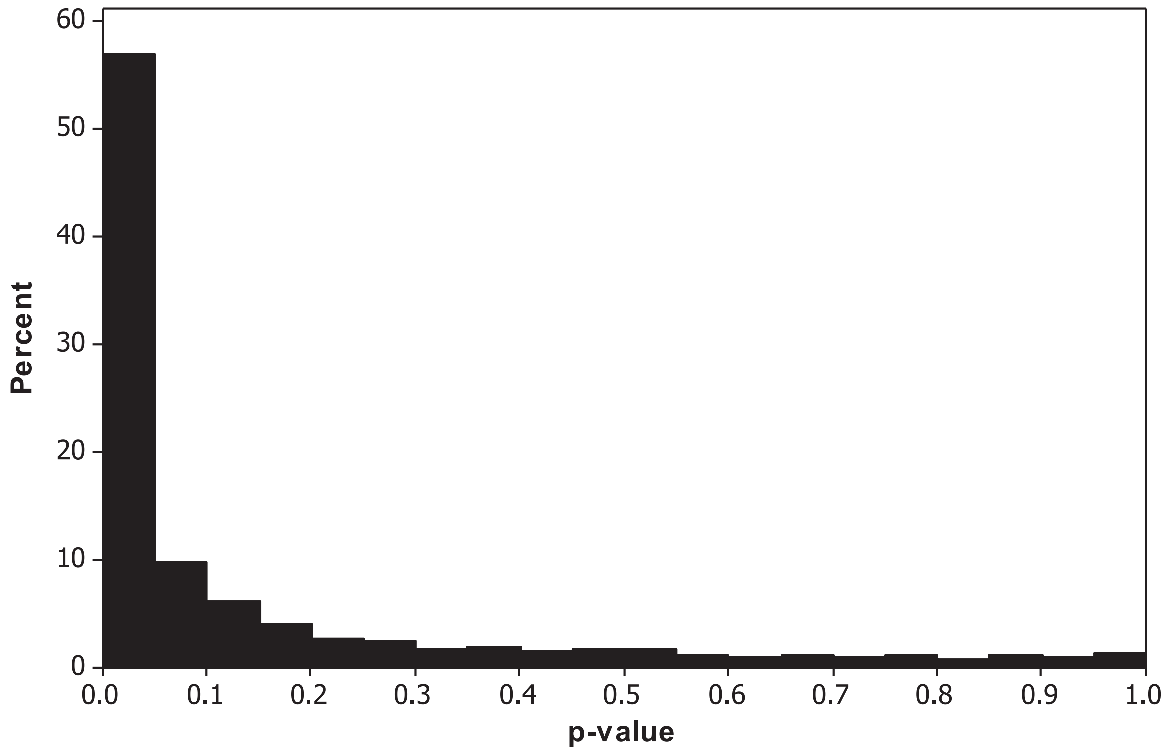


Figure 5. Frequency distribution of probabilities (p-values) for pairs of corncrake recordings (n = 3403) to be from the same individiual; based on the conservative discriminant function analysis of PPD-I values.

