BIBLIOGRAPHY SYNTHESIS ON CORNCRAKES

- CURRENT KNOWLEDGE ON THE SPECIES AND FEEDBACK OF CONSERVATION MEASURES -

LPO Anjou – CEFE-CNRS

CORNCRAKES ACTIONS PLAN

BIBLIOPGRAPHY SYNTHESIS ON CORNCRAKES

CURRENT KNOWLEDGE AND FEEDBACK OF CONSERVATION MEASURES

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SUMMARY

In France, corncrakes' numbers have dropped to a few hundred singing males in recent years. This decline is largely due to the intensification of agricultural practices such as early, rapid, and simultaneous mowing, and to the disappearance and fragmentation of their habitat. In France, the species is mainly found in the meadows of the floodplains, but in other countries they can also occupy other kind of wetlands or crops. While both males and females seem to prefer grasslands mowed the previous year, offering them a specific vegetation structure and litter thickness, unmanaged grasslands are also used in large numbers. Arrivals and departures at the breeding sites occur continuously throughout the season. In addition, within the same breeding season individuals may travel several hundred kilometers in response to disturbances or in search of mates. Current knowledge of habitat use during breeding, especially by females, is very low and based on sparse data. For example, the distance between nest and the singing male is known to be 160 meters for one of the nine pairs monitored by a pilot study in Scotland. Singing males are posted at least 200 meters apart, although they make regular visits to neighboring territories. According to a study based on genetic analysis, independent but still non-flying juveniles may be located between 149 and 601 meters from their father's singing post. Regarding the age of fledging of juveniles, the only knowledge is the departure of juveniles from the birth plots on average at 44 days. Studies have shown that all the juveniles reach the ability to fly and females complete their molt by mid-September. Before this date, juveniles and molting adults remain vulnerable to mowing and can't reach distant refuge areas. Migration routes and winter areas of corncrakes breeding in France are not known. The largest proportion of individuals of corncrakes seems to winter in southeast Africa, but the Scottish individuals followed by geolocators have wintered between Nigeria and Ghana and in the Congo basin.

Countries that have seen corncrake numbers increase in recent years have generally implemented a range of measures simultaneously. Effectiveness of the measures can only be evaluated through a correlation between measures and numbers of singing males. In most cases, mowing has been postponed to mid-August on some meadows and within a radius of 250 m around each singing male. In addition, early cover has been put in place before corncrakes' arrival, and mowing techniques avoiding direct mortality, with the presence of refuge areas, have been introduced. Some countries have also restored grassland habitats and rivers. The strong increase of the species observed in Eastern Europe in the 90's took place during the involuntary abandonment of cultivated plots. Other regions with sustained numbers are characterized by a heterogeneous landscape in terms of habitat type and by mowing dates allowing favorable habitats throughout the breeding season.

In conclusion, this literature review confirms that knowledge about corncrakes in general and the effectiveness of corncrake management measures specifically is incomplete, sometimes even non-existent, and is largely based on small sample sizes and often indirect methods. Ambitious and if possible larger-scale studies, coordinated at a European level, are needed to fill these gaps.

GOALS

The Corncrakes is member of the Rallidae (Gruiformes) mainly found in France in the meadows of the floodplains (Deceuninck, 1999). The species is internationally protected by the Bern Convention and is classified in Annex 1 of the Birds Directive in the European Union. Corncrakes are protected in France under Articles L-411.1 and L-411.2 of the Environmental Code by the decree of October 29, 2009. This decree establishes legal protection of birds, eggs and nests as well as resting places and breeding sites of the species. However, in the last few decades, the French population of corncrakes has declined in numbers and are found only in isolated areas, while the species was formerly distributed throughout the territory. The species is now classified as "Endangered" in the red list of breeding birds in France (MNHN, 2020). Several conservation programs and actions have been set up in France, including two LIFE programs in 1997 and 2011 and two National Action Plans in 2005 and 2013. Despite these measures, corncrakes in France are still in decline, with the number of singing males declining from 2,450 in the 1980s to 223 in 2020 (Broyer, 1985 and LPO49 data).

This document was written following the conclusions in 2019 of the last Corncrake National Action Plan, which highlighted the lack of knowledge to stop the decline of the species. This document serves two purposes : to present current knowledge on corncrakes and their ecology and to synthesize feedback from conservation actions that have taken place in Europe. It is based on scientific publications and international study reports, and is supplemented by comments from managers and scientists interviewed specifically for this synthesis.

MÉTHODOLOGY

The bibliographic corpus was composed thanks to different electronic resources and online databases, academic and national libraries, and contacting selected individuals and organizations. Computer queries were made under the keywords "*Crex crex*" and "Corncrake" and the declination of the species name in different languages. The documents of the bibliography deal directly with the Corncrake or, more rarely, with a group of species that includes the latter.

1. ELECTRONIC RESOURCES AND DATABASES

A. ACADEMIC SEARCH ENGINE AND CNRS ONLINE DATABASES

Most of the references were found thanks to Google Scholar and bibliographic databases used by the CNRS such as Web of Science, Scopus, HAL and Open Dissertations.

All recent scientific articles matching the query were retrieved mainly via Google Scholar, Web of Science and Scopus. A part of the documents was also allowed by other sources (online journals, libraries, Researchgate, direct contact with the authors...).

Some of the "grey" literature - literature not published by publishers, such as theses, internship reports, action plans or study reports - was retrieved through Google Scholar, HAL and Open Dissertations. However, most of the grey literature was located and retrieved through the other search paths described below.

B. ONLINE JOURNALS

Some articles which had not been detected or which were not accessible previously (in particular the oldest ones) were found also on the portals of the journals.

C. LIFE DATABASE

The LIFE program database provided descriptions of each LIFE that was carried out on the species. There are two kinds of reports, the end reports of the projects called "Layman reports" and the "After-life report" for some projects.

This corpus, related to LIFE but also to other action plans, was enriched by reports sent by different people involved in the conservation plans and further online research.

D. GOOGLE

The search engine google.com was queried on different keywords ("Corncrake report", "*Crex crex*" ...). Various international documents were retrieved such as thesis and internship reports, reports related to LIFE as well as other action plans and technical guides.

2. LIBRARY

Other documents were recovered thanks to French and international libraries which have archived and digitized some of them. These documents included theses, training reports, action plans, journals and books.

The references of the documents were obtained by the following tools according to the countries: Sudoc (France), thèse.fr (France), Worldcat (International), Opengrey (Europe), BASE - Bielefeld Academic Search Engine (international), BICTEL (France and Belgium), DART-Europe (Europe), DissOnline (Germany), DIVA (Scandinavia), EThOS (United Kingdom), NDLTD : Networked Digital Library of Theses and Dissertations, RERODOC (Switzerland).

Concerning older scientific publications or in journals, the tools cited have made it possible to determine the location of these articles. More than fifteen articles and books were retrieved or consulted at the CEFE Library in Montpellier or at the National Museum of Natural History in Paris. Others could be retrieved from journals digitized by libraries.

Theses and international internships reports were largely detected by this circuit. If the documents could not be obtained directly (about half of the theses), they were obtained physically at the library, by contact with the authors or with google.

3. PEOPLE

Contacts with people involved in the conservation of the Corncrake in Europe led to obtaining theses, articles and documents on the management projects implemented. A large number of documents and personal comments dealing with the effectiveness of actions were obtained thanks to them.

STATUS OF THE SPECIES

The Corncrake, member of the Gruiformes and the Rallidae family, is the only species of the genus *Crex*. Its closest relative is the African Crake (Crex egregia), which nests in tropical Africa (Del Hoyo et al., 1996). The corncrake is a medium-sized migratory species (27-30 cm) with a wingspan of 46-53 cm. They weigh 140-235 g for the males used as reference in France, and 139-196 g for the females used as reference in Poland. Bear in mind that individuals from Western Europe, especially Scotland, are on average heavier than those from Eastern Europe (Fourcade, 2014). Their plumage is reddish-brown with black streaks and sexual dimorphism is very low, consisting only of a more pronounced blue on the head and neck for males (Figure 1). Immature birds can hardly be distinguished from adult females, while chicks are born covered with black down (Schäffer & Koffijberg, 2004). Corncrakes are inconspicuous, preferring to move under cover in tall grass. Individuals are generally solitary, although there is some social attraction for establishing territories (Budka & Osiejuk, 2013).

Figure 1*:* Representation of Corncrakes: 1. and 2. breeding adult males, 3. breeding adult females, 4. non-breeding adult males, 5. juveniles and 6. day-old chicks (from Schäffer & Koffijberg, 2004)

1. DISTRIBUTION AND POPULATION STRUCTURE

The Corncrake breeding range covers a large part of Europe and northern Asia (BirdLife International, 2016, Fourcade et al., 2013). This distribution is based on different singing males count protocols and with a geographical sampling bias with more surveys in the west of Europe (see Figure 2). The species' range during the breeding season was therefore modeled according to environmental parameters, species ecology and sampling biases (Fourcade et al., 2013) see Figure 3.

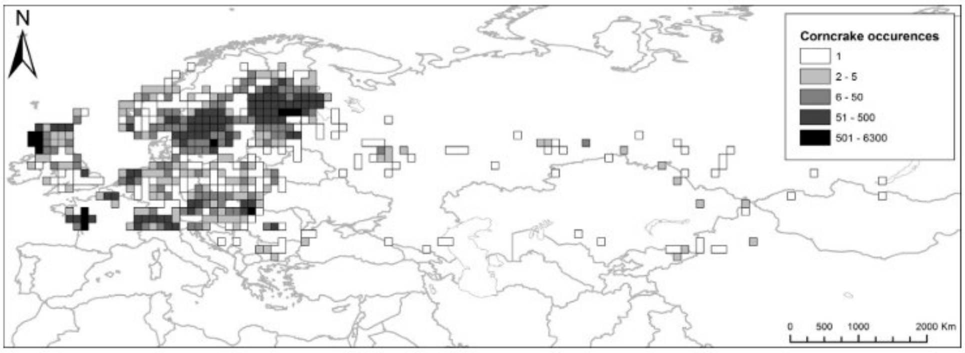

Figure 2 : *Distribution of male corncrakes detected during the breeding season (extracted from Fourcade et al., 2013)*

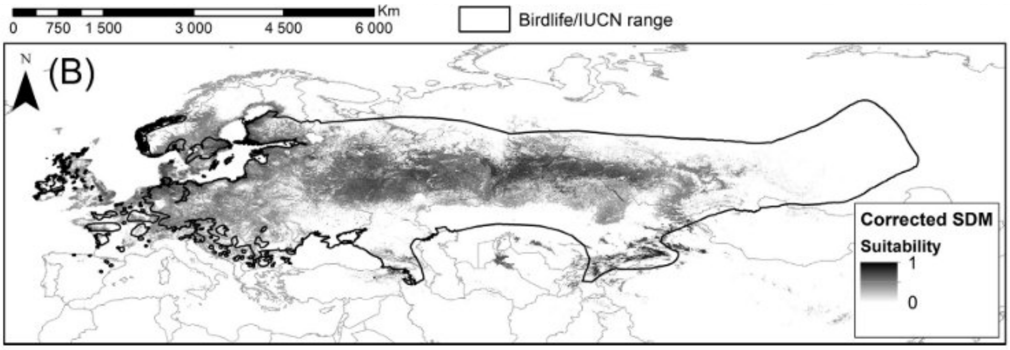

Fig. 3. Corncrake species distribution models, without correction (A) and with sampling bias correction based on the combination of two sub-models (Western and Eastern) and systematic subsampling of occurrences (B).

Figure 3 : Corncrakes breeding distribution model (probability of presence, suitability) taking into account sampling biases and environmental variables related to corncrake ecology (Fourcade et al., 2013)

A large-scale population genetics study was conducted over a large part of the breeding range (from France to western Russia) (Fourcade, 2014). This study is based on 496 samples collected from May to July in 2011 and 2012 in 15 different places in Europe.

The results of the analyses reveal that Corncrake populations show high diversity at the overall species-wide level, but also at the specific population level, even for those that have undergone a very sharp reduction in numbers in recent years (Fourcade, 2014; Fourcade et al., 2019). This is the case for the population in western France, which in 12 years, despite a significant decrease in the number of singing males, has seen a significant maintenance of genetic diversity given the size of the population (Fourcade et al., 2019). Furthermore, although analyses show little genetic structure across the range, three groups stand out within the overall population, one in Eastern Europe, one in Scotland and one including France and Italy (Fourcade, 2014; Fourcade et al., 2016). This is in addition to the fact that there is a demographic imbalance across the range, with the population trends of the western populations having recently declined significantly in contrast to those of the eastern populations. It is therefore hypothesised that gene flow from eastern to western European populations is predominant, and that this flow may bring genetic diversity to small peripheral populations and contribute to the low genetic structure observed and the genetic diversity maintained in small populations (Fourcade, 2014; Fourcade et al., 2016).

4. CORNCRAKE NUMBERS AND CONSERVATION STATUS

EUROPE

The European breeding population estimate in 2016 is 3 - 7 million singing males (BirdLife International, 2016). The population had previously been estimated at 92,000 - 233,000 singing males based on questionnaires reporting numbers for 34 European countries between 1985 and 1994 (Crockford et al., 1996). However, surveys in Russia showed that nearly 90% of the global population was present in its territory (Mischenko & Sukhanova, 1999).

In addition, the Corncrake population increased in several European countries in the 1990s. This is reated to political change in central and eastern European countries and reductions in farming intensity, such as the use of pesticides, and land abandonment (Koffijberg et al., 2016, Grishchenko & Prins, 2016). This can explain parallel increases observed between 1998 and 2003 in other European countries (Koffijberg et al., 2016). The status of the species on a global scale changed from "vulnerable" in the 1990s to "near-threatened" in 2004 and to "least concern" today (IUCN, 2016).

However, although numbers show considerable fluctuation, in many countries trends have now reversed from the peaks of the 1990s and corncrake populations are mostly in decline (Figure 4 and 5) (Koffijberg et al., 2016). This decline is particularly pronounced in the west of the breeding range and at the edge of the range, countries that also support low numbers.

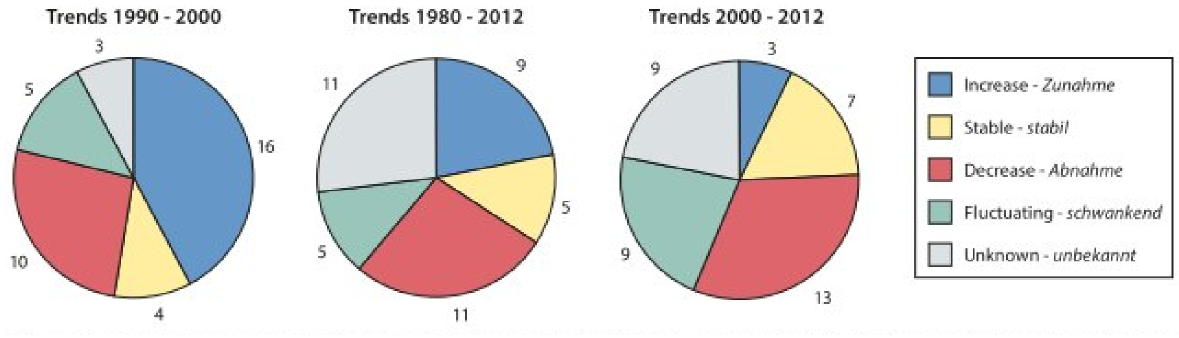

Figure 4 : Proportion of Corncrake populations trends in Europe from 2000 to 2012 (Koffijberg et al., 2016)

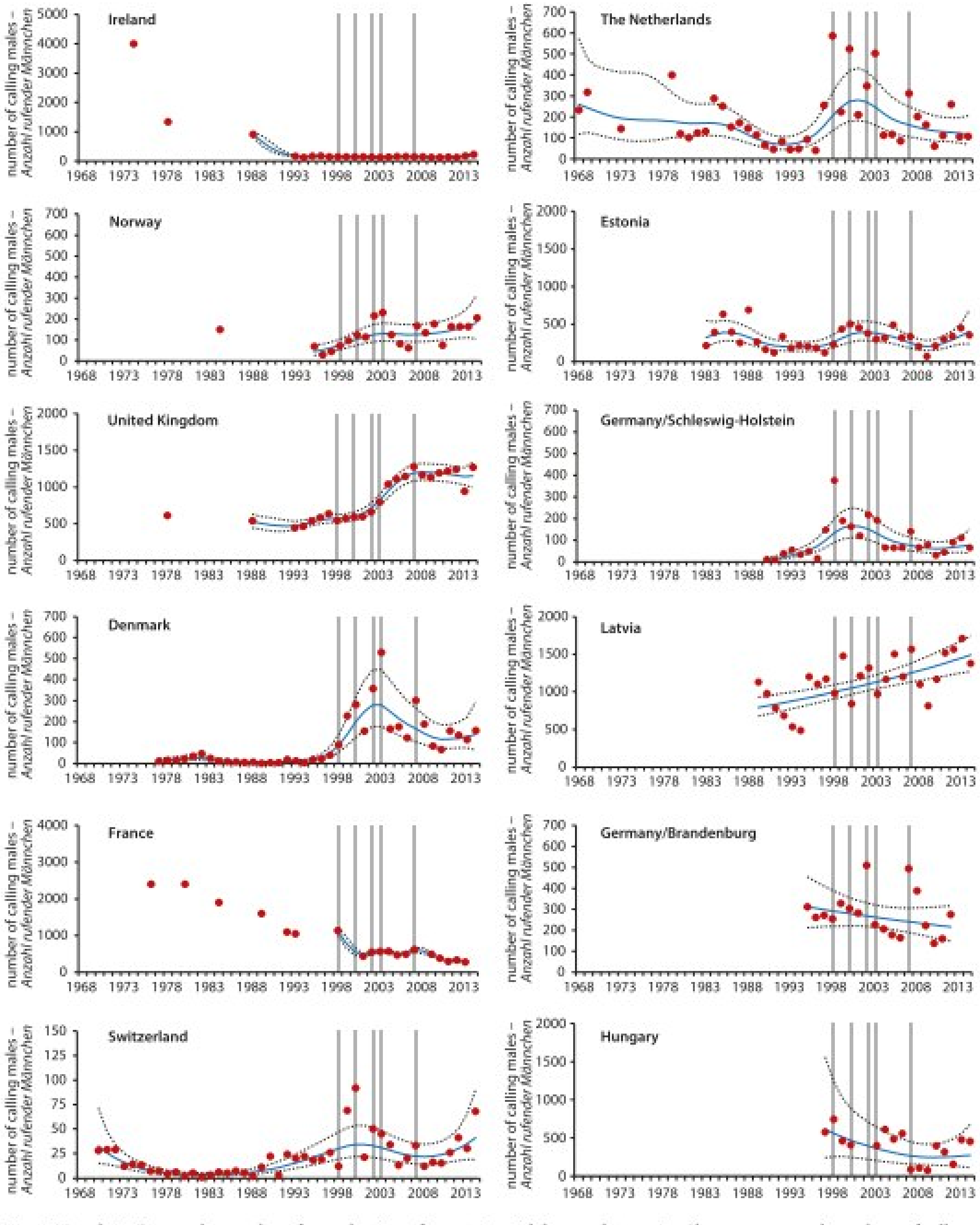

Figure 5 : Trends in singing male corncrake numbers for different countries (Koffijberg et al., 2016)

FRANCE

In France, corncrakes' numbers dropped from a maximum of 2,450 singing males in 1982-1984, to 223 singing males in 2020 (Broyer, 1985 and LPO49 data, figure 6). And corncrakes can be found now in few areas (Figure 7) (Fourcade, 2014). Corncrakes are now considered "endangered" on a national scale, and "critically endangered" on regional scales, with the exception of Pays-de-la-Loire where the species is "endangered" (MNHN, 2020), with low numbers recorded at departmental level (figure 8).

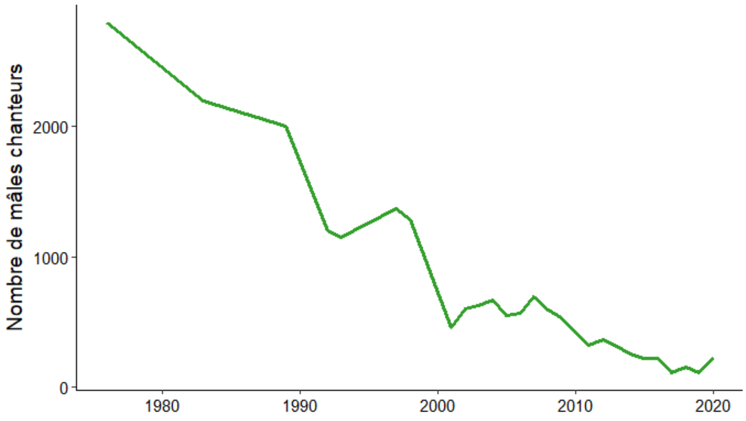

***Figure 6** : Evolution of the number of Corncrake singing males between 1980 and 2020 in France (PNA data, 2020)*

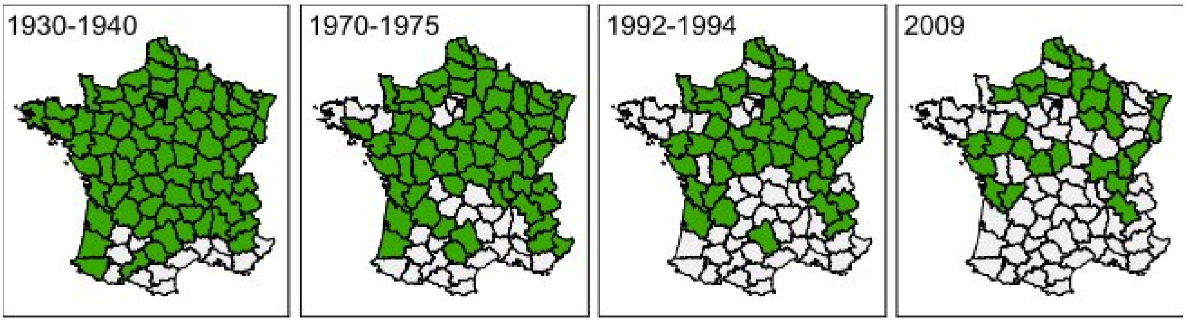

Figure 7 : Corncrake dstribution in France between 1930 and 2009 (Fourcade et al., 2013).