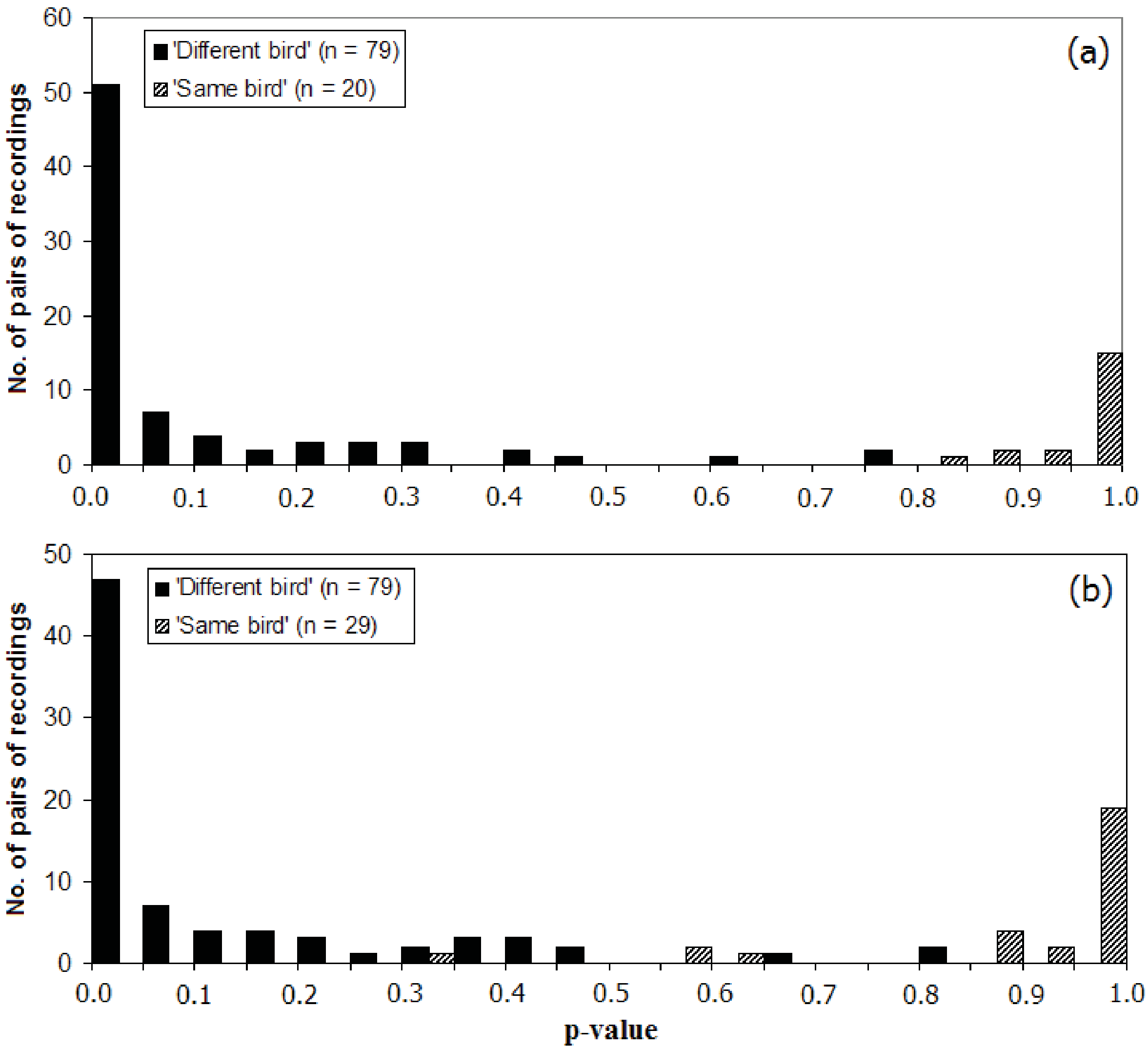
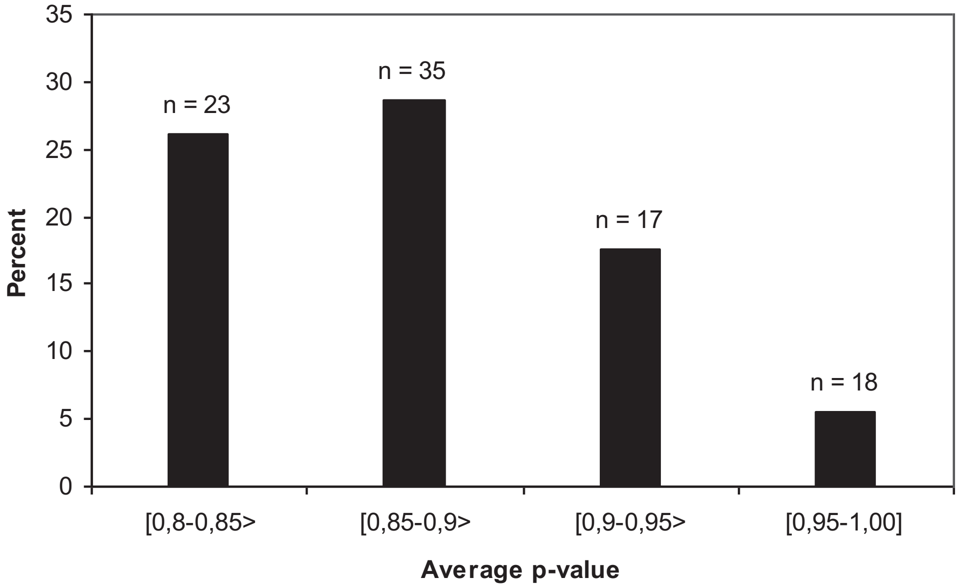


Figure 6. Distribution of probabilities (p-values) for 'same bird' pairs and 'different bird' pairs of corncrake recordings to be from one individual; based on (a) the conservative discriminant function analysis of PPD-I values, and (b) the liberal discriminant function analysis of PPD-I values.



Figur 7. Frequency distribution of degree of overlap in observation dates of potential corncrake movements in the four investigated average probability (p-value) intervals, based on a total of four discriminant function analyses of PPD-I and PPD-II.

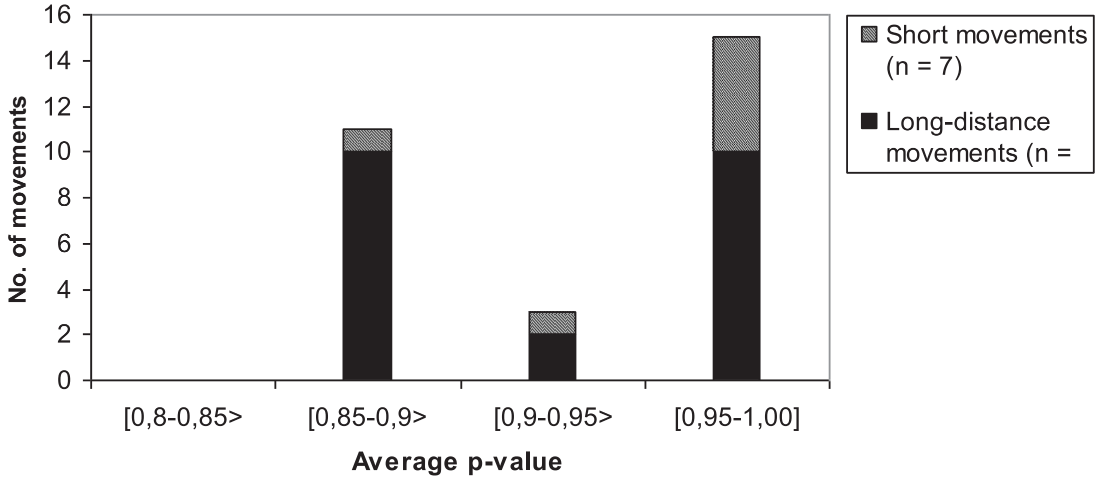


Figure 8. Frequency distribution of short (< 2 km) and long-distance (> 17 km) corncrake movements presented in this study in the four investigated average probability (p-value) intervals, based on a total of four discriminant function analyses of PPD-I and PPD-II.

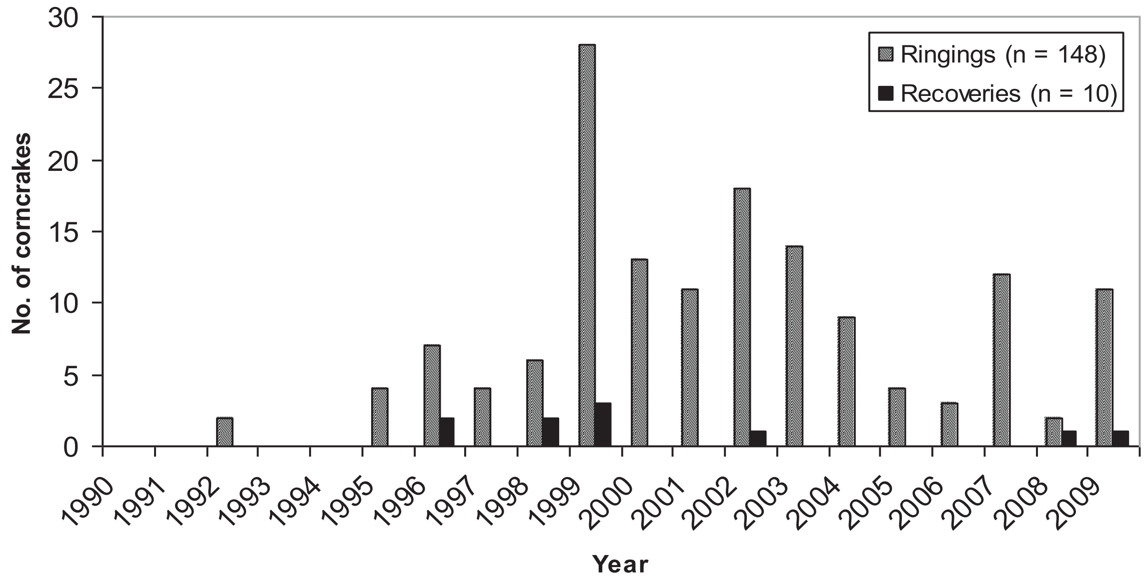


Figure 9. Yearly distribution of corncrake ringings in Rogaland, and recoveries within the breeding season in Norway; period 1990-2009. One recovery outside Rogaland (Aust-Agder in 2002).