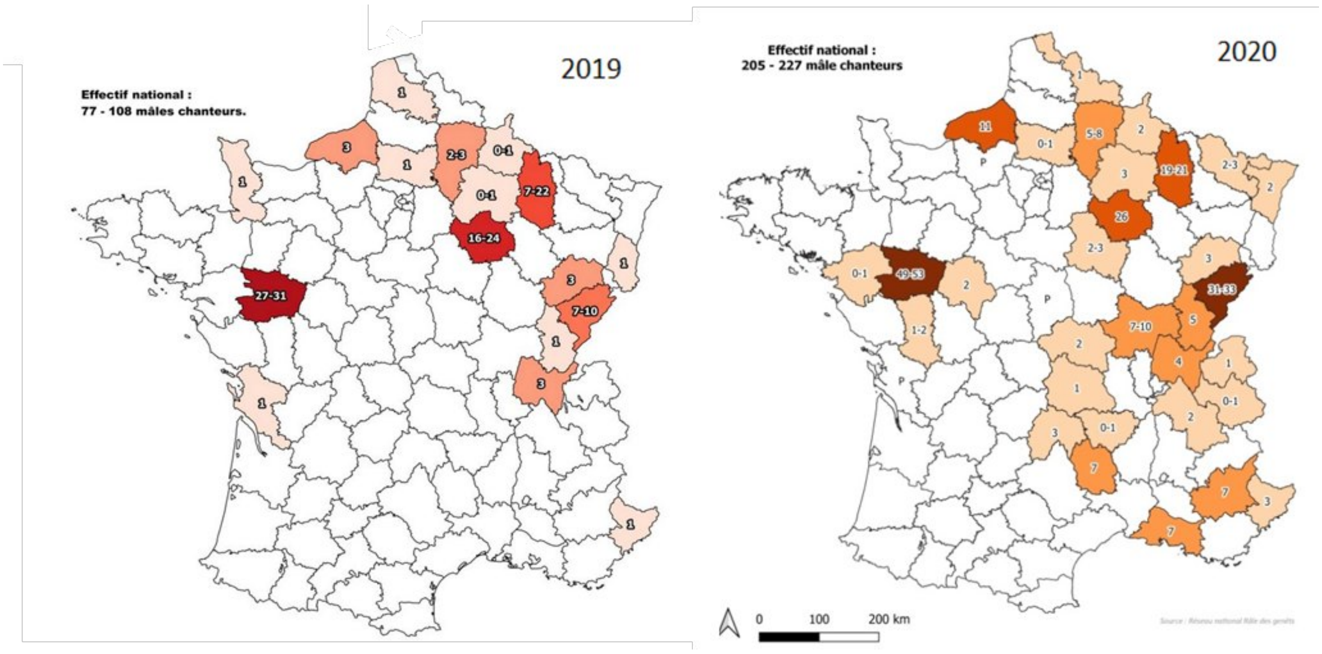

***Figure 8** : Distribution of French singing males by department in 2019 and 2020 (PNA data, 2020)*

5. THREATS TO THE SPECIES

The main threats to corncrakes are agricultural intensification and habitat loss. Indeed, early, rapid and synchronized mowing cause many breeding fails. Mechanised mowing increases the destruction of nests and non-flying juveniles, and, less intensely, the mortality of adults (Broyer, 1996; Green et al., 1997a; Pedrini et al., 2012; Glen A. Tyler et al., 1998). Other forms of agricultural intensification such as drainage, flood control, fertilization, or even application of inputs cause earlier mowing and less favorable habitats for corncrakes. These changes began in the early 20th century and accelerated in the 1960s, particularly in Western Europe (Abebe et al., 2006). In addition, the disappearance and fragmentation of grassland habitats and many wetlands are involved in the decline of the species (Abebe et al., 2006). Corncrakes' habitats are affected by soil artificialisation, conversion to maize, sunflower or cereal crops, and abandonment of grasslands and closure of the environment. Other threats less studied may also have an impact, such as climate change, changes in rainfall or water regime, or flooding of broods, especially by spring floods (Schäffer & Koffijberg, 2004; Tyler & Green, 2004). Predation and hunting can also have impacts, although this seems to be in lesser proportion compared to habitat losses (Baha El Din et al., 1996; Arbeiter & Franke, 2018, Tyler & Green, 2004). Threats outside the breeding area throughout the migration and wintering period remain unknown (Stowe & Green, 1997).

BIOLOGY AND ECOLOGY OF CORNCRAKE

1. HABITAT SELECTION

Most of the relevant studies are based on the locations used by males to sing at night, which may differ from the areas visited during the day. Indeed, nocturnal sites may be selected to amplify songs from a slightly elevated position and may not be good indicators of optimal breeding habitats. On the other hand, if optimal habitat is not present in sufficient area, it is also possible that some males have no choice but to select lower quality sites. Finally, the habitat used by females may differ from those studied by the majority of papers through the location of males. Only one study, presented below, has attempted to answer these questions by investigating which habitats are occupied by females and which have good reproductive success.

A. HABITATS USED

Corncrakes breed mainly in meadows of tall grass. However habitat selection can change seasonally and regionally. In the western part of their breeding range, corncrakes are strongly associated with meadows in floodplains (Budka & Osiejuk, 2013 ; Broyer, 1992). But they are also present at high altitudes meadows such as in the Alps (Brambilla & Pedrini, 2011; Inderwildi et al., 2017c) and on the coasts grassland such as in Scotland and Ireland (Glen Tyler, 1996a). Several studies show a greater preference for hay meadows than for pastures, but without mentioning grazing intensity (Keišs, 2005, Berg & Hiron, 2012, Budka & Osiejuk, 2013).

In addition to hay meadows, other habitats in Europe can support high densities of corncrakes. Indeed, while in some regions several authors have shown that song males avoid cultivated fields (see e.g. Budka & Osiejuk, 2013; Keišs, 2005), in other regions significant numbers of corncrakes breed in alfalfa, caraway, rapeseed and cereal crops such as wheat. For example, in the Netherlands significant numbers of corncrakes breed in alfalfa and winter wheat fields on polder clay soils (Koffijberg, 2017). Similarly, in Romania, significant numbers of singing males were detected in alfalfa fields (Dorresteijn et al., 2015). In eastern Norway, some individuals breed in corn fields (Direktoratet for naturforvaltning, 2008). Koffijberg (2017) talks also about breeding observed in field margins in the Netherlands.

In addition, other wetland habitats may be selected by corncrakes. Indeed, in the study by Dorresteijn et al. (2015), the second most common habitat type occupied by corncrakes after crops was Phragmita (*Phragmites australis*) (31 males recorded in this habitat compared to 25 in hay meadows and 9 in pastures). In Germany, in the Schorfheide-Chorin protected area, very few corncrakes are present but they occupy bogs (Schorfheide-Chorin, 2019) and the species is also observed in marshes near Ljubljana in Slovenia (DOPPS - Birdlife Slovenia, 2003).

Fallows are also selected by corncrakes in some areas. For example, in Romania and Sweden, Dorresteijn et al. (2015) and Berg & Hiron (2012) both showed that some singing males established their territories within fallows (13individuals out of 114 and 15% of territories respectively versus 25 individuals out of 114 and 14% in non-abandoned mowing meadows). Furthermore, the establishment of territories in unused grasslands or abandoned agricultural plots has been shown and can be very important in terms of numbers (Keišs, 2005, Berg & Hiron, 2012, Grishchenko & Prins, 2016). Keišs

(2005) showed that in Latvia densities of singing males were higher in abandoned meadows (3.5/km^2) than in unmanaged meadows (2.85/km^2) and in other types of abandoned crops (2.7/km^2), and densities were lowest in mowed grasslands (1.6/km2). In Sweden, Berg & Hiron (2012) also showed 31% of the territories were in unmanaged grasslands and 14% in mowed grasslands. In addition, Grishchenko & Prins (2016) observed 22 singing males within 96 abandoned plots in Western Russia in 2014. These males were detected mainly on plots that had not been used for five to 15 years. These plots were 80-90% dominated by herbaceous plants such as *Anthriscus sylvestris*, *Galium odoratum* and *Trifolium pratense*.

However, none of these studies compared vegetation characteristics and height with those of mowed grasslands at the time of corncrake arrival, although these factors may influence habitat selection over the season (Budka & Osiejuk, 2013)

E. CHARACTÉRISTICS OF MEADOW HABITATS SELECTED BY MALES

A few authors have focused more precisely on habitat selection in meadows. Budka & Osiejuk (2013) studied habitat selection by 206-229 singing males in eastern Poland, in the Nurzec River Valley. This valley is composed of 46 km2 of hay meadows flooded primarily by beaver dams and secondarily by spring snowmelt and rainfall. In this study, the monitoring of singing males was conducted in 2012 by two successive night counts in May and June corresponding to the period of the first and second broods. Authors studied the factors that influenced the exact location of the singing males and their territories (considered as a radius of 100 m around the singing stations), as well as their evolution during the breeding season.

Management, humidity and area In this study, during both parts of the season, males preferred wet habitats and avoided dry habitats. And 59% of individuals were observed in grasslands, both intensive and extensive, that are mowed at least once during the season. But males chosed preferentially extensive and abandoned grasslands, and avoided intensive fields and meadows. This study also showed that the probability of corncrake presence was positively correlated with water level and the surface of the nearest abandoned grassland (Figure 9).

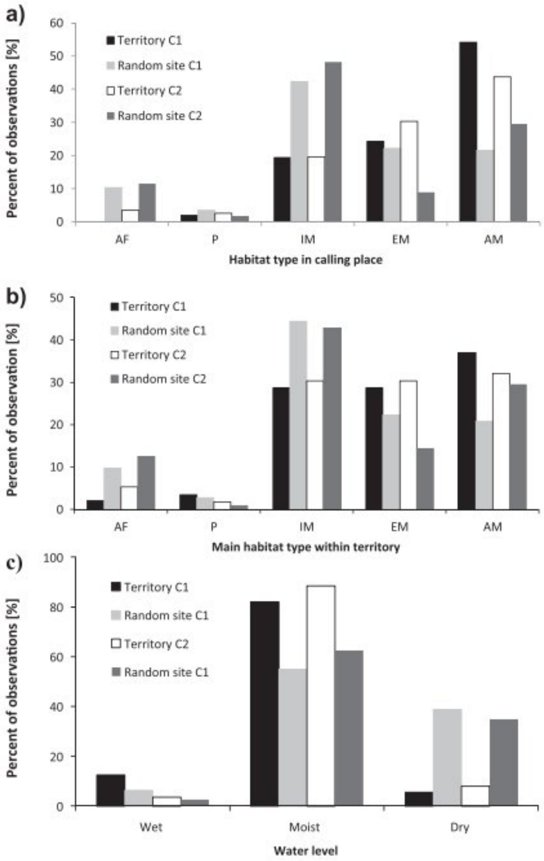

Figure 9 : Habitat type at the calling place in Poland (Budka & Osiejuk,2013)

Evolution of the selection according to the evolution of cover

However, habitat selection by males differed between the first and second part of the breeding season. In the first part of the season, territories covered mostly abandoned grasslands, while in the second part of the season males chosed more extensive mowed grasslands, even though abandoned grasslands were in larger proportion. Moreover, in the first and second part of the season, more precise locations of the singing posts were more in the abandoned grasslands than in the extensive grasslands. The presence of tall vegetation at the time of arrival of males seems to be an important factor in habitat choice. And type of habitat selected appeared to change over the season. In the second part of the season, tall, dense vegetation covered more of the study area. The growth of vegetation and mowing of parts of the study area are considered by the authors as factors that led males to modify the limits of their territories or to abandon them to occupy new ones. This would explain, for example, a greater proportion of hay meadow in territories in the second part of the season. Changes in habitat choice during the season, which may be associated with changes in cover, have been observed in other parts of Europe. Indeed, Tyler's (1996) study in Scotland showed that 23% (n=22) of the nests of first broods were in hay meadows, while 80% (n=15) of the nests of second broods were detected there. The second most used habitat in this study was nettle. Stowe & Hudson (1991a) also show individuals nested and spent more time near buildings, ruins, field margins and iris patches in the early season than in the second part of the season, and in the second part of the season they were mostly in mowing meadows. Brambilla & Pedrini (2011), through a study carried out between 1997 and 2010 in the province of Tronto in northern Italy, also highlighted higher abundances at lower altitude (on average 975 m) during a first period of May-early June, then higher abundances at higher altitude (on average at 1,175 m) during a second from late June-July. The authors interpreted this change in abundances as movements in response to to the evolution of vegetation growth with altitude, the advancement of mowing during the season and the evolution of prey availability.

Ditches and shrubs

In addition, males selected certain landscape structures (ditches, shrubs...) but also showed an evolution in this selection during the season. Indeed, the distance to the nearest ditch was significantly shorter for occupied territories than for random points. These ditches were 0.5-1.5 m wide and about 0.5-2.0 m deep and were overgrown with grasses, plants, and shrubs, and strips around them were not cut during mowing. Some of the males were recorded early in the season in vegetation fragments around shrubs and ditches. However, in the second part of the season, the average distance between males and shrubs, ditches and abandoned grasslands was greater than in the first period.

Forest edges and hedges

Selection of landscape components was studied in France using data collected during night counts in May and June in 2009, 2010, 2011, and 2013 along the Loire River (Besnard et al., 2016). The authors studied the distance to hedgerows of 340 corncrakes detected as well as other grassland passerines. Results showed that while passerines avoided hedgerows, corncrakes were less sensitive to hedgerow density (Figure 10). This result is supposed to be related to a lower vulnerability of corncrakes to predators following hedgerows. Authors also hypothesize that hedges have less negative impacts on social communication of corncrakes and bushes can be used for singing posts.

Similarly the study by Berg & Hiron (2012) in Sweden, shows that 42% of singing males were located within 100 m of forest edges. Edges selection was not significantly different from random points, while other grassland species avoided edges. This study also highlighted that ditches were more frequent in corncrake territories than in random places, confirming the results of Budka & Osiejuk (2013) and Arbeiter et al. (2017a) having shown ditch selection by male and female corncrakes.

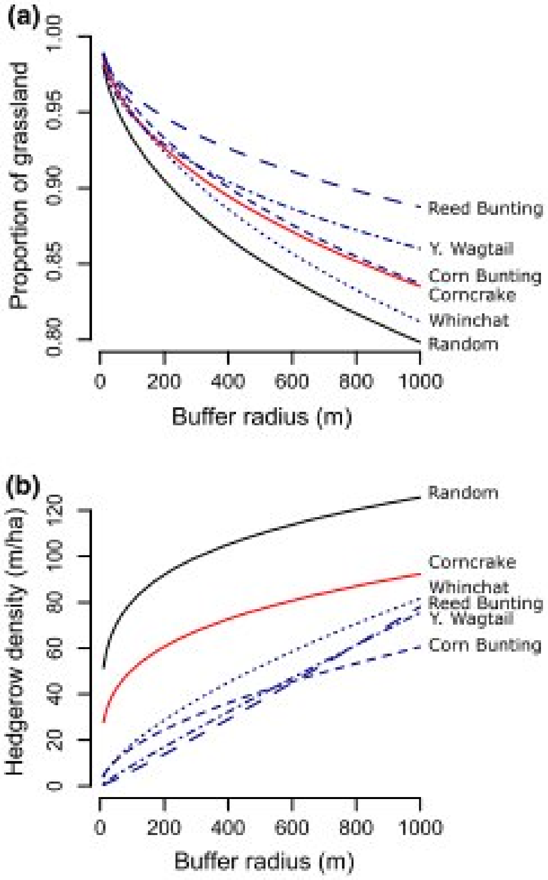

Figure 10 **:** Response of five species studied to a proportion of grassland and the density of hedgerows (Besnard et al., 2016)

F. HABITAT SELECTION BY FEMALES

HABITAT CHARACTERISTICS

The study by Arbeiter et al. (2017a) tracked six females by telemetry in northeastern Germany, on the border with Poland, between 2013 and 2015. The six females were tracked for an average of 14.7 days (extremes of 4 and 33 days) with an average of 23 locations for each of them (extremes of 7 and 46). In the same years, 78 singing males were surveyed and mapped at night on three occasions per month from May to July, and the nocturnal calling sites were checked for calling activity during daytime every three to five days. Of the 23 sites where diurnal calling activity of males were observed, females were captured on eight of them and juveniles were observed on the other 15 diurnal calling sites. Habitat characteristics selected by females was done by comparing these 23 sites with the other 55 sites where diurnal calling activity were not observed.

According to telemetry-tracked female data, the most important habitat caracteristic of females was a high herbaceous cover (>30%) associated with good overall plant species diversity and relief heterogeneity. Comparison with without females or juveniles showed that females have selected low sedge cover (maximum 12%), lower litter heights (1.3 ± 1.9 cm) and more relief heterogeneity (Figure 11). These sites selected by females had elevation differences of 50-100 cm within 0.1 ha and were located closer to ditches or grassland edges (10-80 m).

Habitat caracteristics were found to be significantly different between sites with diurnal calling activity of males, indicative of potential female presence, and only nocturnal calling. Diurnal calling sites included at least 25% grass cover and sedge cover did not exceed 19%. Mean litter height was 1.7cm (±2.6) and distances to ditches or field edges ranged from 19 to 98 m. Sites where only night calls were recorded had lower cover of herbaceous vegetation (minimum 2%), higher cover of sedges (maximum 35%), higher litter heights (7.4 cm ± 6.0), greater distances to ditches (up to 166 m), and more relief heterogeneity (Figure 12).

Structural variation appears to be a key factor for habitat selection in females. The interpretations proposed by the authors are that diverse vegetation provides low resistance to walking with simultaneously high cover, but also increases the abundance of food resources and their accessibility; and that relief heterogeneity facilitates this vegetation diversity.

Furthermore, the authors report the presence of females or chicks closer to ditches or edges than sites without breeding records. In addition, nests were found near the edges of grasslands (minimum distance of 30 m) or ditches (minimum distance of 10 m). However, the importance of ditches for habitat selection was also shown in males by Budka & Osiejuk (2013).

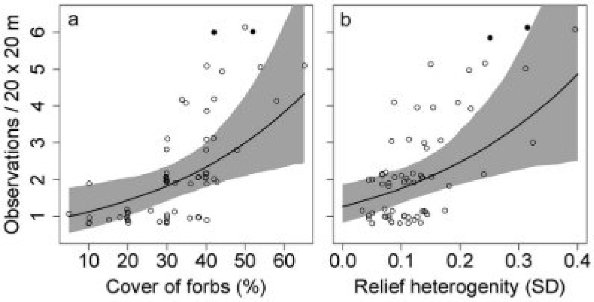

Figure 11 : Habitat characteristics in the home ranges of the six radio-tagged females surveyed by Arbeiter et al. (2017a)

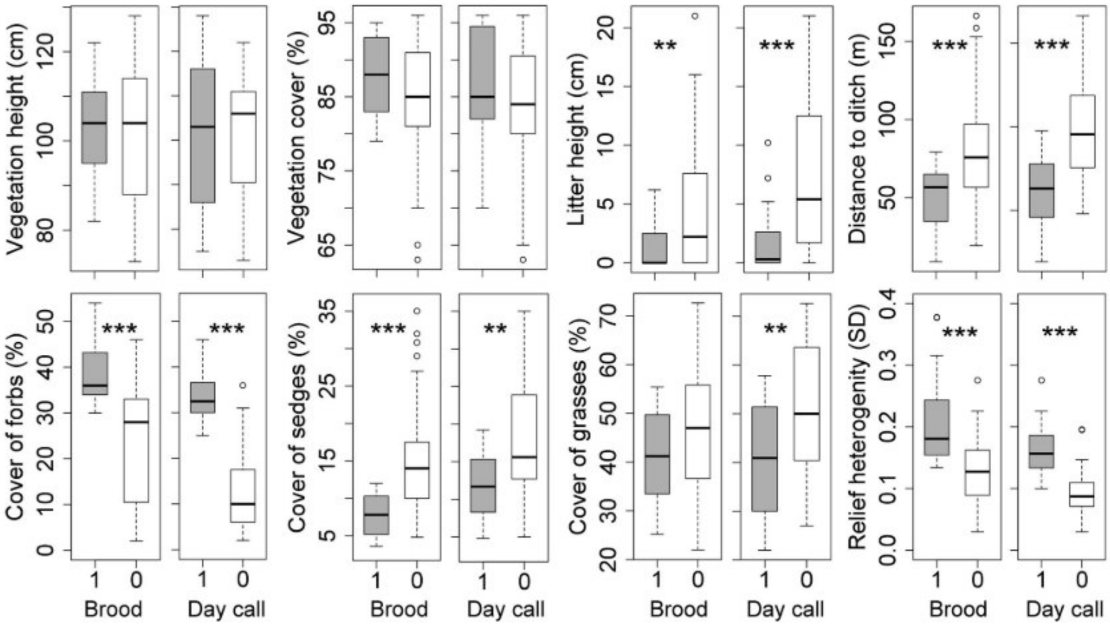

Figure 12 : Comparaison of habitat characteristics of calling sites with or without nest detection (left, 1= present, n=23; 0=absent, n=55); and sites without nest detection in relation to male daytime activity (right, 1= present, n=28; 0=absent, n=27) (d'Arbeiter et al., 2017a)

G. MICROHABITAT OF SELECTED GRASSLANDS

The floristic composition and vegetation structure selected by singing males were studied in France in the Saône Valley in 1984 and 1987 (Broyer, 1992). This study showed a selection of hygrophilous meadows with tall ground vegetation (40-45cm).