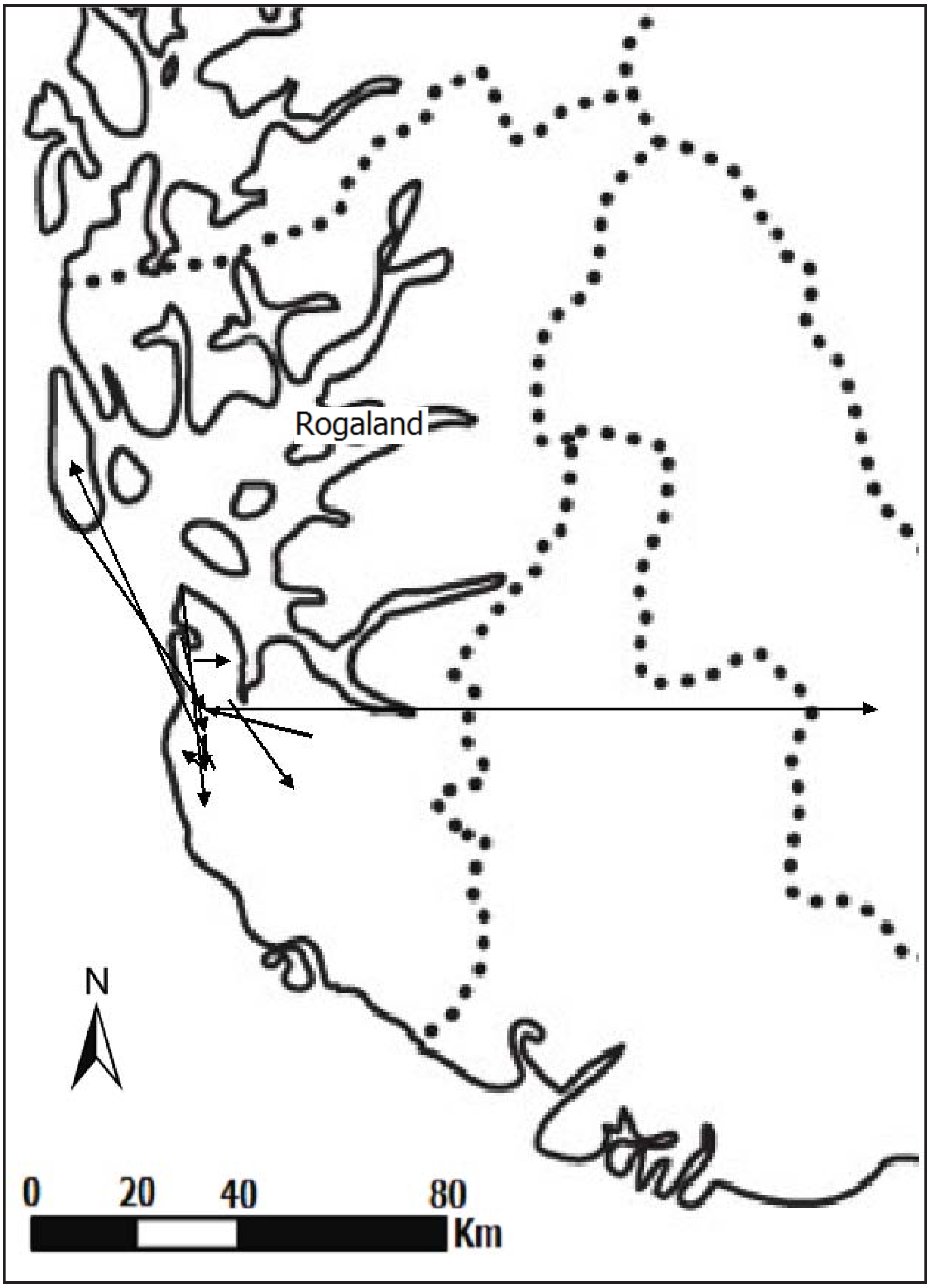


Figure 10. All adult corncrake movements of at least 5 km found by ringing in Norway (n = 10). The map shows S and SW Norway.

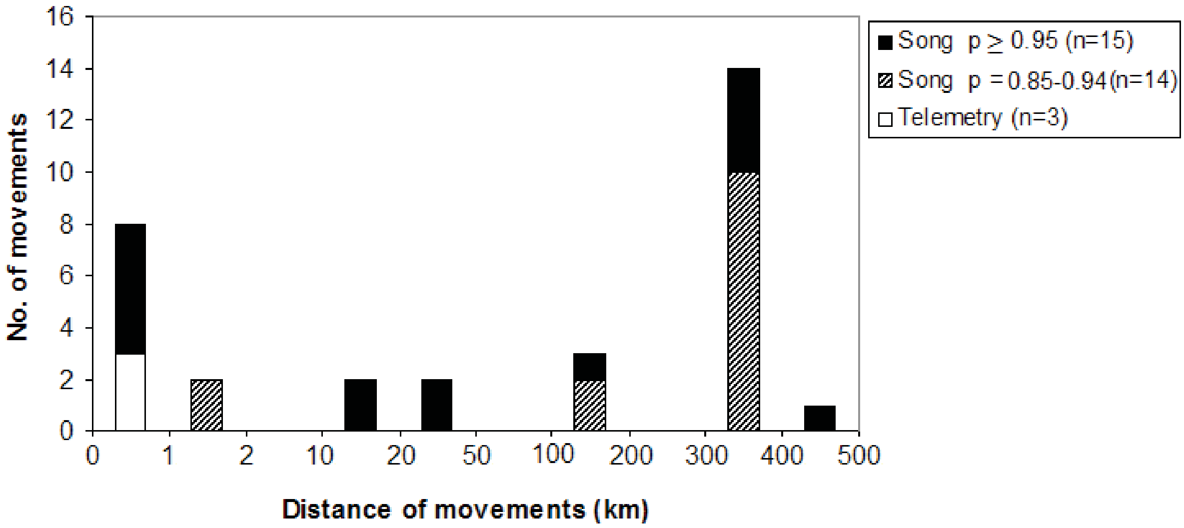


Figure 11. Frequency distribution of distances of corncrake movements longer than 300 m, with methods for finding the movements (song = individual song characteristics; p = probability).

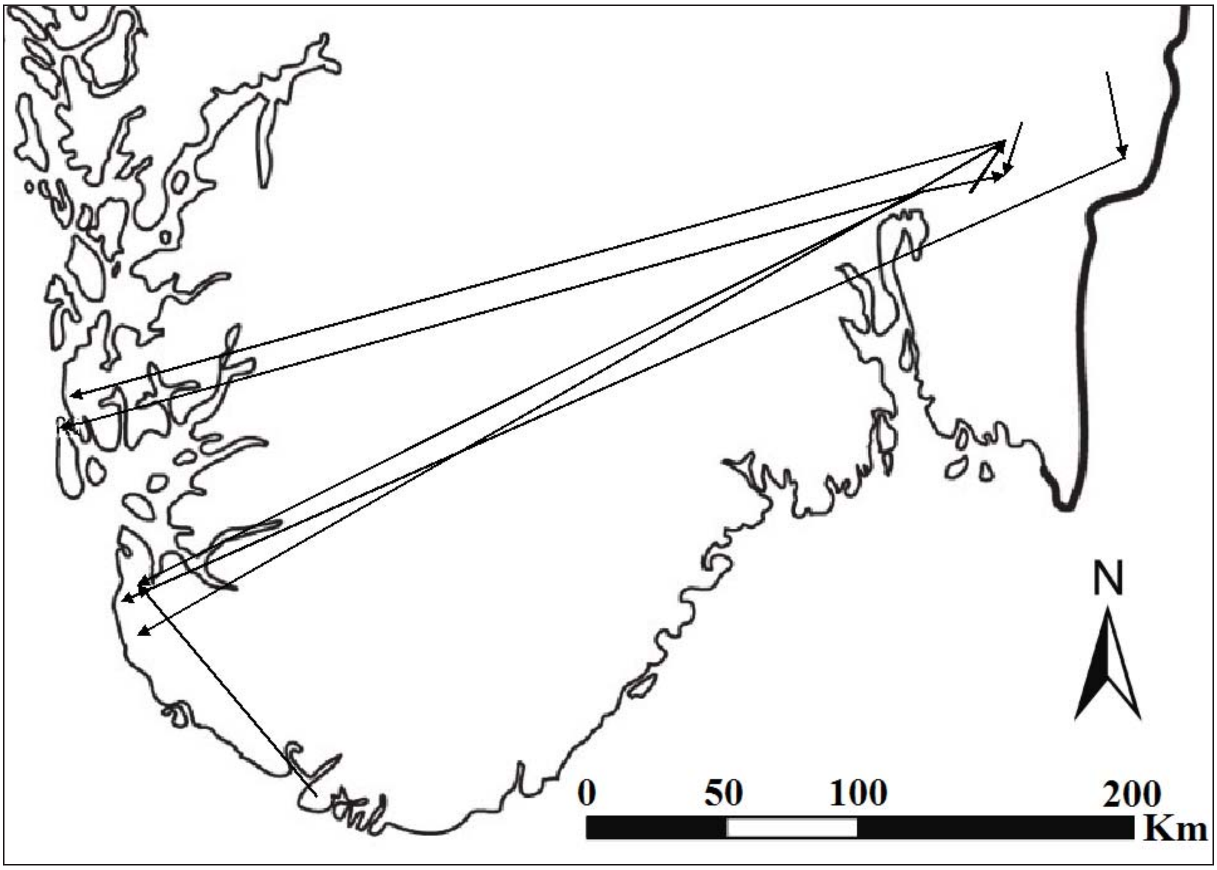


Figure 12. Long-distance corncrake movements (> 17 km) in Norway found by song identification with average probabilities (p-values) ≥ 0.95 (n = 10); based on a total of four discriminant function analyses of PPD-I and PPD-II values.