In this study, the author carried out botanical surveys on quadrat, on 28 points drawn so as to give an account of the composition of the meadows on an extent of 500 ha with in 1984, then on 20 points distributed on 116 ha in 1987. The surveys were also carried out on the places of songs of the males (n=24 in 1984 and n=13 in 1987). The list of species, their cover rate and the height of the vegetation were studied for each survey. The result was that males were mostly located in habitats with hygrophilic tendencies with species such as Alopecurus geniculatus, Phalaris arundinacea, Heleocharis uniglumis, Mentha aquatica, Caltha palustris, Stelaria palustris, Carex sp. ... In meadows where corncrakes have been detected, Broyer (1992) describes that herbaceous vegetation is defined by a first stratum of stems and stems of grasses and some other tall plants (Rumex, Euphorbia...), and a denser lower stratum in which the plant bases are mixed with other lower ones (Mentha, Trifolium, Oenanthe, Achillea...) In the survey sites where the corncrakes were found, this author showed that the high stratum measured in 1984 was between 0.60 and 1.20 m and the low stratum measured in 1987 was 40 to 45 cm. This search for a certain height of vegetation by corncrakes is confirmed by the study of Berg & Hiron (2012) carried out from the follow-up of 113 singing males in 2006 and 2007 in Sweden. These authors showed that the average height of vegetation in corncrake territories was 59 cm compared to 31 cm in randomly drawn territories.

In addition, Tyler (1996) reported that corncrakes avoid dense vegetation and litter that may make their movement harder. This study, conducted in Scotland and Ireland between mid-May and August 1992-1994, and using telemetric tracking of males, showed that corncrakes did not occupy the densest vegetation areas. This result could explain the choice of regularly mowed grasslands mentioned by Arbeiter et al. (2017a).

In the study by Broyer (1992), corncrakes were more present in flooded meadows in the Saône Valley than in the non-flooded Bresse meadows. The author explains this result by vegetation types and dates of growth. This study followed vegetation dynamics in the meadows in the floodplain of the Saône Valley and in the non-flooded meadows of the Bresse. At the end of April 1984, the contribution of the main systematic groups to the vegetation cover of a stratum higher than 15 cm at the beginning of the high vegetation. She thus showed that at the same date, the flooded meadows had mainly sedges and cardamines while the Bresse meadows had mainly grasses. These results led the author to the conclusion that there was a shift from winter-type vegetation (*Cardamine pratensis, fritillaria meleagris, ranunculus repens, acris*...) to summer-type vegetation, with a strong representation of grasses later in the flooded meadows. This suggests preferences in terms of vegetation type on the part of corncrakes.

H. SOCIAL ATTRACTION AND FOOD

Furthermore, Budka & Osiejuk (2013) showed that factors as social attraction could be involved in habitat choice. Indeed, in the second part of the season, the presence of neighbors was an important factor in the location of singing males. Forming small groups of singing males may have been intended to better attract females.

Broyer (1992) showed that arthropod prey resources do not appear to be a factor involved in corncrake selection of floodplain meadows. Barber traps were set randomly from 28 to 30 May in the flooded meadows of the Saône Valley as well as in the hay meadows in Bresse where corncrakes are absent. Only *Collembola* were more abundant in the flooded meadows, but they are not considered to be the preferred prey of corncrakes according to the literature (Schäffer & Koffijberg, 2004). In 1987, Barber traps were set on the 15th of each month from March to July and confirmed that flooded meadows were not a more important source of arthropods than non-flooded Bresse meadows. However, this study did not include other taxa such as molluscs, larvae or earthworms.

I. FREQUENCY AND DATE OF MOWING AND CHARACTERISTICS OF THE HABITAT

The Arbeiter et al. (2017a) study showed that mowing frequency and timing of land use in the previous year had significant effects on vegetation variables involved in female habitat selection, such as herbaceous plant cover, sedge cover, number of plant species, and litter height. Indeed, annual mowing and grazing had significant positive effects on herbaceous plant cover and number of plant species. In addition, mowing that occurred before July 15 of the previous year led to greater herbaceous cover, more plant species, and lower sedge cover on the plots. Grazed sites in the study, without mentioning grazing intensity, also had greater species diversity, but did not differ significantly from abandoned sites in terms of herbaceous cover. In addition, management type and mowing date had a significant effect on litter height. Mowed and grazed grasslands had lower litter heights than abandoned grasslands, and the lowest litter heights were found in grasslands mowed before July 15 (Figure 13).

Similar results are present in the study of Arbeiter et al. (2018) studying males (Figure 13). However, the authors consider that a late mowing of the previous year provides adequate vegetation characteristics for the needs of Corncrakes. This study also shows that an increase in the number of years of unmanaged grassland has a significant negative effect on the probability of occupancy, even in the year following no mowing. However, numerous studies have shown in some places the presence of high densities of corncrake in abandoned grasslands (see habitat section).

Furthermore, the study by Arbeiter et al. (2020) shows that mowing or grazing after 15 July or no mowing at all has a significant positive impact the following year on the abundance and diversity of prey needed by corncrakes (beetles, snails, etc.).

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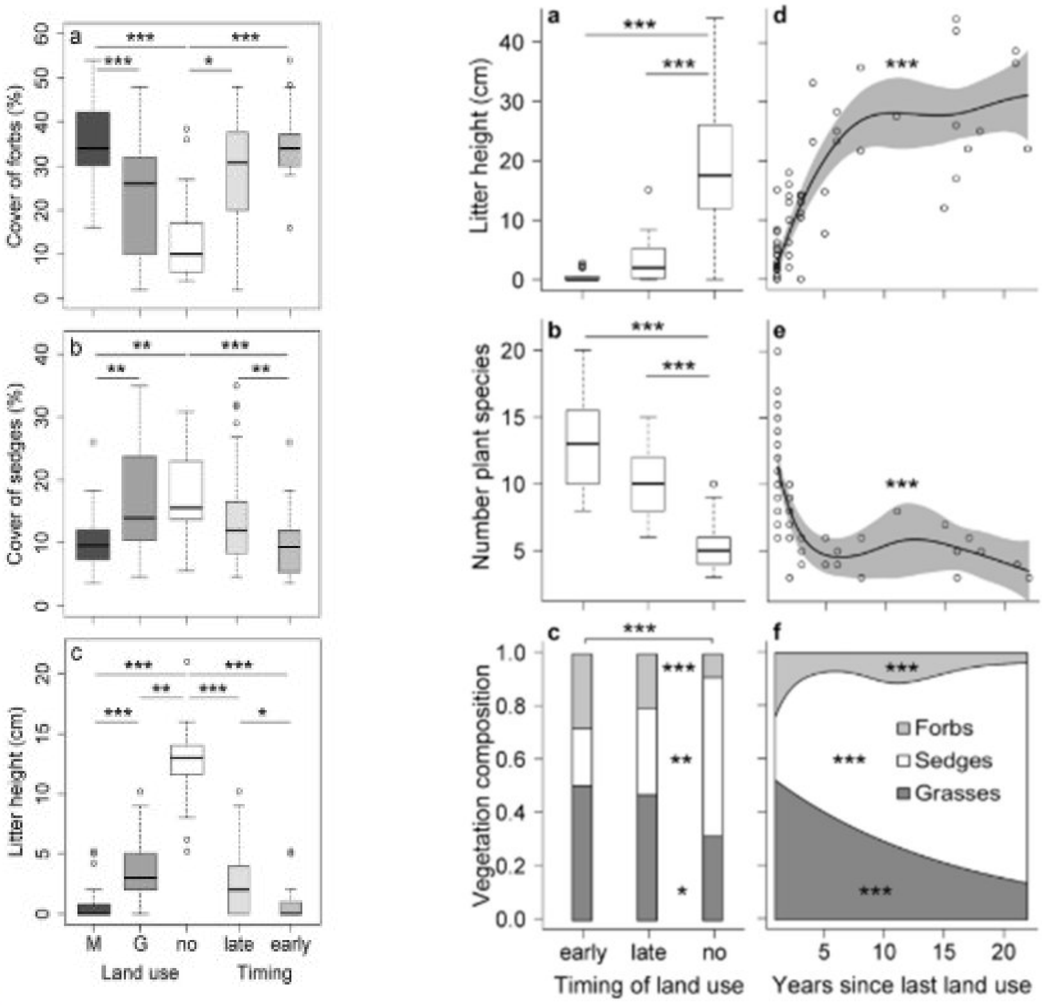


a.

b.

Figure 13 : Vegetation characteristics and litter height according to a. type of use and date of mowing (M=mowing, n=39; G=grazing, n=26; no=no use, n=13) (from Arbeiter et al., 2017a), b. date of mowing and number of years without mowing (from Arbeiter et al., 2018)

A. FLOODING, RAINFALL AND HABITAT SELECTION

Habitat selection along the humidity gradient need more studies. Schäffer & Koffijberg (2004) mention the importance of flooding on the development of suitable vegetation on breeding sites which may have consequences such as delaying mowing. Nevertheless, too late floods can make breeding sites inaccessible or drown broods. That’s why the authors recommend maintaining suitable alternative breeding sites outside the floodplains. Furthermore, Paquet & Derouaux (2016) discuss the positive correlation between May-June rainfall and corncrake presence, which occurred in some years in Wallonia. This may potentially be related to delayed vegetation growth, delayed mowing dates and so the presence of habitat for a longer period.

J. SUBSTITUTE HABITATS

Furthermore, a study has shown the importance of habitat heterogeneity for the conservation of corncrakes (Dorresteijn et al., 2015).

This finding was derived from the study of the locations of singing males during two counts in May and June in 2013, in an area of 3,100 km2 dominated by traditional agriculture in Romania, as well as simulations to assess the potential effects of landscape homogenisation. At the time of the study, the area had a mosaic of habitats comprising 47% forest, 20% pasture and 25% arable land. The distribution of singing males was modelled according to different variables at three different scales. Within 250 m of detected males, the authors studied the proportion of forest vegetation cover, an index of local structural heterogeneity measured by spectral variance, topographic position and potential soil moisture. Within the 100 ha around each singing male, they tested a Simpson's diversity index of land cover and land roughness, and at the village catchment scale, they tested the Simpson's diversity index of land cover, edge density, proportion of arable land cover, and land roughness. The 114 corncrakes detected were present in grasslands and arable fields, and preferentially occupied wet, low topography areas with high land cover diversity at the 100 ha scale. Simulation of the loss of land cover diversity within the 100 ha revealed that even a moderate reduction in land cover diversity could significantly reduce the extent of suitable habitat for corncrakes (Figure 14). For example, an overall decrease of 11% in land cover diversity resulted in a 33% loss of suitable corncrake habitat, and a 35% decrease in cover diversity resulted in a 66% loss of potential habitat.

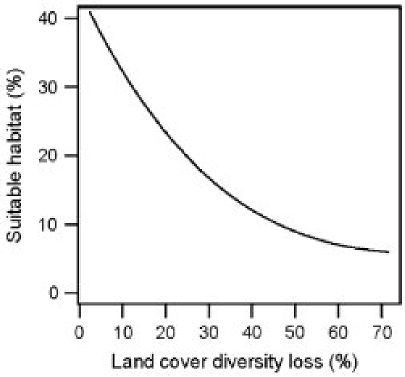


***Figure 14** : Prediction of favourable habitat for corncrakes based on the loss of heterogeneity in the 100 ha around each singing male (Dorresteijn et al., 2015).*

In view of their results, the authors question the interest of other habitats for the species. A diversified land-use mosaic, unmown plots, field margins or ditches can provide breeding or shelter sites as well as food resources for corncrakes at the beginning of the season before the vegetation height is sufficient but also at the end of the season after agricultural work. According to this study, a mosaic of the landscape can therefore offer different types of habitats that can be complementary to an appropriate management of hay meadows. In view of these findings, the authors also mention the importance of maintaining the multifunctionality of farms and coordinating mowing actions in order to create a heterogeneous vegetation structure on a landscape scale including many plots that are not mowed until late in the season.

The use of a diversity of habitats, especially to cope with disturbances, has been highlighted by some studies. In fact, during disturbances, such as major spring floods for example, the shift to different substitute habitats can be significant and diverse. A case of the reaction of corncrakes to a high flood in 1983 in the Saône Valley (France) was observed by Broyer (1992). The 1983 floods submerged a large part of the meadows from April to early June, and Corncrakes were counted in mid-May in a transitional area between the Saône and Bresse plains where there are livestock and market gardens. More precisely, 54% of the singing males on 14-15 May were located by the author in hedgerows or on the edge of groves, 21% in meadows, 15% in wasteland, rushes and nettle patches and 10% in the unsubmerged fringe of hay meadows. A 27% decline in the number of singing males was recorded between 1982 and 1983 (from 34 males in 1982), with some potentially moving to other areas further afield. The author reports that by 21 May the farthest detected singing male from the water's edge was 1.75 km away and that the 16 remaining detected males had returned to pre-flood sites within 24-48 hours of the water's withdrawal. The study by Boldogh et al. (2016) in north-eastern Hungary also clarifies the importance of maintaining potential carryover sites in the event of flooding of normally occupied areas. The study consisted of monitoring a total of 4,194 corncrake territories accumulated between 1997 and 2006 at four sites covering about 1,500 km2 (Figure 15). The authors showed that prolonged flooding led to the disappearance of the species in one of the regions (Bodrogzug) in 2005-2006, while in the other sites the number of territories increased fivefold, threefold and twofold (Szatmár-Bereg). The number of territories was negatively correlated with the maximum water level of the Tisza River in April-May at the Bodrogzug site, whereas this correlation was positive at the other three sites. These results confirm that exchanges between populations were related to changes in water levels and also confirm the importance of alternative sites, here on a large scale.

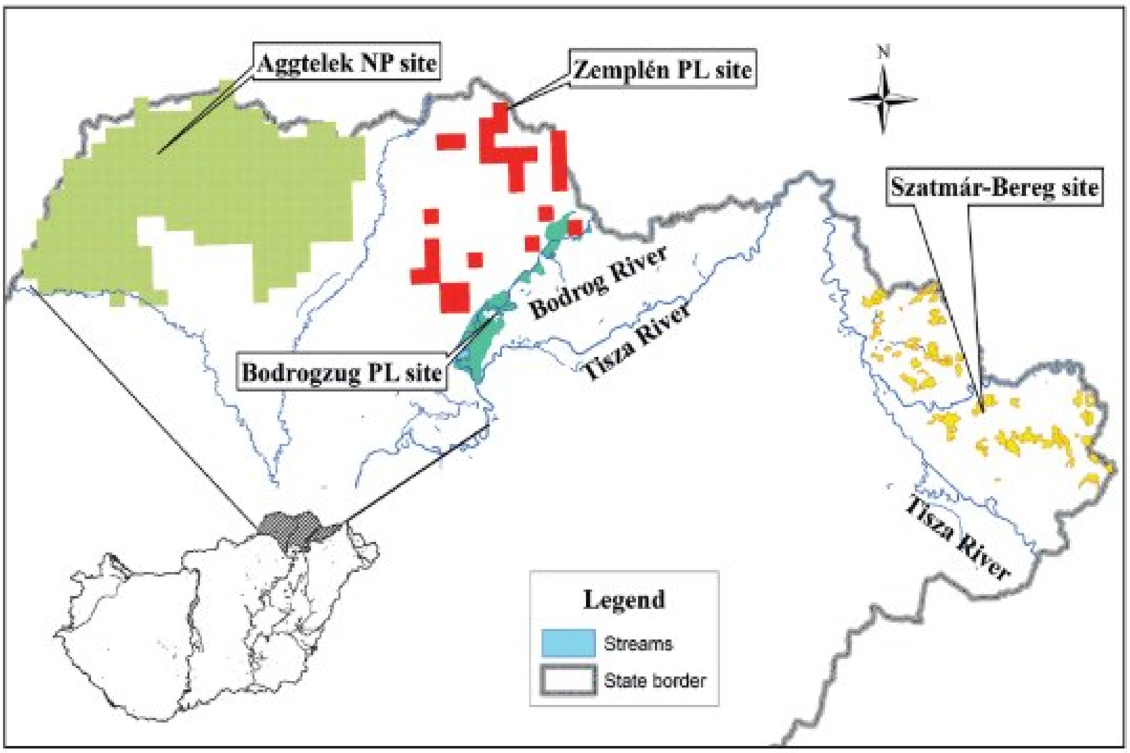


Figure 15 : Distribution of flooded and alternatives sites for Corncrakes in North-East Hungary (Boldogh et al.,2016)

6. FEEDING

The most frequent food sources of corncrakes are insects larger than 10 mm and their larvae, gastropods, araneids, and potentially earthworms and plants.

Indeed, Arbeiter et al. (2020) analysed faecal composition of 22 corncrakes (17 males, two females and three juveniles) between 2012 and 2015 in floodplain in north-eastern Germany. Corncrakes were captured in May and June at probable breeding sites or in refuge strips in July. Authors collected also 30 samples with Barber traps in 2005 and 2013 at selected capture sites. Preys caught by this method were mainly beetles (32% smaller than 10 mm and 26% larger than 10 mm), beetle larvae (18%), spiders (16%), other insects (7%) and gastropods (1%). As a result, corncrakes prefered more gastropods and beetles larger than 10 mm and fewer beetles smaller than 10 mm. However, Barber traps may have underestimated the abundance of gastropods present and different digestion rates of prey may be variable. In this study, no significant differences in diet between males and females were found. Juveniles did not show any beetle larvae in their diet. However, the sample sizes are very small especially for females and juveniles, two and three individuals respectively.

Schäffer & Koffijberg (2004) also report, from personal comments based on field observations and stomach analyses, other possible food sources and potential variations between regions. Preys could be odonates, ants, earthworms, young amphibians, green parts of plants, young shoots and seeds in the diet of corncrakes. According to these authors, the species composition of invertebrates also seems to vary significantly between regions, with for example more earthworms in eastern France than in the west. However, consumed earthworms are not always detected like in Arbeiter et al. (2020) where the availability of earthworms at the sites was not sampled.

Schäffer & Koffijberg (2004) also mention the possibility of a change in diet in the autumn after the breeding season, potentially with more plant material. However, the non-breeding diet remains to be investigated. Moreover we don’t know the dietary requirements in terms of energy needs during the breeding season, which could be a constraint to good reproductive success.

7. REPRODUCTION

A. FROM MIGRATION TO EGG-LAYING

MATING

Corncrakes are sequentially polygamous within one breeding season. There is usually two clutches and a change of partners is possible between breeding attempts (Tyler, 1996; Schäffer & Koffijberg, 2004). Pairs usually associate for several days and then they separete during egg-laying (Tyler, 1996; Green et al., 1997).

This mating system was demonstrated thanks to a telemetry monitoring conducted during Tyler's thesis (1996). The identity of the males mating with radio-tagged females was determined for each broods during the same breeding season. One of the females was paired with a different male for each of the two breeding attempts, while two other females were paired with the same male. Another female paired with different males on her breeding attempts but was found with the male from her second breeding attempt shortly before her first attempt. Such mating system was confirmed by genetic analyses by Green (2019) which found that the two broods of one of the females studied had the same father (with first laying dates 34 days apart), while those of another female had two different fathers (with first laying dates 31 days apart). Furthermore, when males visit the territories of neighbouring males, extra-pair mating seems possible (Schäffer & Koffijberg, 2004; Sklíba & Fuchs, 2004a).

The duration of a pair bond was also monitored by telemetry for nine Corncrakes in 1993 and 1994 on the Isle of Coll, Scotland (Tyler, 1996). For these pairs, individuals were only paired for a short time before egg-laying. Pairs (individuals detected within 5 m of each other) were seen for a median duration of 10.5 non-consecutive days but this duration was highly variable. It varied from 3 to 23 days depending on the pair. This duration could also include one or two days when the individuals were not at a distance of less than 100 m from each other. However, the number of consecutive days of paired individuals was on average 8 days (ranging from 3 to 14 days) (Tyler, 1996).

Tyler's (1996) study also found that pairing time before first egg laying was longer than before second egg laying. The median pairing duration was 10.5 days before the first egg laying (n=6) and only five days before the second egg laying (n=3). The number of consecutive days of association was eight days and five days before each laying (Tyler 1996).