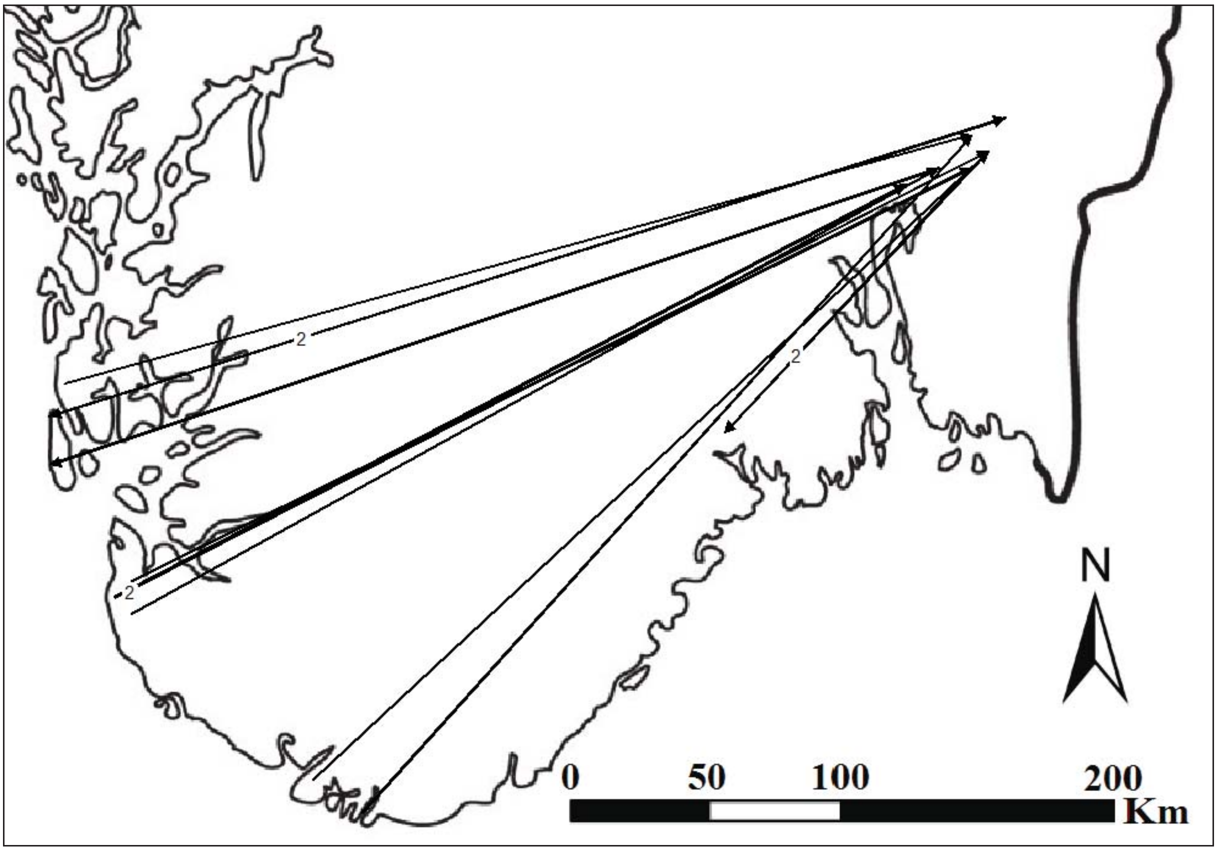


Figure 13. Long-distance corncrake movements (> 17 km) in Norway found by song identification with average probabilities (p-values) 0.85-0.94 (n = 12); based on a total of four discriminant function analyses of PPD-I and PPD-II values. A ‘2’ is added in three cases, where two movements are hard to distinguish from each other.

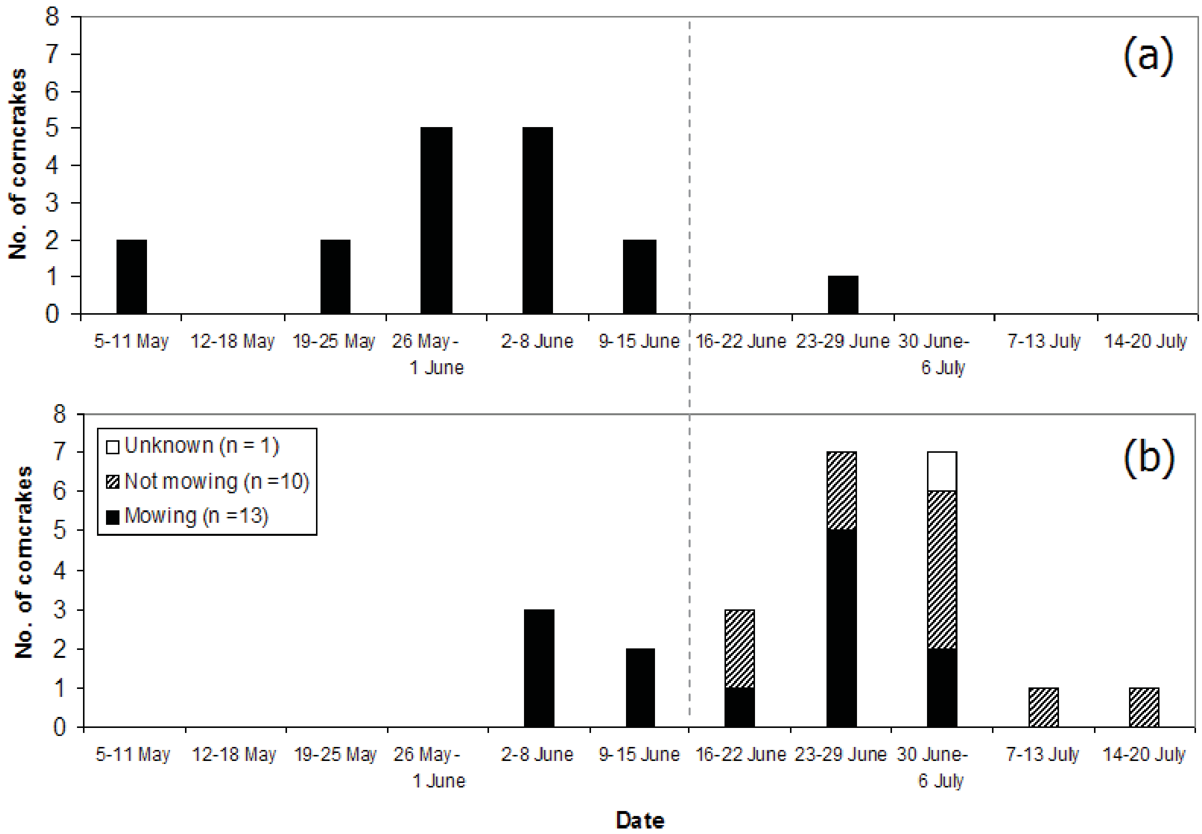


Figure 14. Frequency distribution of (a) corncrake arrival times to assumed first territories in Norway before movements were made (n = 17); and (b) corncrakes arrival times to new territories after movements made (n = 24), with reasons for movements. All movements ≥ 1.0 km. Dotted line separates arrivals prior to 16 June from arrivals from 16 June and onwards.