Separation of the nine pairs for the first and second clutch occurred during egg laying, on average five days before incubation of the first clutch and four days before incubation of the second clutch (Tyler 1996).

In this study, the number of eggs laid at the time of pair separation could only be recorded in one case. Two eggs were present in the nest at the time of pair separation (Tyler & Green, 1996). Furthermore, in an aviary study, Schäffer & Koffijberg (2004) reported that females attacked males during egg laying, which led to the separation of the males.

Subsequently, on the first night of monitoring after pair separation, all nine males studied in Tyler's (1996) thesis were heard singing. So males may have been searching for other partners between 0 and 1,100 metres from the initial calling site, with four of them being more than 150 metres away (Tyler and Green, 1996).

NEST BUILDING

Observations of nest building in aviaries were reported by Schäffer and Koffijberg in "The Birds of Western Paleartic" of 2004. In captivity, males build several nest platforms on the ground and try to attract females by singing. In aviaries then females chose one of the nest platforms, which is completed by both the male and the female. The same authors describe the nest as a cup made of dry grass, 12-15 cm in diameter and 3-4 cm deep. However, Tyler (1996) reported differences between the behaviour of aviary males and radio-tracked males in his study. While captive males were involved in feeding juveniles this was not the case for non-captive males.

EGG-LAYING

Females generally lay two successive eggs per breeding season and approximately 7-12 eggs have been observed per laying in Scotland (from 56 nests, 21 of which were found by survey and 35 by radio-tracking of females) (Tyler, 1996) (Figure 16). For five nests monitored for oviposition during the same project, an average number of eggs laid per day was estimated at 1.21 by Green et al. This estimate was obtained by two methods. On the one hand, during the egg-laying period, the observation of the appearance of a certain number of eggs between two nest checks or between a nest check and the start of incubation, made it possible to estimate a number of eggs laid per day of 1.16, i.e. 12 eggs in 8 days. On the other hand, the authors made a calculation based on the date on which the females stopped caring for the first clutch and the date on which incubation of the second clutch began. This calculation estimated an egg laying rate of 1.25 eggs per day. However, there is still some uncertainty in this last method, which assumes that the second clutch begins as soon as the first clutch is independent.

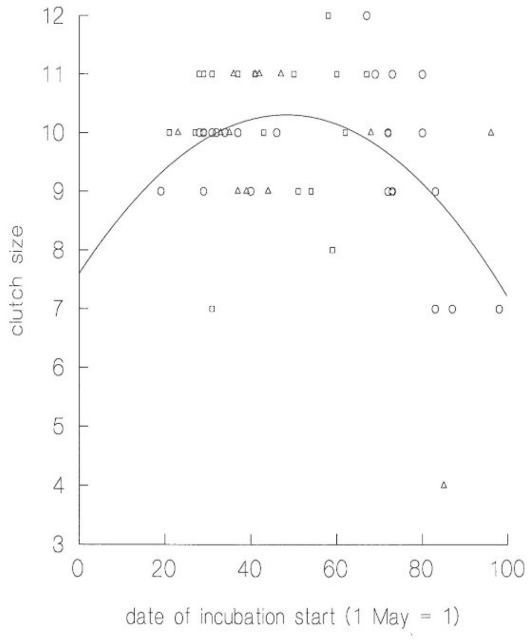


***Figure 16** :* Number of eggs per clutch as a function of incubation start date (1 May=1). Data from Coll are shown as circles, from North Uist as triangles and from South Uist as squares (Tyler, 1996).

K. FROM INCUBATION TO JUVENILE INDEPENDENCE

INCUBATION

Tyler & Green (1996) monitored 34 nests in Scotland and found incubation period of 18.6 days on average for the first clutch and 17.1 days for the second clutch. However, this study shows that it is the date of laying, rather than the order of laying, that appears to determine this duration of incubation. Indeed, the model linking the incubation period to the date of laying fit the data better (r=0.506, P=0.002) in this study than the model treating first and second broods as a factor (r=0.378, P=0.025). The duration of incubation is therefore dependent on the date of the start of egg-laying, but does not appear to vary between years or between sites (Figure 17). Two observations made during this study showed incubation start on the day the last egg was laid.

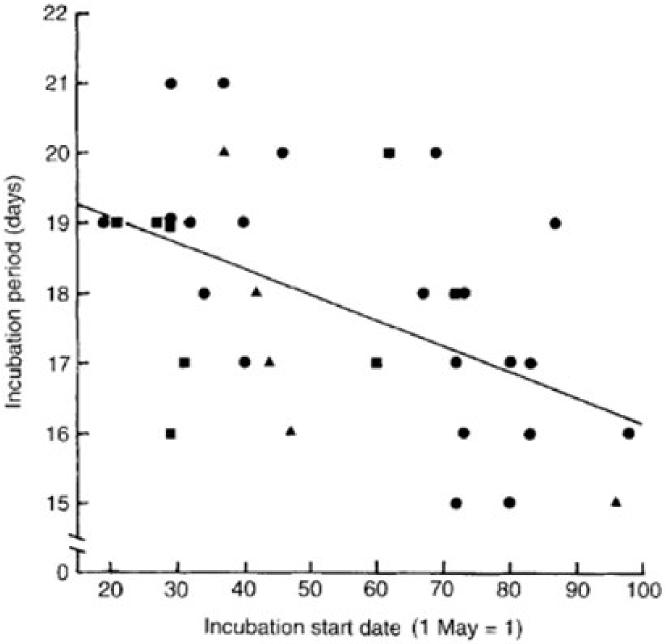


***Figure 17* :** Length of incubation period in relation to date of the start of incubation (1 May=1). Symbols denote different study areas. (Tyler & Green, 1996)

CARE OF THE YOUNG

Chicks are nidifugous and leave the nest one to two days after hatching and gradually moving away from the nest (Schäffer & Koffijberg, 2004; Stow & Hudson, 1991). According to Schäffer & Koffijberg (2004), female care alone for chicks. She provides to them warmth for several days, especially at night, and feeds them for three to five days before showing them the food. Sometimes during this period, males have been observed near females, probably in an attempt to breed again (Schäffer & Koffijberg, 2004).

The average duration of female care for juveniles was estimated at 18.3 days (ranging from 16.4 to 19.6 days) by Green (2010), based on 32 females observed in August and September. This average, based on capture or observation of adults and chicks in Scotland between 1998 and 2009, is not significantly different from the one estimated by Green et al. (1997) with a telemetry monitoring of nine females (figure 18). This study also showed that the duration of care for the first clutch was shorter than the second one, at 11.6 days and 16.7 days respectively on average (Green et al., 1997).

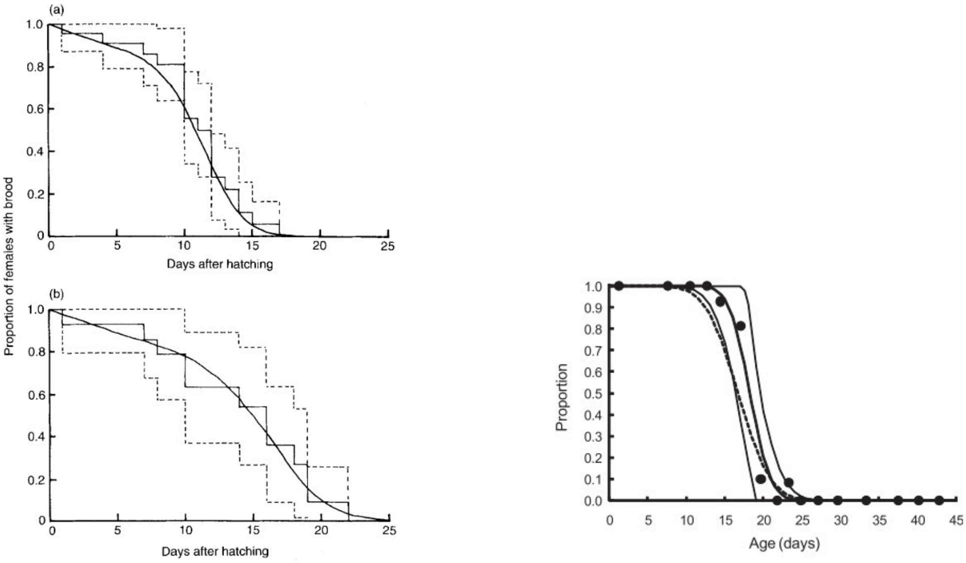


Figure 18 : Proportion of Corncrake chicks that were accompagnied by the mother in relation to their age (Green et al., 1997 et Green, 2010).

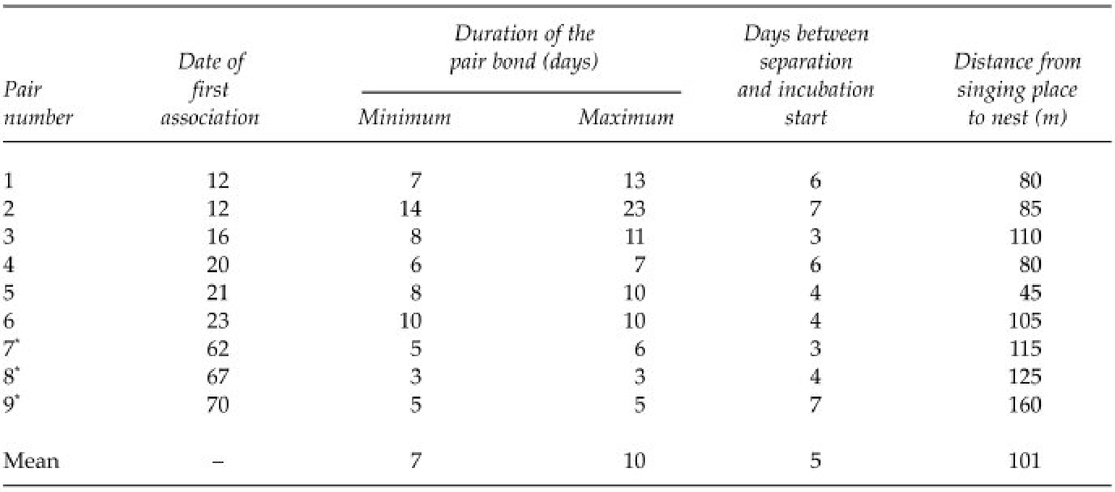
AGE OF FLEDGING OF JUVENILES

The age at which juveniles are able to fly has long been described as around 35 days, according Cramp and Simmons (1980) reporting an age of 34-38 days. However, more recent study use now an age of around 45 days (i.e. Green, 2019). Indeed, telemetric tracking of 29 juveniles by Donaghy et al. (2011) in Ireland gives an estimation of the ages and dates of departure of juveniles from the breeding grounds, and so a maximum age of acquisition of flight ability. This study in Ireland shows that juveniles leave the breeding grounds when they reach an age between 36 and 55 days. Green & Tyler (2005). While there is no study of the development of the remiges of juveniles born in natura that are older than 40 days, the study by Tyler & Green (2004) shows that the remiges of juveniles born in natura are not fully developed until they reach an average weight of 169 g, while the 35-day-old juveniles captured in the study weighed about 140 g.

L. NEST LOCATION AND HOME RANGES

DISTANCE FROM THE MALE'S SINGING SITE TO THE NEST

Few information is available to know the distance between nests and calling sites of males. For the nine pairs monitored by Tyler and Green (1996), all of the nests were located between 45 and 160 metres from the male's calling site, with an average distance of 101 metres. However, second nests were significantly further from the calling site (average 133 metres) than first nests (average 85 metres) (Figure 19).



Pair number	Date of first association	Duration of the pair bond (days)		Days between separation and incubation start	Distance from singing place to nest (m)
		Minimum	Maximum		
1	12	7	13	6	80
2	12	14	23	7	85
3	16	8	11	3	110
4	20	6	7	6	80
5	21	8	10	4	45
6	23	10	10	4	105
7*	62	5	6	3	115
8*	67	3	3	4	125
9*	70	5	5	7	160
Mean	–	7	10	5	101

Figure 19 : Minimum and maximum duration of the pair bond (see text), timing in the breeding cycle of separation, date of first association (1 May =1) and distance of nest site from the male's nocturnal singing position for 9 pairs of raddio-tagged Corncrakes. Pairs marked with asterisks were producing second clutches (Tyler & Green, 1996)

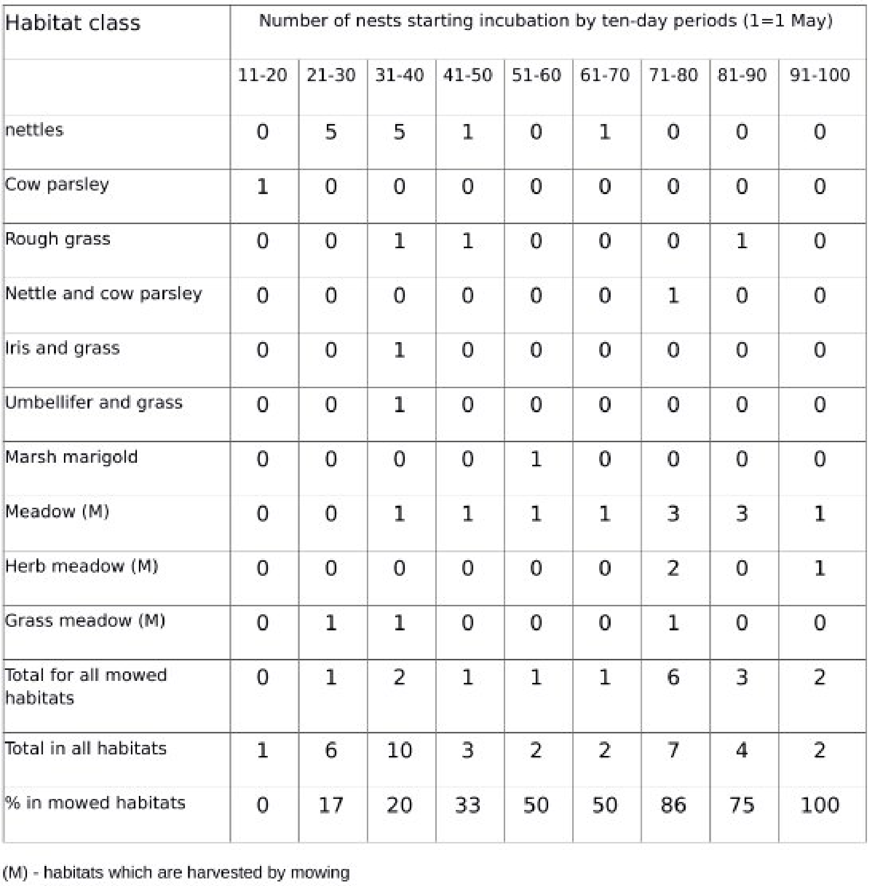
LOCATION OF NESTS

The location of nests is also still not well known. However, some studies carried out abroad, in sometimes different landscape contexts, provide information on the types of habitats that may be chosen for nesting.

Arbeiter et al (2017a) report that, in addition to demonstrating the presence of females or chicks closer to ditches or verges than sites without breeding records, nests were found close to grassland edges (minimum distance of 30 m) or ditches (minimum distance of 10 m). Tyler's (1996) study in Scotland described the type of habitat surrounding 37 nests found thanks to radio-tracked females. As the season progressed, the nests of the first and second broods were not found in the same habitat types (Figure 20). Indeed, 23% (n=22) of the nests of the first brood were found in meadows, whereas 80% (n=15) of the nests of the second brood were found in meadows. Outside of meadows, the most used habitat was found in nettle beds.

Stowe and Hudson (1991a) tracked corncrakes by telemetry in Scotland and report that they used different habitats at the beginning and the end of the breeding season. In the early season, individuals spent more time and nested near buildings, ruins, field margins and iris patches, and at the end of the breeding season they were in meadows.

In addition, Green et al. (1997b) show differences in nest location between regions, for example between Scotland and Ireland. According to the authors, while in Scotland the first nest of most females was in tall grass or marsh vegetation, in Ireland, where grass grows earlier, most of the first nests were located in meadows.



Habitat class	Number of nests starting incubation by ten-day periods (1=1 May)								
	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
nettles	0	5	5	1	0	1	0	0	0
Cow parsley	1	0	0	0	0	0	0	0	0
Rough grass	0	0	1	1	0	0	0	1	0
Nettle and cow parsley	0	0	0	0	0	0	1	0	0
Iris and grass	0	0	1	0	0	0	0	0	0
Umbellifer and grass	0	0	1	0	0	0	0	0	0
Marsh marigold	0	0	0	0	1	0	0	0	0
Meadow (M)	0	0	1	1	1	1	3	3	1
Herb meadow (M)	0	0	0	0	0	0	2	0	1
Grass meadow (M)	0	1	1	0	0	0	1	0	0
Total for all mowed habitats	0	1	2	1	1	1	6	3	2
Total in all habitats	1	6	10	3	2	2	7	4	2
% in mowed habitats	0	17	20	33	50	50	86	75	100

(M) - habitats which are harvested by mowing

Figure 20 : Location of nests by habitat. Nests were found by location of radio-tagged females by Tyler (1996) in Scotland.

SIZE OF HOME RANGE USED BY ADULTS AND JUVENILES DURING BREEDING SEASON

Some studies report that home range sizes of females, males and juveniles are different and change during the breeding season.

Firstly, the home range of breeding females is estimated at 5.5 ha based on telemetry monitoring by Stowe and Hudson (1991a) between 1984 and 1987 in Scotland. Home ranges of females were very different, from 0.24 to 28 ha, with one female having a home range of up to 96 ha. The median home range size during the pre-incubation phase was 3 ha. And the size did not exceed 1 ha during incubation and rearing of young under 13 days old (monitoring could not extend beyond this). It should be noted that the exact number of females radio-tracked in this study is not mentioned, but it is at least five for a total of 89 corncrakes captured, including 31 females and a total of 58 tags placed. The frequency of recovery of locations is also not specified for this radio-tracking and individuals were not tracked until the juveniles were independent.

Secondly, in the same study, the median home range size of males was 15.7 ha (between 3 ha and 51 ha depending on the individual). More specifically, between May and July, the maximum monthly home range did not exceed 26 ha and the median home range did not exceed 8 ha.

Finally, Green (2019) showed, through a genetic study of 14 broods, that juveniles younger than 20 days old were between 4 and 151 m from their father's calling site, and that independent but non-flying juveniles could be between 149 m and 601 m from this calling site. The flying juveniles in this study were caught up to 823 m from the father's calling site.

Furthermore, it was shown by Sklíba & Fuchs (2004) that the home range of males can be extended by visiting the territories of neighbouring males. This study was based on the telemetric monitoring of 11 males on three consecutive days between 06:00 and 21:00 in 1999 and 2000 in the southern Czech Republic. This allowed the creation of 19 areas used over three days by these individuals and the creation of a model to analyse the movements of the males. It was found that in nine cases the movements of the males were not independent of the position of neighbouring males, which can be described as visiting a neighbour's territory. Indeed, the majority of males that had a neighbouring male within 600 m of their night calling site were located at least once within 48 m of the neighbour's calling site.These analyses also showed that males with close neighbours undertook more frequent but shorter visits to neighbouring territories. Males have visited every day or two when neighbours were close, but once every three days when neighbours were further away. The maximum time spent in the neighbouring territory was noted when the distance between the two calling sites was 200 m. In addition, authors observed that males didn't sing in a neighbour's territory and were able to cross unsuitable habitat (100 m of forest in one case) separating their own territory from that of the neighbour. One possible explanation for such behaviour may be a search for females.

M. TIMING OF BREEDING

ARRIVAL DATES ON THE BREEDING SITES

The earliest arrival of corncrakes on the breeding grounds in Europe is in April, although these dates vary greatly between regions (see section on migration). Moreover, as movements can be very large between two broods, the arrival and departure of males on the breeding sites can be present throughout the breeding season, from April to July (see section on intra-seasonal movements, Schäffer & Koffijberg, 2004; Verbelen et al., 2016; Arbeiter et al., 2017). It should be also noted that only the arrival of males can be detected with their calls. The presence of females is only known by determining a pairing, detected by a change in the frequency of the male's song (see below).

MÉTHODS OF DETERMINING PAIRING DATES ON MALE SONG FREQUENCY

Monitoring nocturnal and diurnal male songs can be effective for detecting pairings.

Indeed, Tyler and Green (1996) showed that males stop nocturnal calls when they are paired. The authors reported that males sang 92% of the time between 23:00 and 2:00 a.m. when they were unpaired, whereas they sang only 12% of the time when they were paired. For the ten males monitored in this study, eight produced significantly less songs when they were with females, one produced more and one had the same song frequency. However, for these latter two individuals, the sample size was small (5 and 4 nights of monitoring respectively). During the period when the males were with females, they didn't sing during all listening sessions.

The study shows that song frequency is a good indicator for detecting pairs but that several nights of monitoring are necessary. Indeed, for nights when males were silent, 11 times out of 33 (33%), the females were not seen with the male the previous day. And, when males didn't sing two consecutive nights, 7 times out of 8 (88%) a female was seen at least one night out of two with the male. For males singing on two consecutive nights, 22 out of 24 times (92%) no female was seen with the males. In this study, weather factors (clouds, rain, wind) did not seem to have an impact on the presence or absence of singing (Tyler and Green, 1996).

Furthermore, when nocturnal songs are less frequent but dawn and sometimes daytime songs are added, then a pair is most likely formed (*pers. comm.* Green).

EGG-LAYING DATES

Some studies have shown that clutching started at the beginning of May and spread out until mid-July. And we can’t see every time peaks associated of the two clutches.

Clutch dates have been observed or calculated from the age of juveniles by the study of Arbeiter et al. (2017b) in Germany. According to this study, the first clutches can be initiated at the beginning of May with a peak in mid-May, and then clutch starts were spread out until the end of July (Figure 21). However, during the data collection, nests and juveniles were detected during mowings and very few of them occurred at the end of July and during August. Later broods may therefore have been undetected. Studies in Scotland by Green (2010) and Green et al. (1997b) estimated that the last clutches were laid on average by 17 July (with values between 10 and 25 July) and 13 July respectively.

Furthermore, while Broyer (1995) demonstrated the existence of two hatching peaks, and thus clutches, this is not the case in the study by Arbeiter et al. (2017b). In this latter study hatching appear to occur throughout the season without peaks (Figure 21). Broods initiated in mid-June may, for example, can be first broods but also second broods, as the first early broods may already be independent at that time. However, in this study a second peak may not have been detected because of a bias in the observation of late clutches (not detected due to mowing concentrated in the months preceding August).

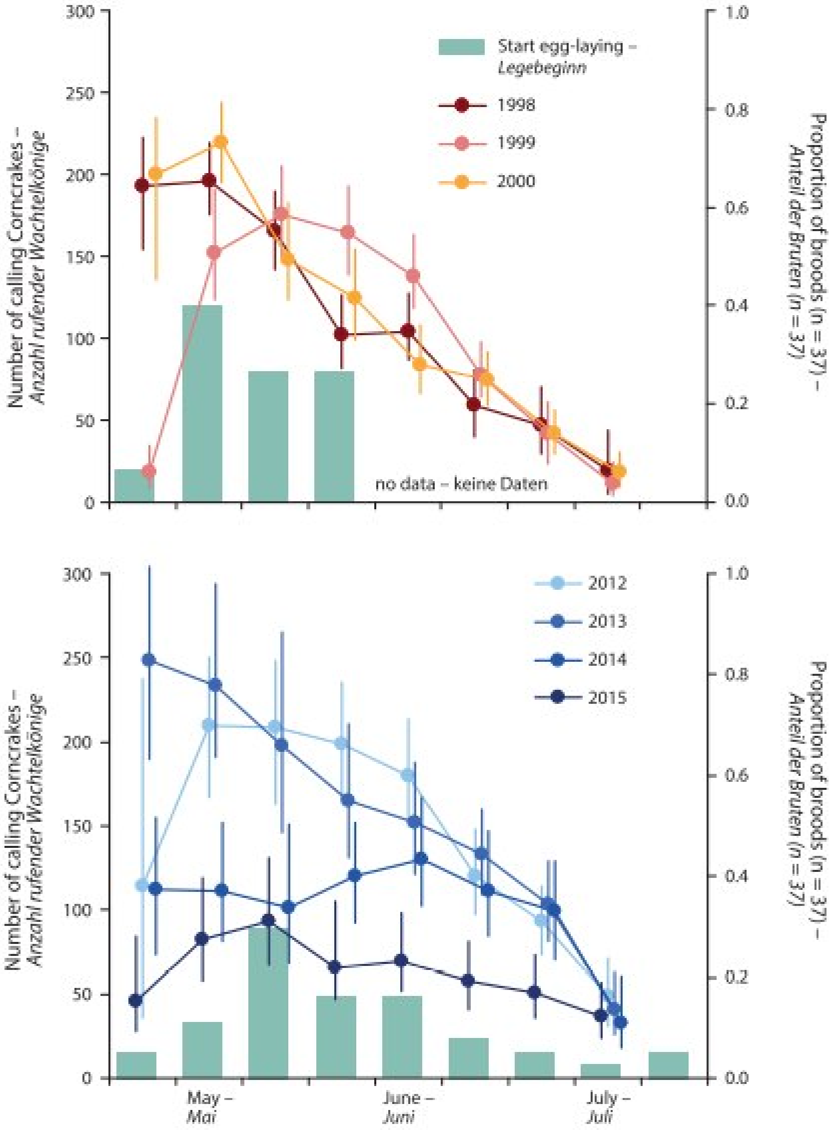


Figure 21 *:* Estimates of the number of calling corncrakes during the breeding period and seasonal progress of brood initiation (Arbeiter et al., 2017b)

HATCHING DATES ACCORDING TO REGION AND YEAR IN FRANCE

The study by Deceuninck et al. (1997) showed, based on the calculation of hatching dates, that there could be significant differences in the breeding calendar of corncrakes between regions of the same country (France in this study) and between years within the same region (Figure 22).

In this study, observers captured and determined the age of juveniles observed during mowing in 1994 and 1995 in six regions, the Basses Vallées Angevines (Maine-et-Loire), the Val de Charente (Charente and Charente-Maritime), the Loire estuary (Loire Atlantique), the Saône valley (Côte d'or and Saône-et-Loire) and the Seine estuary (Seine-Maritime). Egg-laying dates may differ by regions and years. Indeed, reproduction seems to have strated earlier in the Charente, Charente-Maritime and the Basses Vallées Angevines than in the other regions studied. The dates of hatching may also vary in the same location, depending on the year and potentially linked to weather conditions, according to the authors. For example, in Charente-Maritime, the 1995 data show that hatchings took place about ten days earlier than in 1994. However, all the data in this study are dependent on the mowing dates of each region and year. It is therefore difficult to determine whether this is a bias related to shifts in mowing dates or a real difference in laying dates.

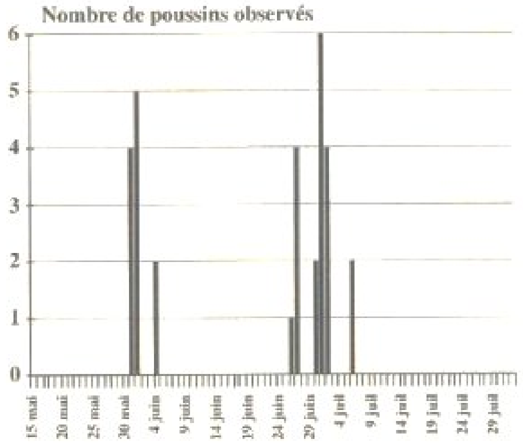


FIG. 3.– Dates d'éclosion des poussins calculées d'après l'estimation de l'âge des individus observés lors des suivis des fauches en Charente en 1995.

Dates of hatching calculated from age estimation of those young birds seen during controlled cutting in Charente in 1995.

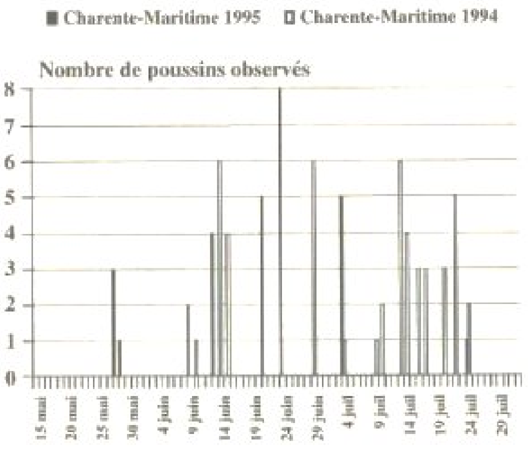


FIG. 4.– Dates d'éclosion des poussins calculées d'après l'estimation de l'âge des individus observés lors des suivis des fauches en Charente-Maritime en 1994 et 1995.

Dates of hatching calculated from age estimation of those young birds seen during controlled cutting in Charente-Maritime in 1994 and 1995.

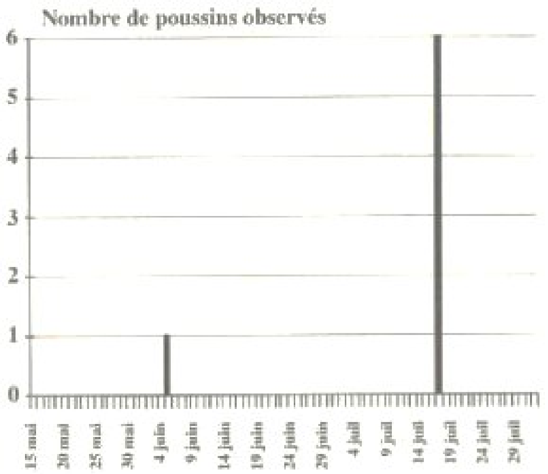


FIG. 5.– Dates d'éclosion des poussins calculées d'après l'estimation de l'âge des individus observés lors des suivis des fauches en Val de Saône en 1995.

Dates of hatching calculated from age estimation of those young birds seen during controlled cutting in Val de Saône in 1995.

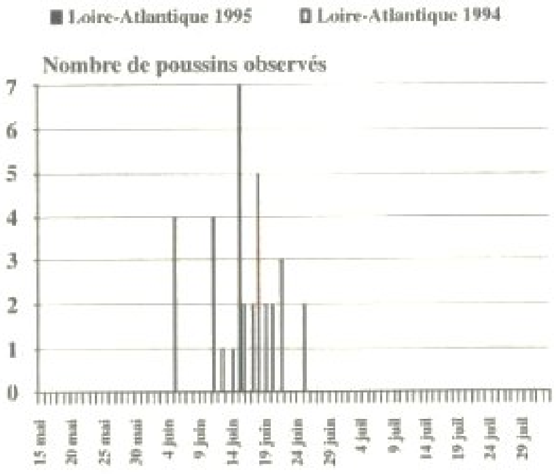


FIG. 6.– Dates d'éclosion des poussins calculées d'après l'estimation de l'âge des individus observés lors des suivis des fauches en Loire-Atlantique en 1994 et 1995.

Dates of hatching calculated from age estimation of those young birds seen during controlled cutting in Loire-Atlantique in 1994 and 1995.

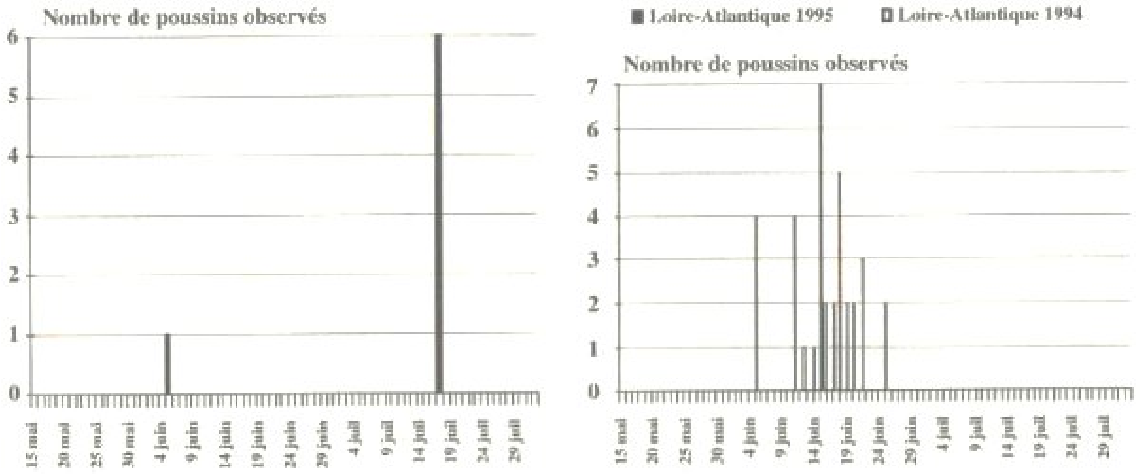


FIG. 5.– Dates d'éclosion des poussins calculées d'après l'estimation de l'âge des individus observés lors des suivis des fauches en Val de Saône en 1995.

Dates of hatching calculated from age estimation of those young birds seen during controlled cutting in Val de Saône in 1995.

FIG. 6.– Dates d'éclosion des poussins calculées d'après l'estimation de l'âge des individus observés lors des suivis des fauches en Loire-Atlantique en 1994 et 1995.

Dates of hatching calculated from age estimation of those young birds seen during controlled cutting in Loire-Atlantique in 1994 and 1995.

***Figure 22** : Dates of hatching calculated from age estimation of those young birds seen during controlled mowing in different reas in France (Deceuninck, 1997)*

LATE OBSERVATIONS OF MATERNAL CARE

Maternal care of juveniles was observed until mid-August in the study by Green (2010). The author's work showed that 71% (15/21) of the females caught between August the 1st and the 17th were accompanied by chicks, but none of the 11 females observed at later dates were accompanied by chicks.

FLEDGING DATES OF JUVENILES

The last juveniles born during a breeding season are often not able to fly until mid-September. Indeed, the monitoring of 29 juveniles by telemetry in Ireland by Donaghy et al (2011), showed that the departure from the birth site of the first brood takes place globally between mid-July and the first week of August. The departure of the second brood takes place between August 20th and mid-September. The monitoring of 52 broods in Germany by Arbeiter (2020) also showed that 80% of broods can fledge without disturbance if mowing is delayed until 15 August (Figure 23).

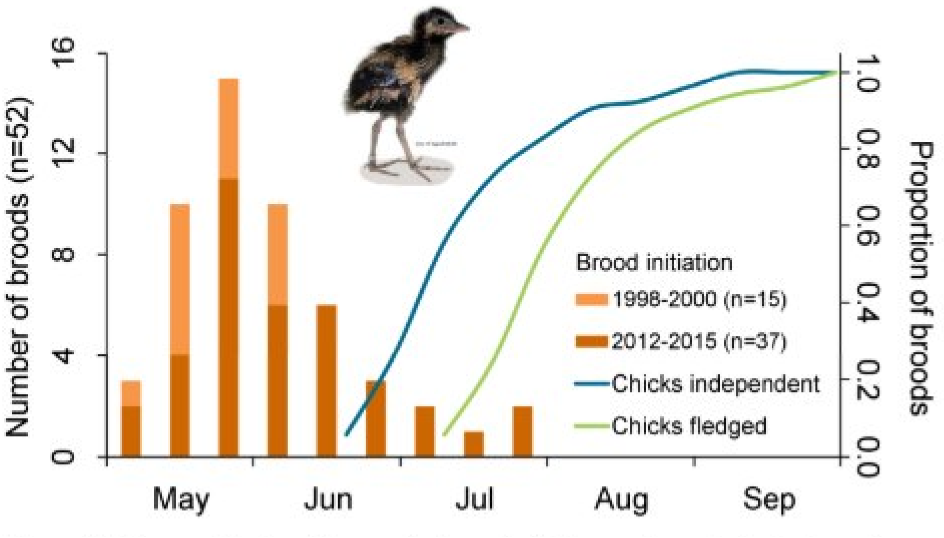


Figure 23 : Seasonal timing of Corncrake brood initiation and cumulative independence and fledging of broods in a study area in Germany (Arbeiter, 2020).

N. DATES OF MOULTING AND FLIGHT ABILITY OF ADULTS

MOULTING IN THE BREEDING AREA

Males and females begin a simultaneous postnuptial moult of the remiges and rectrices in July-August just after breeding. According to Green et al. (1997) and observations in Poland, Ireland and Scotland corncrakes can't fly for some time because they lose all their primary and secondary remiges within a few days. Indeed, Green's (2010) study found that females caught with primaries less than halfway through moult were unable to fly, and that a mean duration of complete moult was 32.6 days (± 13.0 days). The moult of females captured in Green (2010)'s study started on average August 12th (± 4.7 days). The end of the moult of the primaries was on average September 13th (Green 2010). The moult may be completed in late August to mid-September, but sometimes tectrices are still moulting in October. According to Demongin (2015), individuals with late wing moults (October) appear to be late breeders. This was verified by Green (2010) where females captured before August 15th that had chicks had significantly lower moult than those that did not have chicks (Figure 24). The moult of the remiges seems to begin during or after the period of care given to the last brood. It should be noted that during this study, some females accompanied by broods were able to flee and avoid capture. Their moult had therefore probably not yet begun.

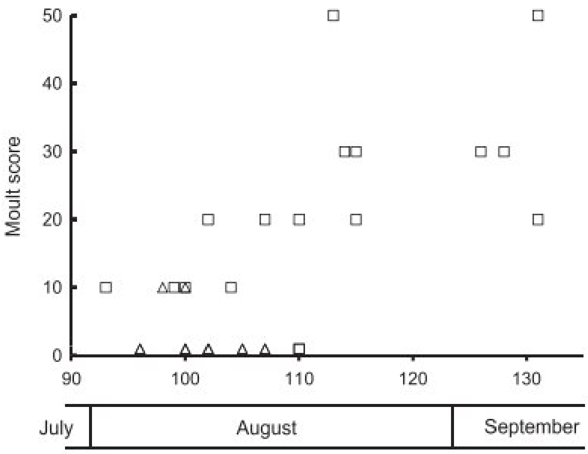


Figure 24 : Primary moult scores of adult female Corncrakes, captured in 1998-2003, 2005, 2006 and 2009 in Scotland, in relation to date (1 May = 1). Birds with score zero had not yet shed their old flight feathers and those with score 50 had all 10 of their primaries freshly grown. Triangles represent females that were associated with chicks and squares represent females without chicks (Green, 2010).

The postjuvenile moult is partial between mid-July and mid-September at the end of growth when the remiges are still growing. And the moult ends a month later with the head and body moult (Demongin, 2015).

MOULTING IN THE WINTERING AREA

In the wintering areas, a partial prenuptial moult occurs between December and March-April. This moult is limited to the head and body (perhaps not completely), the tail and sometimes some of the coverts (Demongin, 2015). A partial prenuptial moult of juveniles occurs from February to April and includes the tectrices and part of the coverts (Demongin, 2015).

8. INTRA-SEASONAL MOVEMENTS

Corncrakes move a lot during the breeding season and some movements recorded, only for males so far, represent several hundred kilometres. These movements can be explained by changes in habitat during the season (particularly due to mowing) and by search for partners for a other brood.

A. EVIDENCE FOR THE MOBILITY OF THE SPECIES DURING THE BREEDING SEASON

Several studies have shown arrivals and departures of singing males throughout the breeding season. Indeed, Mikkelsen et al. (2013) detected in Norway songs on new territories throughout the period from May to June. And 42% of territories appear after 15 June (56/132 territories). In addition, territory abandonments were observed during the months of June and July, with 68% of territories (52 territories) abandoned before 15 June. So a significant proportion of territories were abandoned before detection of new ones. Similar results were found by Arbeiter et al. (2017b) in Germany, who consider continuous arrivals and departures from breeding areas throughout the season. In this study, singing males were counted twice, in mid-May and mid-June, throughout the 54 km^2 study area, and every ten days from early May to late June in parts of this area from 1998 to 2000 and from 2012 to 2015. Sites were considered abandoned if no song activity was detected during three consecutive nights throughout 30 days monitoring periods. And new song detections in abandoned territories were considered as arrival of a new individual. A total of 412 site occupations were recorded and a model was used to estimate the probability of occupying a site, taking into account the bias of the detections and working in an open population. So in the study area, throughout the breeding season and for each ten-day period, there are continuous arrivals and departures.

Furthermore, results of the study by Brambilla & Pedrini (2011), in the Alps, suggest a shift of individuals from lower to higher altitudes as the season advances. These conclusions are based on the comparison of counts of singing males, monitored between 1997 and 2010 in northern Italy, in two areas at different altitudes (one area at 975.5 m on average, the other at 1175 m on average). Each area was monitored at two times during the breeding season, once at the end of May/beginning of June before the first mowing and once at the end of June/beginning of July between the first and second mowing. These counts showed higher abundances at lower altitudes during the first period than during the second, while the opposite was observed at higher altitudes (Figure 25). This result suggests an altitudinal shift of the singing males during the breeding season. However differences between altitudes of these two categories are small and not all areas were monitored in all years.

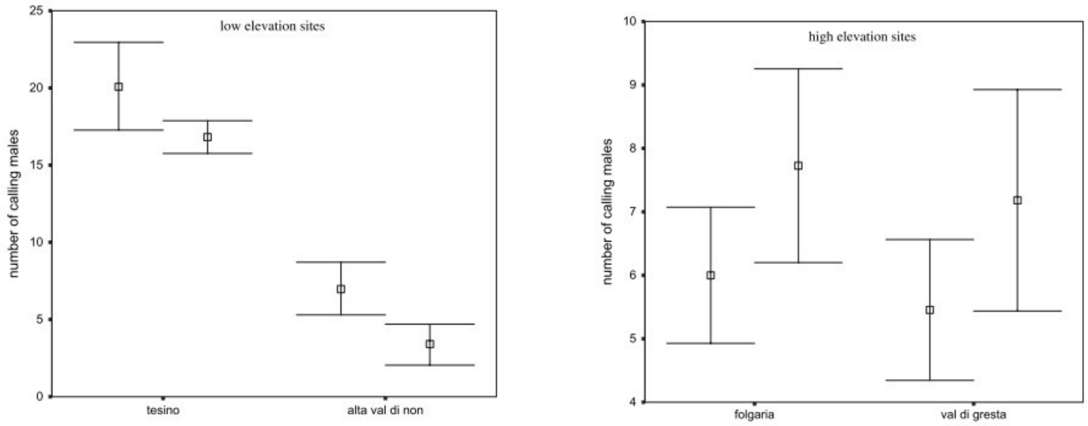


Figure 25 : Mean number of calling males during early (left value) and late (right value) periods, for low elevation and high elevation areas (Brambilla & Pedrini (2011)).