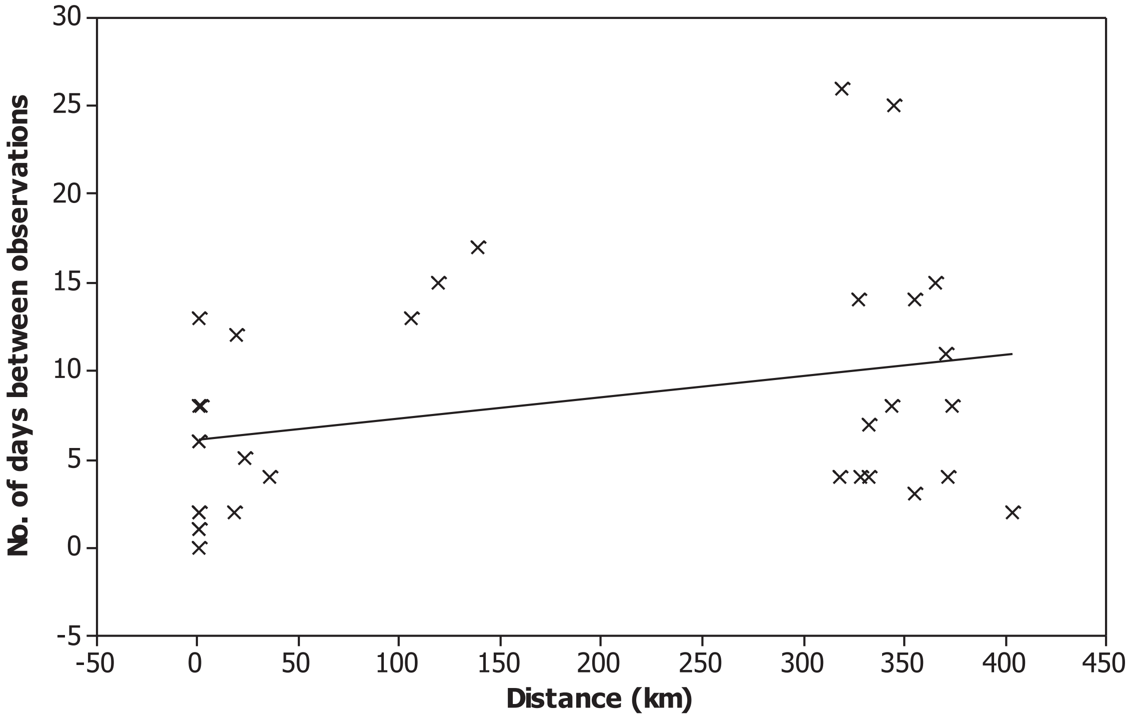


Figure 15. Number of days between observations in territories prior to and after movements in relation to distance of movements (n = 32).

Appendix

A table of all presented movements in this study, sorted after average probability (p-value), is shown on the next page of the appendix.

Abbreviations in table:
Munincip. = Munincipality
Cty. = County
AK = Akershus
HE = Hedmark
RO = Rogaland
TE = Telemark
VA = Vest-Agder
CNS-I = Linear discriminant function analysis of PPD values in syllable-I, based on conservative classification
LIB-I = Linear discriminant function analysis of PPD values in syllable-I, based on liberal classification
CNS-II = Linear discriminant function analysis of PPD values in syllable-II, based on conservative classification
LIB-II = Linear discriminant function analysis of PPD values in syllable-II, based on liberal classification
Avg. = Average
Telem. = Telemetry
*r*1 = correlation SYL1
*r*2 = correlation SYL2
Dist. = Distance (km)