O. VARIABLE AND LARGE DISTANCES TRAVELLED DURING THE BREEDING SEASON

Mikkelsen et al. (2013) identified individual song of each male in Norway and have shown that a significant proportion of individuals move during the breeding season. They estimate also the distances and frequency of these movements.

This study shows that the individuals monitored were able to move sometimes more than 300 km away, that some males made several trips during the breeding season and that some returned to sites they had previously occupied in the same season. These results are based on the analysis of 83 songs from 60 different territories recorded between May and July 2009 in east and southwest areas of Norway. Considering errors due to a possible degree of similarity between songs of some individuals, 31-45 males were detected. Nineteen individuals are presumed to have made 29 movements, with eight of them who made more than one. These movements ranged from 0.3 to 404 km (median 318 km) with, depending on the degree of song similarity considered, 24% to 61% of males having moved more than 0.3 km and 18% to 48% more than 10 km. Movements higher than 300 km in this study represent movements between the two monitoring sites separated by habitats not very favourable for corncrakes. In addition, some records suggest that some males that moved from southwest to eastern Norway subsequently returned to their first site.

The mobility of males monitored in Norway was confirmed by recaptures during the same breeding season of 11 ringed corncrakes (Mikkelsen, 2010). Recaptures occurred 132 km away for one of these individuals, 67 km away for another individual and less than 10 km away for half the individuals. However, the capture effort was greater close to the initial banding site, which may introduce a bias in recapture distances. Other recaptures of ringed males several hundred kilometres away during the same breeding season were also carried out at different locations in Europe. For example, a male captured in the Czech Republic on 4 June 1999 and was recaptured in Switzerland on 1 July 1999, i.e. 614 km away (Inderwildi et al., 2017).

P. A BEHAVIOUR CERTAINLY INDUCED BY A SEQUENTAL POLYGAMY SYSTEM AND BY DISTURBANCES

Some studies have attempted to understand factors influencing movements of singing males during the breeding season. Results show that disturbances such as mowing may cause males movements. But they do not explain all movements. Some studies have shown that habitat characteristics didn't explain te choice to leave or stay. So the search for a new partner to produce another brood may be one explanation for these movements.

Indeed, Mikkelsen et al. (2013) have shown, based on song identifications in Norway, that corncrakes movements can be caused by mowing. 52% (n= 80) of last detections of males occured shortly before the mowing of the sites. Most of these last detections occured one to three days before mowing, except when males were detected at the edge of the plots one to two days after mowing. However, not all probable movements observed in this study are correlated with the mowing of the site. In some cases, departures occured before mowing. In other cases, males moved from crop fields that were not mowed before the end of the breeding season.

Furthermore, there are changes in local conditions of corncracke's habitat throughout the season. However, the study by Michalska-Hejduk et al. (2017) in Poland showed that while corncrake habitats did change over the season, the choice of males to stay or leave is not correlated with habitat's characteristics.The authors realised six counts of corncrakes from May 12th to July 4th 2001. For the 170 male territories detected before 20 June, neither plant community types, light and soil moisture indicators nor vegetation density had a significant effect on the choice of males to stay or leave.

Large intra-seasonal movements of males may certainly be the search for females for a other mating (Michalska-Hejduk et al., 2017; Mikkelsen et al., 2013), as such behaviour probably increases the chances of reproductive success in a sequential double-brooded polygamous system.

9. WINTERING AND MIGRATION

Corncrakes are long-distance migrants, flying mainly at night between their breeding grounds in Europe, used from April to September, and their wintering grounds in Africa (Del Hoyo, 1996). Wintering areas, migration routes and strategies are not well known, including habitat used, intra-seasonal movements and threats in wintering sites.

A. CHRONOLOGY OF MIGRATION

Corncrakes arrive on the breeding grounds in Europe starting in April (Schäffer & Koffijberg, 2004). The average arrival date was estimated to be 21 May (30 April-15 June) by Green et al. (1997). This result comes from a questionnaire sent to 28 countries in the species' breeding range in the 1990s. However, these arrival dates differ between regions. In western France, for example, the first corncrakes arrive around the beginning of April (with also earlier detections in some years, such as March 15th in 1999), which is earlier than in other regions (Schäffer & Koffijberg, 2004). In Poland, the study by Schaëffer (1999) shows arrivals on average on May 4th (Apri 28th- May 6th). In Scotland, same arrival in late April-early May was observed in 2011 for five geolocated males (Rhys E. Green, 2013). In the Netherlands, the highest numbers of conrcrakes are observed the last week of May or early June (Koffijberg & Van Dijk, 2001). However, in some regions, arrivals do not take place until mid-June. These dates may correspond to a new attempt of breeding after a first one or disturbances at previously used sites. This is the case for example in Wallonia where, between 1966 and 2015, out of 214 males detected, 124 were detected in June (58%) against only 43 in May (20%) and 46 in July (21%) (Verbelen et al., 2016).

The departure of corncrakes to Africa after the breeding season is less easy to study. Some authors talk about a start of migration in August with a probable peak in September (Del Hoyo, 1996, Stowe & Hudson, 1991b ; Walther et al., 2012). Several studies support this idea of a peak in September, with observations in North Africa in late September - early October thanks to interviews with 50 birders, ringing data and literature (Stowe & Hudson, 1991b). Capture of 767 corncrakes between September 6th and October 11th 1994, with a peak of capture on September 22in hunting nets in Egypt, confirms these results (Baha El Din et al., 1996). This idea is also confirmed by the arrival in West Africa in October of five males tracked by geolocators from Scotland (Rhys E. Green, 2013). In addition, Peške and Vlček (2017), thanks to Argos tracking of 12 males in Germany and Czech Republic between 2012 and 2015, showed a migration departure in the first week of September for six males, and between August 20th and 31th for three others (the others could not be tracked until migration departure). However, differences between regions, sexes, adults and juveniles are possible but are not well known. Indeed, Green (2010) showed that for the 32 females captured in his study in Scotland, the date of completion of the primary moult, and so the ability to migrate, is on average September 13th. Donaghy et al (2011) showed, through a telemetric study in Ireland, that for the juveniles the departure from the breeding sites takes place between mid-July and the first week of August for the first brood, and between 20 August and mid-September for the second brood. However, during departures, the question of the use of pre-migration sites and the use of intermediate sites or a migration departure remains unresolved.

The study by Stowe & Hudson (1991b) report observations of corncrakes in North Africa in late September-early October, in Kenya in November and in southeast Africa in December. Departures from the wintering grounds are described to be in February-March, with corncrakes observed in North Africa in early April. Green's (2013) study shows an arrival of five males, tracked by geolocators from Scotland, in West Africa (between Nigeria and Ghana) in October and then a departure after 30-50 days to western Congo where the individuals remained from November to March.

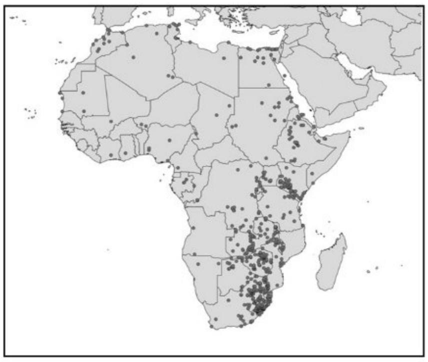
Q. WINTERING DISTRIBUTION OF CORNCRAKES

The distribution of the corncrake outside the breeding season is also not well known. Field observations and modelling of potential winter distribution suggest a winter distribution mainly in south-east Africa (Del Hoyo, 1996; Walther et al, 2012). However, individual monitoring of corncrakes show also western wintering areas, particularly for individuals coming from western Europe (Walther, 2008; Green, 2013) (Figure 26).

Figure 26 : Global distribution of the Corncrake during the breeding season (brown) and wintering season (in yellow the majority area, and in blue the more recently discovered wintering areas for Scottish Corncrakes), and location of migration routes (blue arrows) (map source: Hennique et al., 2013)

The data collected by Walther et al. in 2012, as well as the modelling carried out by this same study, allow to estimate a winter distribution covering 3,567,933 km^2 , mainly in south-eastern Africa (Uganda, Kenya, south-eastern Democratic Republic of Congo, Tanzania, Zambia, Malawi, part of Botswana and Mozambique, Zimbabwe, Lesotho, Swaziland and eastern South Africa) (figure 23). Wintering in South-East Africa, Kenya, Tanzania and Zambia was confirmed by Argos tracking of 12 males captured in the Czech Republic and Germany between 2012 and 2015 (of which 9 males were tracked until migration departure and 6 could be tracked throughout their migration), (Peške and Vlček, 2017) (Figure 28c). Very occasional corncrakes observations were noted in West Africa by this study. Walther (2008) mentioned some observations between December and in West Africa (Mali, Ghana, Cameroon) and some observations in Sudan and even near the Mediterranean.

It should be noted that the distribution map of the Walther et al. study (2012) is based on a relatively limited number of observations (around 1200) which are distant in time and probably subject to a strong geographical bias regarding sampling effort (more observers in South Africa than in Congo for example). Furthermore, the prediction of winter distribution, made from a model based on climatic variables, shows significant differences with that of real observations. This distribution map of corncrakes in Africa should therefore be treated with caution because of these two methodological limitations (extrapolation simply on the basis of climate and strong geographical bias of the surveys).



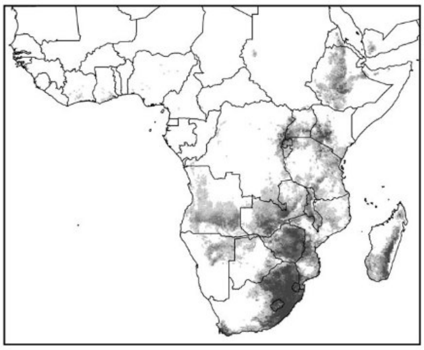
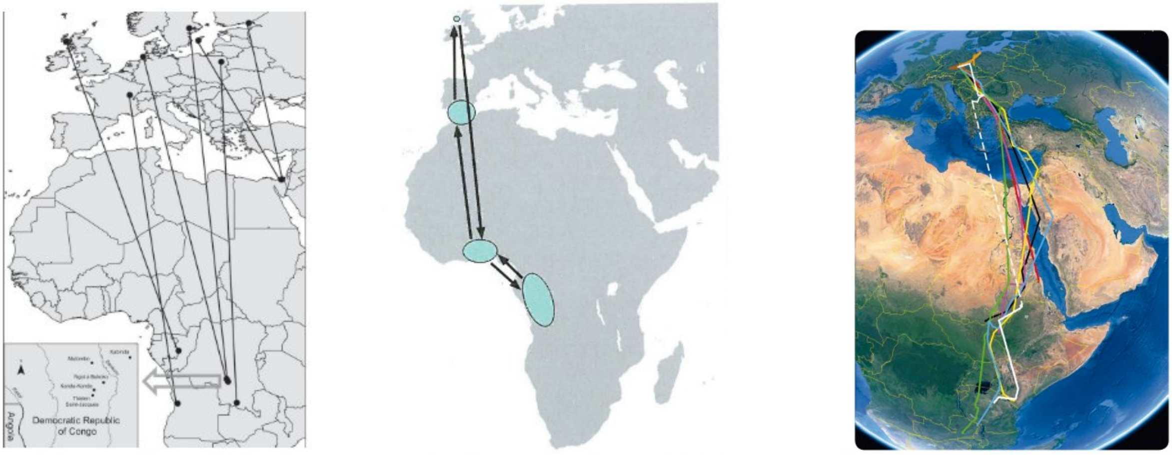


Figure 27 : Corncrake records distribution in Africa (a) and corncrakes' modelled wintering distribution (b) (Walther, 2012)

Other studies based on individual tracking have also shown the presence of wintering areas in Central and West Africa. Indeed, the five geolocators recovered (out of 50) from males from the same breeding site in Scotland showed that all these individuals had wintered in the Congo Basin with a 30 to 50 day stopover in Nigeria and Ghana (Green, 2013) (Figure 28b). The results obtained by Walther in 2008 are similar and have shown wintering in Congo, Democratic Republic of Congo and Angola of five individuals ringed in different countries such as Scotland, France, Poland, between 1929 and 1994 (Figure 28a). According authors, there are still questions about relationship between the low number of observations made in Central and West Africa and the lower numbers in the Western European populations.

It should be noted that these precise ringing and tagging studies of migration and wintering are based on few birds and have only involved adult males.

Corncrakes breeding in France have not yet been studied to determine their wintering area. The ringing of an individual ringed in the Jura in May 1970 was repeated in March 1971 in the province of Cuanza Sul in Angola (Walther, 2008) but this is the only data available for the French populations.



a. *b.* *c.*

Figure 28 : Breeding and wintering sites of some individually monitored corncrakes : (a) European ringing and African recovery localities of some Corncrakes (Walther, 2008), (b) geolocators monitoring (Green, 2013) and (c) Argos tracking (one color for each individual) (Peške and Vlček, 2017)

R. MIGRATION ROUTES

Corncrakes migrate along several routes, at least one to the east, crossing Egypt and Sudan in particular, one to the west, passing through the Iberian Peninsula and mainly Morocco, one passing through Tunisia and one crossing the Red Sea with entries in Sudan and Ethiopia (Stowe and Hudson, 1991b; Del Hoyo, 1996; Walther et al., 2012). The majority of migration is supposed to be through the Egyptian and Middle Eastern routes, as shown by Walther et al. in 2012, who used 1284 observations data.

A strong bias in the sampling effort is however present in these works. And the migratory routes used according to the origin of the individuals are still poorly known.

The use of the western route by individuals coming from western Europe was confirmed by five males tracked with geolocators (Green, 2013). In this study, these five individuals from Scotland migrated in both directions in the western route. They reached their wintering grounds via the UK, France, Morocco and Algeria before crossing the Sahara and then returning via the Maghreb and Spain.

The use of the eastern route by corncrakes from the Czech Republic and Bavaria was demonstrated by tracking six Argos-tagged males (Peške and Vlček, 2017). Within this study, three individuals reached their wintering grounds via the Mediterranean and then Egypt, and three individuals crossed the Mediterranean, Saudi Arabia and then the Red Sea. A ringing record of an individual from north-eastern Germany, indicating a passage via Cyprus (Walther, 2008), suggests that individuals from this area use the same route as individuals in the Peške and Vlček (2017)'s study. Similarly, rings of individuals from Sweden and Finland were checked in North Sinai in Egypt in October 1971 and September 1991 (Walther, 2008).

However, the monitoring of corncrake rings from the same geographical area in the Netherlands suggests that the correlation between breeding area and migration route is not complete. Indeed, rings of individuals ringed in these areas were recovered in France, Belgium and Switzerland, while another individual was killed in Syria in April 1976 (6 years after ringing) (Van den Bergh, 1991).

For the French population we don't know yet about the migration route and wintering area of the individuals.

S. MIGRATION STRATEGY

There are at least two migration strategies of corncrakes: a continuous migration strategy and a strategy with long stopovers.

Indeed, among the six individuals tracked by Argos tags along the eastern route, some migrated very quickly, travelling up to 1,600 km in 48 h, while other individuals migrated more slowly with stopovers, staying for long periods in southern Sudan in particular (Peške and Vlček, 2017). Males from Scotland also made a major stopover of 30-50 days between Nigeria and Ghana before travelling nearly 2,000 km in five days to western Congo, where they remained from November to March.

Hypothesis of a loop migration has been proposed by Cramp & Simmons (1980). This hypothesis was based on the more numerous observations in Tunisia in spring and in Egypt and Cyprus in autumn. But Walther (2008) does not support this hypothesis and the return route taken by the five Scottish males do not support also this loop-migration hypothesis (Green, 2013). On their way back, these five individuals crossed the Sahara, then the Maghreb and Spain. A migration through West Africa was observed for at least one bird, but it is difficult to know as the latitude could not be estimated precisely at this time of the equinoxes (Green, 2013).

T. HABITATS AND LAND USE IN WINTERING AREAS

The different habitat types used during migration and wintering in Africa were analysed by Walther et al. (2012) based on 200 observations from different sources. According to this study, corncrakes mainly use grassland habitats (67.9% natural grasslands dominated by grasses, pastures, natural grasslands in forests, savannahs, airfields...), followed by wetlands (at 21.8% grassy areas in drainage areas, on the edges of wetlands, flood plains, riverbanks, streams or dams, but also seasonal and permanent marshes), and to a lesser extent crop fields (wheat, oats, maize, millet, sugar cane, etc.) and abandoned fields. Argos-tracked males from the Peške and Vlček (2017)'s study stayed for a long time in southern Sudan, in a new agricultural area that has been created in the last few decades by irrigation. The geolocator locations of Green (2013) are not precise enough to define the type of habitat used. However, the area used is composed of savannahs, fields and pastures as well as forests with areas kept open by forest elephants, buffalo and antelopes (Green, 2013). Taylor in 1984 noted the grouping behaviour of corncrakes during the wintering period.

Finally, more studies are needed to understand the effect of seasonal and annual environmental changes on the movements and winter distribution of corncrakes. Indeed, the results of Green (2013) raise the question of the causes of large intra-winter movements. Such as movements observed by the departure from the first stopover in Ghana and Nigeria after 30-50 days to reach western Congo 5 days later, which might be triggered by habitat drying and determined by rainfall patterns.

U. THREATS IN WINTERING AREAS

The threats to corncrakes in the wintering areas are still not well known. One of the threats identified is hunting, particularly netting on the Egyptian coast, which appears to kill important numbers of corncrakes during the autumn migration. Baha El Din et al (1996) recorded 487 corncrakes killed in 1993 and 767 in 1994 in this area. The study by Eason et al. (2016) also showed that corncrakes were the species most affected by hunting in Egypt (apart from quail) with 3,108 individuals killed in five years between 2008 and 2012. However, other potential threats such as land use change in wintering areas or climate change have not yet been studied.

V. SURVIVAL AND DISPERSION

SURVIVAL RATE

Although the maximum banding lifespan of a Corncrake is 6 years (Schäffer & Koffijberg, 2004), the annual survival rate is estimated to be 0.2 - 0.3, with some variation by sex and age category (Green, 2004). Thus, this study showed that the survival rate for adult females is estimated at 0.259 and is not significantly different from that estimated for adult males at 0.298. These results were derived from the use of three methods: ring recovery from dead birds, capture-mark-recapture by banding, and distinguishing yearling adults from older adults by the shape of the secondary remiges. Another study, Green (1999), showed that the survival of first-year males is of the same order of magnitude as the results of Green (2004), and that there is no significant difference between the survival rates of the first and second brood. In addition, the study by Tyler & Green (2004) in Scotland sought to estimate the survival of chicks to the age of eight days. For 34 broods monitored in the 1990s, it was shown that 85% of them still had at least one chick eight days after hatching. It was also shown that although neither temperature nor precipitation after hatching had a significant effect on the complete loss of the brood and on the proportion of surviving juveniles within a brood, this proportion was nevertheless shown to depend on the size of the brood at hatching. This can potentially be explained by competition for the food provided by the female. It should therefore be noted that the inter-annual survival of Corncrakes is low, so fecundity plays a major role in maintaining populations.

DISPERSION

The information known to date on the dispersal of individuals, whether in terms of proportion of philopatry, inter-generational difference or distance between dispersal sites, still raises many questions for a better understanding of the flows and conservation of the species.

Budka et al. (2020) sought to investigate the inter-annual fidelity of males to the breeding site between 2015 and 2018 in Poland. In this case philopatry was found to be very low, with only 2-5% of 40-56 males recaptured the following year. In the same study, monitoring of territories occupied each year showed that on average 32% of territories were formed in the same location as a territory from the previous year.

Dispersal distance, at least for males, is highly variable and seems to differ between juveniles and adults. Green's (1999) study in Ireland and Scotland, using ringing data, showed that most adult males returned within a few kilometres of the ringing site, and that juvenile ringed birds appear to have dispersed further, although it is not yet possible to be certain. Indeed, in this study movements greater than 10 km between years were found in greater proportion for juveniles (20%) than for adult males (6%) but the samples in this study are small and the difference between juveniles (10 recaptured in subsequent years out of 339 ringed) and adult males (30 recaptured in subsequent years out of 582 ringed) is not significant. In addition, long movements were probably under-sampled given the spatial distribution of the recapture effort. A correction for this sampling bias in the model suggests larger and more different proportions of movements between age classes (43% of recaptures over 10 km in subsequent years for birds ringed as chicks and 10% for those ringed as adult males).

While this study by Green (1999) also showed that several individuals were recaptured two years in a row at distances of less than one kilometre, some individuals were recaptured up to several dozen kilometres away and other studies refer to sites chosen by the same individual from one year to the next that were several hundred kilometres away. Indeed, one of the males tracked by Argos beacons from the Czech Republic settled in the Dolomites in Italy on 24/25 June. The distance to its previous nesting site was therefore 350 km. The latest data in May from tracking the second Argos-tagged male from the Czech Republic in this study showed that he had returned to Serbia to a location where he had made a long stopover the previous year (Peške & Vlček, 2017).

It should be noted that this knowledge of dispersal is only for males and that differences can potentially exist between Scotland, Ireland and other areas of the breeding range. However, in view of intra-annual and inter-seasonal dispersals (see Intra-seasonal movements section) and the contributions of genetic studies (see Distribution and genetic structure of populations section), it is suspected that there are significant flows between populations and that these remain to be better studied.

These initial answers to the question of dispersal provide further support for questions about the estimates of survival by capture-mark-recapture, which are certainly underestimated. They also raise questions about the level of geographical coordination needed for the study and conservation of the species.

EFFECTIVENESS OF CONSERVATION MEASURES

In order to protect corncrakes (adults and juveniles) during the breeding season it is necessary to preserve grassy areas that provide a certain height, structure and density of cover and richness of flora that guarantee food resources and protection from predators. The availability of this habitat throughout the breeding season is important to allow the stability or even the increase of the species' numbers. The corncrake is a short-lived species (Schäffer & Koffijberg, 2004), with rapid turnover, and the dynamic is therefore largely based on fecundity. In this context, one of the main threats to corncrakes'populations is the early and simultaneous mowing of large areas of grassland habitats. There is a loss of breeding habitat but also direct mortality during the passage of the mowers. Many mowings occur before chicks are able to fly and before adults have finished moulting. And loss and modification of the grassland habitat is also an important threat.

In response to this, many conservation actions in Europe try to provide adequate plant cover, adapted to the breeding phenology and aimed at reducing the mortality of individuals during mowing. In addition, restoration programmes have been set up in some areas to stop the loss of habitat. Finally, a case of reintroduction of the corncrake, which has been going on for many years, allows us to gain some perspective on this action. While some actions have been directly evaluated for their effectiveness, many are evaluated based on indirect correlations between the start of the measures and the evolution of the numbers in the following years.

1. RESTAURATION AND MAINTENANCE OF THE HABITAT OF CORNCRAKE

The disappearance of corncrakes' habitats is a major threat. For example, meadows are increasingly abandoned. Changes in the functioning of watercourses are having also an impact on ecosystem dynamics and the presence of a suitable habitat for corncrakes.

A. RESTORATION

In some cases, habitat restoration actions have been carried out. One case study of habitat restoration that has had a significantly positive effect on corncrakes is the implementation of a LIFE programme in Latvia. This programme, which aimed to face the abandonment of grasslands and the decline in water levels in the Dviete River in this area, was carried out between 2010 and 2015 by the Latvian Fund For Nature (Ķerus et al., 2015). In the targeted area, the regime of the Dviete water system was restored over 2 km and 113 ha of trees and shrubs were removed, creating a continuous area favourable to corncrakes over 300 ha. In addition to these actions, in order to maintain areas favourable to the reproduction of the species, contracts for extensive grazing (with the presence of "Konik" horses and "Highlander" cattle) were concluded between the local association and the owners. Initially, these contracts were signed for 4-5 years, and then subsequent contracts were agreed for 10 years. In order to maintain the condition of the meadows and pastures over time, when contracts finish, they are renegotiated by the Dviete Valley Parish Association (DSPA). This association has made a 20-year commitment, until 2035, to work to maintain the restored grasslands.

This restoration programme has made it possible to recover functions of the Dviete and the presence of meadows favourable to corncrakes. The numbers of corncrakes have shown a much greater increase in the restored areas than in the rest of the park and the rest of the country (figure 29). The fluctuations in numbers can potentially be explained by management actions that took place within the project.

The main problem encountered during this programme was cooperation with landowners. Indeed, before the start of the project, oral agreements were made rather than written agreements. Subsequent experience has shown that the refusal of one landowner had a significant impact on the outcome of the project, as it prevented ecological continuity in the restoration of the river.

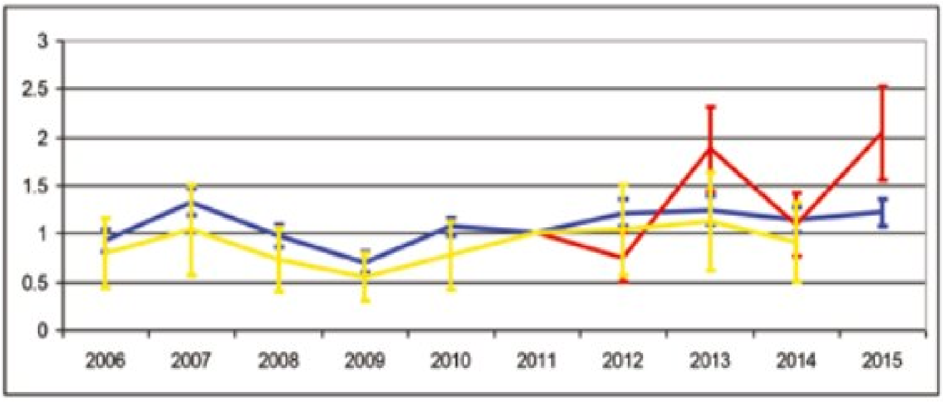


Figure 29 : Trend in the project area (red), in the entire Dviete nature park (blue), and in Latvia (yellow) (Ķerus et al., 2015)

B. MAINTAINING MEADOWS FOR CORNCRAKES AND FIGHTING AGAINST ABANDONMENT

Following the restoration of meadows that are welcoming to the corncrake, the second challenge is to maintain these meadows in the long term. Maintenance of the grasslands is necessary to avoid closure of the area.

This has been achieved in different ways depending on the conservation plans, either by setting up mowing contracts with farmers (Ķerus et al., 2015), or by using very extensive grazing, as has been the case in Latvia with the use of cattle and horses (Ķerus et al., 2015) and in Germany with the use of water buffaloes in some areas (Schorfheide-Chorin, 2019). The maintenance of grasslands should be extensive to preserve their quality and their potential to host corncrakes (see Habitat section). Indeed, the use of fertilisers and drainage causes a modification of the vegetation, and reduces the floristic diversity present in grasslands with varied relief (depressions, humps, flooded areas, sloping areas, etc.). The diversity and abundance of food resources for corncrakes may also be affected, especially if other types of inputs such as plant protection products are used.

However, one example should draw attention to the conditions under which these contracts have sometimes been set up to face grassland abandonment. In fact, in order to counteract the abandonment of grasslands, compensation payments were introduced in 2000 in the province of Trento in Italy as part of the Rural Development Programme. The objective of these contracts was to maintain 14,000 ha of grassland between 2000 and 2006. However, these allowances led to the simultaneous mowing of all plots, as farmers joined forces to save time and maximise economic benefits. The mowing was therefore carried out in one or a few days and without marginal areas that had previously remained unmown and which also became mown for economic gain. It was thus observed that the shift from spatially and temporally heterogeneous mowing to simultaneous mowing coincided with a decline in corncrake populations in the region, whereas other regions showed some stability over this study period in Western Europe (Brambilla & Pedrini, 2013).

2. PRESENCE OF COVER ADAPTED TO THE PHENOLOGY AND ECOLOGY OF THE CORNCRAKE

The protection of corncrakes requires covers adapted to the phenology in order to allow a good reproductive success. Corncrakes generally lay two broods, and the success of both is necessary to allow the viability of the populations (Green, 1999). The choice of mowing date to allow the fledging of the young ones is therefore important for the viability of the species' populations. In addition, the grass surface used by adults and chicks is an important factor. Moreover, for a management on the scale of a group of meadows, mowing at different times and in different places may be an option. That can be influenced by simultaneous disappearance of the cover.

A. ESTABLISHMENT OF EARLY COVER

The presence of tall vegetation at the time of the corncrake's arrival in April (see Reproduction section) is an essential and limiting condition for the settlement of individuals on a territory in order to start their breeding cycle (see Habitat section).

This is why the National Parks & Wildlife Service (NPWS) in Ireland has installed the Corncrake Farm Plan Scheme (CFPS) (National Parks & Wildlife Service Report, 2015). The aim of the scheme is to engage farmers in a five-year plan to create and maintain ELC (Early and Late Cover) areas with early and late cover. One of the aims is to achieve blocks of early cover of at least 0.1 ha corresponding to at least 5% of the total land managed for corncrakes. It takes 2-3 years to establish a cover, so a 5-year planning period is required. In this programme, cover requirements focus on hard-stemmed but sparsely growing species such as cow parsley, iris and nettles. This is to provide a height and density of vegetation that corresponds to the needs of the species (see Habitat section). Ploughed crops, such as potatoes or cereals, were not selected as suitable alternatives to provide cover for the arrival of corncrakes. On grasslands adjacent to these early cover creations, the management plan also requires a commitment from farmers to delay mowing to 15 July, and in the case of Corncrake presence, to mow inside-outsidely by 20 August or 1 September within 250 m. In 2015, the total area covered by these five-year agreements was 59.24 ha on ten farms registered with the Corncrake Farm Plan Scheme and spread across the Mullet Peninsula SPA, Fanad Head SPA and Malin Head SPA. Of this total contracted area, approximately 5% (2.98 ha) is earmarked for early cover creation and maintenance over five years. The managers' preferred approach has been to target areas adjacent to existing schemes to form a larger land management unit capable of attracting and supporting corncrakes.

Some landowners have voluntarily committed to the creation of these ELC areas on their land, especially as there is no significant negative impact on farmers' incomes. Other landowners did not want the introduction of targeted plant species on their land and so another method was used to create early cover outside this Corncrake Farm Plan Scheme. This was achieved by fertilising marginal areas and excluding livestock, which allowed natural vegetation to develop more rapidly than in the surrounding fields to provide early cover for the arrival of corncrakes.

W. IMPORTANCE OF THE DATE OF MOWING

BREEDING CALENDAR AND MOWING DATES

To allow two broods to be successfully fledged implies mowing in September in view of current knowledge of the species' ecology and phenology and certain feedback from experience.

For example, Donaghy's (2007) study in Ireland reported that the second brood fledged around 7 September on average.) The ability of females to fly (after completing their summer moult) and therefore to flee from mowers may also be very late. Indeed, according to Green (2010) of 21 females studied in Scotland, the average date of completion of moult of their primaries was 13 September.

A study of the proportion of nests affected according to the date of mowing was carried out by Arbeiter (2020) in Germany on a sample of 52 nests (Figure 25). The date of laying of the broods was determined by searching for nests (n=5) and capturing or observing the juveniles (n=47), taking into account that the average laying and incubation period is 25 days. The date of fledging of the young was defined as 50 days from the last song detection. Thus, in this study, no brood reached the ability to fly before July, whereas 80% of the broods had potentially reached this stage by 15 August (Figure 23). In this study, mowing on 15 July enabled 65% of the broods to have reached independence and to be fast enough to escape inside-outside mowing with the presence of refuge strips nearby (Tyler et al., 1998).

However, early mowing is frequent in July at the study sites and may have introduced a bias into the dates of observation of the broods, leading to a circular argument (since late broods do not occur, the percentage of early broods is overestimated). Furthermore, it should be noted that the phenology and timing of breeding vary between countries, nesting areas and years (Arbeiter et al., 2017b; Deceuninck et al., 1997; Broyer, 1995; Budka et al., 2014, see Reproduction section). Finally, the fledging date is most likely later, as the fledging age of the juveniles is most likely higher than the one used in the study (see Reproduction section).

Case study of late mowing dates

Scotland, a particularly interesting case in view of the significant increase in corncrake numbers observed since the 1990s, has since implemented mowing at dates appropriate to the species' phenology and likely to protect the two broods (Beaumont, 2016). Throughout the 1990s, various programmes were set up in Scotland in order to contractualise plots so that there would be no mowing or grazing before the beginning of August. From the early 1990s, these contracts were supplemented by the introduction of local protection measures when singing males were detected throughout Scotland. Mowing is only permitted within 250m of the male from 1 August throughout Scotland and only after 10 August in RSPB reserves. It is particularly in the latter reserves that the numbers of corncrakes are best maintained (O'Brien et al., 2006). In subsequent years, these measures have been adopted as part of government-funded agri-environment schemes with staggered payments for mowing on 1 August, 15 August and September (Beaumont, 2016).

Other regions tend to put contracts in place to ensure that plots are not mown until mid-August or September. This is the case in Murnauer-Moos, Bavaria, where mowing also takes place mostly in September with a financial support of 1,000 Euros/ha (with a minority of sites mowed on 1 August). However, the effectiveness of the management applied in this region can only be assessed by observing the stability of the population (with a low number of 30-35 singing males) (pers. comm. Heiko Liebel).

Case study of early mowing dates

In other localities, measures have also been implemented to postpone mowing, but at set dates in June or July, thus making it possible to preserve only one of the two broods. This is the case in the Alps in Italy (province of Trento), where the Rural Development Programme initiated in 2000 encourages no mowing between 5 May and 15 or 25 July, depending on altitude, in order to adapt to the movements of Corncrakes during the season (Pedrini et al., 2012). Following the introduction of these measures, it has been observed that populations are still decreasing in most Italian regions (Pedrini et al., 2012).

Another example is the Warta Mouth Park in Poland. In this area it is imposed not to mow or graze before 15 June, and in case of detection of corncrakes on a plot not to mow before 15 July (pers. comm. Michal Wolowik). However, for this area, the evaluation of the effectiveness of this measure and the monitoring of the trends in numbers have not been carried out (pers. comm. Michal Wolowik).

Case study of early mowing combined with localised late mowing

In another example, in the Netherlands, land ownership by biodiversity managers and the leasing of land to farmers make it possible to introduce delayed mowing on 15 June or 1 July for the conservation of avifauna and flora (Koffijberg, 2017). However, these mowing dates disrupt the breeding cycle of corncrakes because they are too early. These contracts are therefore supplemented by mowing on 1 or 15 August when Corncrakes are located in unprotected plots (Jan Schoppers, pers. comm.). The effectiveness of these measures has not been evaluated.

In addition, it should be noted that in the Netherlands not all individuals are found on these mown grasslands, but a significant number of corncrakes are found in alfalfa and winter wheat fields on the clay soils of the polders. In the alfalfa fields, the harvest takes place at the end of May and beginning of June and does not allow for good breeding success, any more than in the early mown meadows. Wheat fields are not harvested until August. In the Netherlands, breeding is also observed in field margins (Koffijberg, 2017). Measures cannot therefore focus solely on hay meadows. National numbers, although fluctuating, remain at low levels in the Netherlands with the measures currently in place (a maximum of 260 males detected in 2012 and a minimum of 41 in 2017 with a number of 118 in 2018) (Boele A. et al., 2020).

MOWING DATE AND BREEDING PHENOLOGY: INDIVIDUAL DETERMINATION

Another possible approach to defining mowing dates is based on the calculation of the fledging date of juveniles in cases of targeted protection of individuals. In this case, the date is based on the date of a local pairing estimated from the male's song data and the duration of the different stages of reproduction (see section on reproduction). However, the duration of pairing (between 5 and 10.5 days), laying (8 days and starting during the pairing period) and incubation (17-18 days) used for these calculations are only known from the monitoring of a very small number of 9 pairs studied in Scotland in the 1990s (Tyler, 1996b). In addition, there are variations in the length of time spent caring for the young. Green's (2010) results show an average care duration of 18.3 days. Green et al (1997) show a shorter care duration for the first brood (11.6 days) than for the second (16.7 days). Finally, the age at which juveniles are capable of flying and fleeing from mowers is now considered to be around 45 days. Based on these data, it is therefore estimated that mowing is possible at around 70 days after the detection of the pairing to allow the juveniles to become flightless. However, the wide variations and uncertainty in the duration of each stage make this figure rather fragile scientifically, and this is only when considering the completion of one of the two successive broods.

Case study of targeted mowing delay based on individual data

The Lower Elbe SPA in Lower Saxony, Germany, is one of the few examples of mowing delays implemented based on the calculation of fledging dates (early July, early August or early September) (LIFE+ report Wachtelkönig & Uferschnepfe). For the year 2019, the date of mating (or potentially abandonment of the plot) was defined for 18 males out of the 23 detected based on the monitoring of nocturnal song interruptions, daytime calls and the use of repassing (see section on reproduction). From July onwards, if there was a suspicion of abandonment rather than pairing then protection was not applied. Once the pairing date was defined, the date of fledging of the juveniles, and therefore of possible mowing, was determined for early July, early August or early September for each case. This date was calculated by adding 55 days to the end of the mating phase, taking into account a laying phase of 3 days, an incubation phase of 17 days and a phase of acquisition of independence and flight ability of the chicks of 5 weeks (the source of these values is not detailed in the study). In this area, almost half of the territories of the corncrakes were thus mown after mid-August according to the calculations. Mowing in this area is also carried out slowly and in an inside-outside manner, which may contribute to the stability of the observed numbers. The effect of these measures in 2019 is not known, but the decline of this population has continued since 2018 (after 6 years of stability) as in many German sites, without the reason being clear yet (pers. comm. Christiane Hinck).

MOWING DATES ADAPTED TO INTRA-SEASONAL MOVEMENTS

Another management option is to work on a landscape scale and define mowing dates adapted to the ecological temporal dynamics of vegetation growth and corncrake movements. There are very few places where this management method has been implemented so far. The only case we have identified is that of a differentiated management according to altitude, in the Natura 2000 sites in Trento, Italy (Pedrini, 2012). As corncrakes tend to move to higher altitudes with the advancement of the breeding season, below 1,000 m altitude mowing is forbidden between 5 May and 15 July and until 25 July above 1,000 m. In addition, in this zone, inside-outside mowing is imposed in these plots and the dates can be postponed by 5 to 10 days in order to adapt each year to the arrival of the corncrakes. However, in this area, the meadows are mown simultaneously and completely, and the results of monitoring show that, despite staggered mowing according to altitude, the corncrake populations are decreasing overall.

STAGGERED MOWING DATES

Mosaic management in the distribution of mowing dates for the different plots is a management option that has not been tested very much, despite its potential interest in view of the major threat posed by simultaneous mowing. Indeed, these mosaics can make it possible to permanently maintain plots that are favourable to juveniles and females. However, due to the scarcity of examples of this type of management, the factors to be taken into account, such as the surface areas and the dates of staggered mowing, have also been little studied. The detection of pairings by song and an estimation of the age of the juveniles, the home range used by these juveniles and their possible escape distance could make it possible to determine the dates and locations of the mowing of the different plots to be managed in mosaics.

Case study

The positive effect of mosaicing is observed in Italy in an area that has the particularity of having mosaic mowing, the Tesino area, and which happens to be the only place in Italy where the corncrake population is maintained at a correct density (Pedrini, 2012). The mosaic implemented in this area is "passive", as it is linked to a subdivision of the plots between different owners who do not mow simultaneously. However, these Tesino meadows are now threatened by the abandonment of mowing and the consequent closure of the area.

10. LOCAL PROTECTION OF INDIVIDUALS

Another management method, used among other things in the case of small populations and in addition to contractualisation of plots, consists of introducing local protection when singing males are detected, particularly in non-contractualised plots. The area and date of mowing to be recommended on this area must then correspond as closely as possible to the ecology of the species. In order to implement these measures, it is at least necessary to have an estimate of the location of the nests and females in relation to the detected singing males, to know the size and characteristics of the home ranges used by these individuals and the duration of the protection required. While this period of time required to preserve the two broods seems to be determined in mid-August or even September according to several studies (see previous section), very few studies have been able to quantify the first two points.

AREA TO BE PROTECTED AROUND SINGING STATIONS

A choice of a 250m radius of protection around singing males has long been implemented by some countries or advocated by others seeking to achieve this (Arbeiter, 2020; Donaghy, 2007; Inderwildi et al., 2017; Laudelout et al., 2020; O'Brien et al., 2006). According to the study by Tyler (1996), a radius area of 250 m around the singing male is considered to encompass the nests and the area used by juveniles still dependent on maternal care. In this study, the furthest nest from the male was 160 m away and the results of the radio-tracking of the females showed an area of 3.2 ha used when they were still accompanied by the chicks (i.e. a radius area of about 100 m). This choice of radius (160 m distance from the nest + 100 m of the female's home range) is therefore intended to avoid the destruction of the nest and the young before independence from maternal care. It should be noted that the data used for this calculation comes from a small sample of 9 pairs monitored by telemetry.

However, during late mowing, it is necessary to avoid the mortality of non-flying juveniles. In order to know the protection area to achieve this goal, Green (2019) studied the distances between the capture of non-fledging juveniles and their fathers' singing stations for 14 broods. This was based on microsatellite markers and in the absence of disturbance by mowing. The results show that juveniles less than 20 days old were between 4 and 151 m away from their father's singing position, and that independent but non-flying juveniles can be between 149 m and 601 m away from this position. Flying juveniles were found to be up to 823 m from the father's singing position.

This study has therefore led Green (2019) to propose more recently a 500 m unmown radius area around the singing males to avoid direct mortality of non-flying juveniles and to meet their needs.

Case studies

Some examples show the use, sometimes for many years, of a 250 m radius around singing males to ensure protection. In Scotland, for example, late mowing within this radius is one of the measures that has been implemented since the 1990s and has been correlated with significant increases in corncrake numbers. This has been achieved since 1992 across Scotland, by prohibiting mowing between 15 May and 31 July. However, in the RSPB reserves on the main islands where Corncrake populations are best maintained, since 1991 mowing has not taken place within this 250m radius of males between early March and 10 August (O'Brien et al., 2006). This 250 m choice is also used in Ireland where the Corncrake Grant Scheme offers staggered payments for delayed mowing within this radius (250 EUR/ha for mowing by 5 August, 325 EUR/ha for mowing by 20 August, 375 EUR/ha for mowing by 1 September with an additional 45 EUR/ha for inside-outside mowing). In 2018, in Ireland 125 farmers were involved for a total of 352.78 ha covered (O'Donoghue, 2019). This choice of radius was also adopted in Flanders, with a delay until 15 August, also combined with inside-outside mowing. However, little progress towards population recovery has been observed in this area despite these actions (Paquet & Derouaux, 2016).