Territory before movement				Territory after movement				Probability					Correlation		Dist.	Reason
Locality	Munincip.	Cty.	Duration of stay	Locality	Munincip.	Cty.	Duration of stay	CNS-I	LIB-1	CNS-2	LIB 2	Avg.	r1	r2		
Pollestad 1	Klepp	RO	26 May - 31 May	Pollestad 2	Klepp	RO	1 June					Telem.			0.3	Mowing (?)
Pollestad 2	Klepp	RO	1 June	Pollestad 3	Klepp	RO	2 June					Telem.			0.4	Mowing (?)
Anda 1	Klepp	RO	29 May - 3 June	Anda 2	Klepp	RO	3 June					Telem.			0.4	Mowing
Nugguren	Kongsvinger	HE	30 May - 8 June	Bråta	Eidskog	HE	13 June - 26 June	0.99	0.99	0.99	0.99	0.99	1.00	1.00	23.4	Mowing
Tjelta 1	Sola	RO	20 June - 23 June	Tjelta 2	Sola	RO	6 July - 16 July	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.5	Not mowing
Lunder	Sørum	AK	28 June - 29 June	Hønsi	Sørum	AK	(17 June? -) 7 July	0.98	0.98	0.99	0.99	0.98	0.99	0.99	0.6	Not mowing
Leikvoll	Sørum	AK	7 June - 15 June	Esval 2	Nes	AK	27 June - 29 June	0.98	0.98	0.99	0.99	0.98	0.99	1.00	19.2	Mowing (?)
Bossemoen	Kongsvinger	HE	8 June - 13 June	Tronbøl	Kongsvinger	HE	15 June - 26 June	0.98	0.98	0.97	0.97	0.97	0.99	0.98	0.5	Not mowing
Bråta	Eidskog	HE	13 June - 26 June	Reve	Klepp	RO	28 June - 3 July	0.97	0.96	0.98	0.98	0.97	0.98	0.98	403.7	Mowing (?)
Store Brennengen 1	Oslo	Oslo	7 June - 8 June	Dysjaland	Sola	RO	4 July - 16 July	0.96	0.96	0.98	0.98	0.97	0.99	1.00	319.0	Not mowing
Maridalen kirke	Oslo	Oslo	1 June - 15 June	Hauge	Karmøy	RO	19 June	0.97	0.97	0.96	0.96	0.97	0.94	0.93	318.1	Not mowing
Pollestad 3	Klepp	RO	2 June - 3 June	Lynghaug	Klepp	RO	5 June - 8 June	0.97	0.97	0.96	0.96	0.97	0.99	0.99	0.3	Mowing (?)
Tronbøl	Kongsvinger	HE	15 June - 26 June	Vestre Berger 2	Kongsvinger	HE	2 July - 21 July	0.94	0.94	0.99	0.99	0.97	0.97	1.00	0.7	Mowing
Esval 2	Nes	AK	27 June - 29 June	Ualand	Hå	RO	14 July - 15 July	0.95	0.95	0.98	0.98	0.96	0.99	0.99	365.5	Not mowing
Hananger	Farsund	VA	10 May - 7 June	Tjelta 1	Sola	RO	20 June - 23 June	0.97	0.97	0.96	0.96	0.96	0.99	0.98	106.1	Mowing (?)
Store Brennengen 2	Oslo	Oslo	15 June - 25 June	Frøyhov	Nes	AK	29 June - 9 July	0.97	0.97	0.93	0.95	0.96	0.99	0.88	35.3	Not mowing
Esval 1	Nes	AK	27 June - 29 June	Tornesvatnet	Haugesund	RO	2 July - 17 July	0.94	0.94	0.96	0.96	0.95	0.99	0.98	354.8	Not mowing
Bekkevoll	Nes	AK	7 June - 27 June	Ramdal	Nes	AK	29 June (- 17 July?)	0.97	0.97	0.93	0.93	0.95	0.97	0.94	17.8	Mowing
Revtangen	Klepp	RO	26 May - 29 May	Vestgard	Nes	AK	6 June - 16 June	0.93	0.94	0.93	0.94	0.94	0.99	0.95	373.2	Mowing
Leanuten	Sandnes	RO	28 May - 30 May	Leikvoll	Sørum	AK	7 June - 15 June	0.88	0.89	0.96	0.96	0.92	0.97	0.98	344.3	Mowing
Helgeneset	Kongsvinger	HE	6 June - 24 June	Vestre Berger 1	Kongsvinger	HE	30 June - 1 August	0.87	0.88	0.92	0.93	0.90	0.97	0.97	1.0	Mowing
Austad kirke	Lyngdal	VA	24 May - 2 June	Rustad	Nes	AK	6 June	0.91	0.92	0.87	0.87	0.89	0.93	0.88	328.5	Mowing (?)
Gjerda	Time	RO	4 June - 12 June	Hauger	Nittedal	AK	16 June - 18 June	0.86	0.89	0.89	0.90	0.88	0.95	0.94	332.8	Not mowing
Breidholen	Klepp	RO	29 May - 1 June	Skjerven	Oslo	Oslo	15 June - 12 July	0.79	0.85	0.93	0.94	0.88	0.96	0.98	327.6	Mowing (?)
Tærud	Skedsmo	AK	15 June - 17 June	Grønnerød 2	Skien	TE	2 July - 22 July	0.88	0.88	0.85	0.86	0.87	0.92	0.89	119.2	Mowing
Munkeruddalen	Nes	AK	6 June - 15 June	Grønnerød 1	Skien	TE	2 July - 22 July	0.86	0.88	0.85	0.87	0.86	0.96	0.97	138.5	Not mowing
Hananger øst	Farsund	VA	10 May - 2 June	Auli kirke	Nes	AK	27 June - 29 June	0.94	0.94	0.77	0.81	0.86	0.97	0.88	345.0	Mowing (?)
Hauge	Karmøy	RO	19 June	Skarnes Bilhuggeri	Sør-Odal	HE	30 June	0.81	0.84	0.90	0.90	0.86	0.93	0.91	371.1	Unknown
Hauger	Nittedal	AK	16 June - 18 June	Mosbron	Karmøy	RO	25 June - 8 July	0.78	0.83	0.92	0.92	0.86	0.95	0.94	332.6	Mowing
Tornesvatnet	Haugesund	RO	23 May - 13 June	Esval 1	Nes	AK	27 June - 29 June	0.86	0.87	0.85	0.87	0.86	0.95	0.94	354.8	Not mowing
Auli kirke	Nes	AK	27 June - 29 June	Tangen	Nes	AK	7 July - 23 July	0.87	0.88	0.81	0.83	0.85	0.94	0.91	1.3	Not mowing
Skarnes Bilhuggeri	Sør-Odal	HE	30 June	Stange	Karmøy	RO	4 July - 17 July	0.79	0.83	0.89	0.89	0.85	0.94	0.93	371.6	Not mowing