On the other hand, in Switzerland, but also in the Freiburg district in Germany and in Wallonia where the presence of corncrakes is becoming rarer, the protected areas around the singing males are now much more restricted with a smaller choice of radius. In Switzerland, since 1996, one-year contracts have been put in place when corncrakes are detected. These contracts allow for a mowing on 15 August and on 1 ha (radius of about 60 m around the singing males) associated with refuge strips of 5 to 10 metres on the plots concerned (Inderwildi, 2016; Inderwildi et al., 2017a). Fencing can also be installed in grazing areas. In this area, the amount of compensation varies between CHF 1,500 and 3,000/ha depending on the financial loss of the farmers. In the district of Freiburg, Germany, another area with a low density of Râles, the annual contracts establish a protection of 3 ha (radius of about 100 m) around the singing males until September. In addition to these 3 ha, a 50 m wide strip is also delayed but can be mown slowly from the outside inwards if necessary (Ingmar Harry, pers. comm.). Finally, we can take the example of Wallonia where currently an area of 4ha (radius 112m) is protected for at least 65 days when a singing male is detected (Laudelout et al., 2020).

In the latter two cases, births have been observed (pers. comm. Ingmar Harry, Inderwildi, 2016). In Switzerland, these contracts could be the explanation for the increase in the number of probable and certain nestings (from 9 between 1970 and 1994 to 61 certain and 176 probable between 1996 and 2015) as well as the number of Corncrakes. However, it is possible that some of these increases are due to an increase in monitoring effort in parallel with the implementation of management measures (Inderwildi, 2016; Inderwildi et al., 2017). Laudelout et al. (2020) calculate that with the implementation of the 4 ha recommended today in Wallonia, one third of the nests of the Tyler (1996) study (for which distances to males are known) would have been directly destroyed by the mower.

TEST TO ESTABLISH TERRITORIES BY RE-PASSING ON FAVOURABLE PLOTS

The location of the males' territories cannot be anticipated, as studies have so far shown very little philopatry and reuse of sites from one year to the next for the establishment of territories (see Survival and Dispersal section). In order to control the location of territories for individualised protection, the idea was put forward to induce the installation of males at the beginning of the season on favourable plots by repassing. However, this method has been tried many times in the UK and feedback from experience gives little hope of success (pers. comm. Rhys Green).

11. RÉDUCING MOWING-INDUCED MORTALITY

In addition to providing cover, it is essential to reduce mortality caused by mowing, which can take place in places and on dates when non-flying individuals may still be present. Indeed, such mortality annihilates both reproduction, affecting fecundity, which is the parameter that contributes most to the dynamics of these populations, and the survival of adults, thus representing a potentially considerable impact on the populations.

Although the speed of mowing and the width of the mower are undeniably involved in the destruction of nests and the mortality of juveniles and adults, no study has observed the differences in impacts according to the agricultural tools, their speed, or their width existing in France and in Europe. Similarly, the effectiveness of the use of a scare bar in front of the cutter bar has never been quantified. In order to reduce direct mortality caused by mowing, it is therefore widely recommended that inside-outside and slow mowing be carried out, leaving sufficiently large and well-localised refuge strips. The aim of these measures is to allow juveniles and moulting adults to have time to flee from the mower and take refuge in an accessible favourable habitat. In order for this measure to be effective, the refuge must also be large enough to allow the broods to finish the season while avoiding the aggravation of the risk of predation and the creation of ecological traps.

A. INSIDE-OUTSIDE AND SLOW MOWING

The inside-outside mowing technique is part of many action plans (Crockford et al., 1996; Inderwildi et al., 2017; Williams et al., 2008) to reduce direct mortality of non-flying juveniles that become trapped during outside-inside mowing (Figure 30).

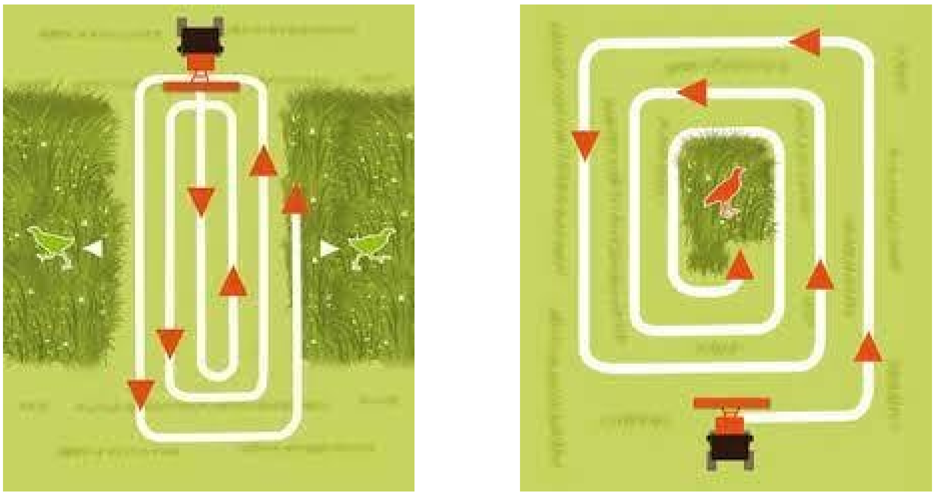


Figure 30 : SInside-outside mowing increasing corncrakes survival (left) and outside-inside mowing increasing mortality (Guide technique du Programme LIFE + Nature Râle des genêts 2011-2015)

The effectiveness of inside-outside mowing to ensure better survival of corncrakes in comparison to the impact of outside-inside mowing has been demonstrated by Broyer (1996). In this study, the mortality of non-flying juveniles was 17.5% during inside-outside mowing and 86% during outside-inside mowing. In this study, for the 86 individuals observed in 1994 and 1995, 2.3% of adults and juveniles able to fly were killed.

X. MAINTAINING REFUGE STRIPS

Two studies in Germany and in France (Arbeiter, 2017 and Broyer, 2003) have shown the effectiveness of refuge strips in preventing the destruction of broods during mowing and allowing juveniles to reach fledging age. The flight behaviour of adults and juveniles in front of the mowers was observed in the case of outside-inside mowing leaving a refuge strip in the centre of the circuit between 10m and 30m wide (Arbeiter, 2017 and Broyer, 2003), as well as in the case of inside-outside mowing leaving refuge strips 5m wide at the edge of the plots (Broyer, 2003).

In all cases, these refuge strips were effective, with a greater number of juveniles escaping from the mowers. Broyer (2003) confirmed after mowing that the density of corncrakes in the 10 m refuge strips was higher than in the rest of the mown meadows (4.7 individuals/ha and 1.3 individuals/ha in 1996 and 1997 respectively). However, of the corncrakes present in the 10m wide refuge strips, 88.5% and 100% (in 1996 and 1997 respectively) of the individuals present in the 10m wide strips were juveniles. Similarly in Arbeiter's study (2017) while 68% of the adults studied (n=31) escaped to the edges of the plot or to neighbouring unmown plots, the majority of families (70%, n=10) and juveniles (76%, n=37) remained within the plot. This can be explained by the fact that juveniles cannot fly over open areas (juveniles fled 8.5 m on average to reach another cover with a maximum of 30 m) as large as the adults do (average of 29.5 m with a maximum of 100 m, with escape by flight observed in 78% of cases) (Arbeiter et al. 2017c). In this study, strips were used by 49% of independent juveniles, 30% of families and 23% of adults. However, refuge strips were also found to be useful for adults from a certain distance between the disturbance point and the edge of the plot. In the study by Broyer (2003), when the distance between the mower and the edge of the meadow was greater than 59.6 m, more than half of the adults fled to the refuge strips or failed to escape.

The location and arrangement of the refuge strips is therefore very important to avoid mortality during mowing. The location of strips may be more important than the size in reducing direct mortality (but not in accommodating juveniles until they fledge) (Broyer, 2003). Indeed, in Broyer's study (2003), during outside-inside mowing, an unmown 10 m strip avoid 33.3% of contacts between juveniles and the mower (9 contacts out of 27 observed in 1996 and 1997). And during inside-outside mowing, the 5 m unmown strip at the edge of the plot prevented 34.9% (15 out of 43) of contacts between juveniles and the mower.

The width of the refuge strips is important to accommodate the juveniles until they fledge and to allow their survival. Refuge strips 10 m wide have been shown to be effective in avoiding direct mortality of juveniles and adults during mowing (Broyer, 2003 ; Arbeiter et al., 2017c). However, this is the minimum width recommended, as individuals leave these strips afterwards, not to mention the risk of predation (Arbeiter et al., 2017). This study by Arbeiter (2017) shows that while all adults left the strips the day after mowing, independent juveniles stayed in refuge strips 15-30 m wide more than 22 days after mowing, despite the presence of neighbouring unmown grasslands (Arbeiter et al., 2017c).

12. REINTRODUCTION PROGRAMME : CASE OF ENGLAND

Another option for the conservation management of the target species is reintroduction. Examples of reintroductions in England provide some insight into this option (RSPB papers, Pensthorpe and personal communication R. Green). Indeed, such a programme was carried out at the Nene Washes RSPB reserve in Cambridgeshire in the UK, where corncrakes had disappeared around 1920 (Carter & Newbery, 2004). This programme, set up by the Pensthorpe Conservation Trust, the RSPB, English Nature and the Zoological Society of London, allowed the release of 50 to 100 juveniles per year between 2002 and 2016, with the aim of reinstating a stable population of 30 to 50 singing males. These releases were coupled with the management of more than 100 ha of habitat in favour of the Corncrake, with mowing delayed until the end of August. From 2016 onwards, releases took place at another site, Norfolk in the Wensum Valley, with 69 birds (32 males and 37 females), 154 (68 males and 86 females) and over 150 released in 2016, 2017 and 2018 respectively, with further releases continuing in 2019 and 2020.

In hindsight, the reintroduction operation since 2002 at Nene Washes of captive bred juveniles gives some clues as to the effectiveness of such a programme. Firstly, it has been noted that corncrakes have reproduced successfully in captivity, although the use of incubators and hand-feeding were subsequently necessary. Indeed, from a stock of 30 juveniles imported from a German breeding farm in 2001 and 2002, 140 eggs were laid in 2003. While the programme started in 2002 with the release of only six chicks (due to predation by European Weasels in the pens) and the following year no railings were heard or seen in the release area, the following years were more encouraging. From 2003 onwards, 52 juveniles were released, and then between 50 and 100 individuals were reintroduced per year. The data from the beginning of the programme also suggest that the juveniles are successfully adapting to their environment and migrating. A radio-tracking study showed that only one of the juveniles monitored had been lost to predation before migration. Ringing data also showed that the migration route used by the Scottish corncrakes was used by a reintroduced female; the latter was found hit by a car in the south of France in 2017. Furthermore, ringing and recapture of individuals has shown that the return migration rate of released corncrakes is close to that of those born in Scottish grasslands (20%). It was further observed that of a sample of 11 corncrakes that could be captured at the reintroduction site, 9 of these were birds released the previous year, the two unringed males may have bred in the reserve the previous year. It is also possible that Scottish corncrakes were stopping at this site for breeding, attracted by the songs of the released corncrakes. In Norfolk, 4 males released the previous year were recaptured in 2017. Breeding has also been observed since 2004 on the Nene Washes reserve. Numbers there have reached 12 singing males in 2008, 21 in 2010 and between 18 and 21 in 2015. In 2021, five years after the end of releases, a small population (numbers are currently being studied) is still present at Nene Washes, with almost all the males in this population monitored at the site not being born in captivity. In parallel, the reintroduction to Norfolk does not appear to be showing signs of success. This may be partly due to the presence of excessive grazing at this site, which is believed to have an impact on the nests (pers. comm. R. Green).

Breeding and release technique

The breeding programme is based on thirty captive-bred juveniles that were imported from Germany in 2001 and 2002. On arrival, an initial quarantine was carried out at Chester Zoo and the individuals were then moved to suitable breeding and wintering facilities at Whipsnade Wild Animal Park and Pensthorpe Conservation Trust. Corncrakes were gathered in autumn and winter and then put into separate pens during breeding. The loudest singing males were then placed with a female. When about three eggs were laid the males were removed so that they would not be attacked by the females. As the first few years of rearing suffered heavy losses in chicks reared by captive females, the eggs were subsequently placed in incubators in this programme. The chicks were then hand-fed with as little human contact as possible. At around day 10, the juveniles were transferred to pens at the release sites. There they were fed with live prey caught in nets and seeds. The aim of this operation was for them to become self-sufficient in food. After 28 days, the juveniles were finally released into the reserve after a veterinary check. This date was later extended to the 35th and then the 45th day.

13. CONCLUSION

It is important to maintain the presence and quality of the habitat corresponding to the needs of the corncrake and to protect the two successive broods of the females until they fledge. Feedback from certain corncrake conservation actions has shown that they can be effective. It should be noted that the effectiveness of these actions has rarely been directly evaluated, with the primarily analysis mechanism consisting of studying indirect correlations between the implementation of measures and the evolution of local corncrake numbers in subsequent years. For example, in response to the disappearance of a favourable habitat, one example showed the positive effect of creating a continuous favourable habitat area of sufficient size (300 ha) on corncrake numbers. This was achieved by restoring the hydraulic regime of the river adjacent to the meadows, by clearing trees and shrubs, and then maintaining meadows by very extensive grazing (Ķerus et al., 2015). The maintenance of grasslands and an open environment has also been achieved by introducing allowances for mowing, especially since annually mown extensive grasslands seem to be more selected by corncrakes than unmown pastures or meadows. Experience shows that certain pitfalls should be avoided and that certain mowing conditions have proven to be effective in increasing numbers. In fact, one experiment involving the introduction of compensation for unconditional mowing led to a shift from spatially and temporally heterogeneous mowing to mowing during the breeding season at the same time and without leaving any marginal areas, which led to a drop in corncrake numbers (Brambilla & Pedrini, 2013a). Other contractualisations, on the contrary, are linked to increases in numbers. This is the case of the defence of meadows until the beginning or middle of August within a radius of 250 m around each singing male. Furthermore, although the effects of agricultural mowing, speed and width have not been tested, studies have shown the direct positive effect of inside-outside mowing and the presence of 10 m wide refuge strips on the survival of adults and juveniles. Refuge strips of 15-30 m width were shown to be able to accommodate juveniles over a longer period. Furthermore, experiments have shown that the location of the refuge strips is also of great importance, as beyond a certain distance juveniles and adults are unable to reach them.

To take into account the fluctuating occupation of sites by corncrakes from year to year (see Survival and Dispersal section), Arbeiter et al. (2018) propose flexible mowing dates and a concentration of the latest mowing dates, which are necessary in September for the protection of the two broods, on the meadows occupied by corncrakes. The dates of mowing should be staggered to cope with the impact of the simultaneous disappearance of the cover, and the use of inside-outside mowing with sufficiently wide and well-localised refuge strips is recommended. Further recommended is individual protection within a radius of at least 250 m around the singing males, which has already shown to be effective, although it has been shown that non-flying juveniles (up to about 45 days of age, i.e. about 70 days after the detection of pairing (see Reproduction section)) move up to 600 m away from their father's singing post. Arbeiter et al. (2018) also recommend financial rewards for late mowing and the development of alternative hay use in cases where mowing is delayed until late August or September.

This is the case in north-eastern Germany, where a regional heating plant is fuelled by grassland mown between July and September (Wichtmann et al., 2016). Therefore, energy production could provide an alternative income and increase the acceptance of corncrake protection measures.

BIBLIOGRAPHY

Abebe, Y. D., Baker, N., & Berruti, A. (2006). International Single Species Action Plan for the Conservation of the Maccoa Duck. AEWA Technical Series, 14(14).

Arbeiter, S., Franke, E., Helmecke, A., & Tanneberger, F. (2017a). Habitat preference of female Corncrakes Crex crex : implications for the conservation of breeding sites in a secretive species. Bird Study, 64(2), 255–263.

Arbeiter, S., Roth, T., Helmecke, A., Haferland, H., & Bellebaum, J. (2017b). How to count a vagabond? – Population estimation in the Corncrake Crex crex. Vogelwelt, 137(March), 6.

Arbeiter, S., Helmecke, A., & Bellebaum, J. (2017c). Do Corncrakes Crex crex benefit from unmown refuge strips ? Bird Conservation International, 27(4), 560-567.

Arbeiter, S., Roth, T., Helmecke, A., Haferland, H. J., Tanneberger, F., & Bellebaum, J. (2018). Conflict between habitat conservation and Corncrake Crex crex brood protection in managed floodplain meadows. Agriculture, Ecosystems & Environment, 265(February), 15–21.

Arbeiter, S., & Franke, E. (2018). Predation risk of artificial ground nests in managed floodplain meadows. Acta Oecologica, 86(November 2017), 17–22.

Arbeiter, S. (2020). Challenges for the conservation of Corncrakes Crex crex breeding habitats in managed floodplain meadows. Thesis. Universität Greifswald.

Arbeiter, S., Flinks, H., Grünwald, J., & Tanneberger, F. (2020). Diet of Corncrakes Crex crex and Prey Availability in Relation to Meadow Management. Ardea, 108(1), 55.

Baha El Din, S. M., Salama, W., Grieve, A., & Green, R. E. (1996). Trapping and shooting of Corncrakes Crex crex on the Mediterranean coast of Egypt. Bird Conservation International, 6(3), 213–227. https://doi.org/10.1017/S0959270900003117

Beaumont, D. J. (2016). The Corncrake Crex crex population in Scotland from 1993 to 2015 with an overview of conservation measures taken during this period Conservation management in Pak Thale-Lam Phak Bia EAA Flyway, Thailand View project The Royal Society for the Protection of. Vogelwelt, 136(September), 153–161.

Berg, Å., & Hiron, M. (2012a). Occurrence of Corncrakes Crex crex in mosaic farmland landscapes in south-central Sweden – effects of habitat and landscape structure. Bird Conservation International, 22(2), 234–245.

Besnard, A. G., Fourcade, Y., & Secondi, J. (2016). Measuring difference in edge avoidance in grassland birds: the Corncrake is less sensitive to hedgerow proximity than passerines. Journal of Ornithology, 157(2), 515–523.

Boele A., Van Bruggen J., Hustings F., vAn Kleunen A., KoFFiJBerg K., vergeer J. W. & vAn der M. t. (2020). Broedvogels in Nederland in 2018. Sovon-rapport 2020/07. Sovon Vogelonder- zoek Nederland, Nijmegen.

Boldogh, S. A., Visnyovszky, T., Szegedi, Z., Habarics, B., Horváth, R., Krajnyák, C., & Lengyel, S. (2016). Where can flood refugees go? Re-distribution of Corncrakes (Crex crex) due to floods and its consequences on grassland conservation in North-Eastern Hungary. Ornis Hungarica, 24(2), 18–31.

Birdlife International (2016). Crex crex. In: IUCN 2016. IUCN Red List of threatened Species. www.iucnredlist.org.

Brambilla, M., & Pedrini, P. (2011). Intra-seasonal changes in local pattern of Corncrake Crex crex occurrence require adaptive conservation strategies in Alpine meadows. Bird Conservation International, 21(4), 388–393.

Brambilla, M., & Pedrini, P. (2013). The introduction of subsidies for grassland conservation in the Italian Alps coincided with population decline in a threatened grassland species, the Corncrake Crex crex. Bird Study, 60(3), 404–408.

Broyer, J. (1985) Le râle de genêts en France (Crex crex). Lyon: Union Nationale des Associations Ornithologiques.

Broyer (1992). Le Râle des genêts Crex crex : importance et tendances évolutives des populations, habitat, conditions nécessaires pour une conservation de l'espèce. Mémoire EPHE

Broyer, J. (1995). Définition d'un calendrier de fenaisons tolérable pour la reproduction du Râle des genêts Crex cres en France. Alauda, 63(3), 209–212.

Broyer, J. (1996). Les « fenaisons centrifuges », une méthode pour réduire la mortalité des jeunes Râles de genêts Crex crex et cailles des blés coturnix coturnix. Revue d'Ecologie (La Terre et La Vie), 51(3), 269–276.

Broyer, J. (2003). Unmown refuge areas and their influence on the survival of grassland birds in the Saône valley (France). Biodiversity and Conservation, 12(6), 1219–1237.

Budka, Michał, & Osiejuk, T. S. (2013). Habitat preferences of Corncrake (Crex crex) males in agricultural meadows. Agriculture, Ecosystems & Environment, 171, 33–38.

Budka, Michal, Mikkelsen, G., Turčoková, L., Fourcade, Y., Dale, S., & Osiejuk, T. S. (2014). Macrogeographic variation in the call of the corncrake Crex crex. Journal of Avian Biology, 45(1), 65–74.

Budka, M., Kokociński, P., Bogawski, P., Nowak, M., Białas, J. T., & Machura, M. (2020). Seasonal changes in distribution and abundance of a local Corncrake population. Journal of Ornithology, 0123456789. https://doi.org/10.1007/s10336-020-01827-z

Carter, I., & Newbery, P. (2004). Reintroduction as a tool for population recovery of farmland birds. Ibis, 146 (SUPPL. 2), 221–229.

Cramp, S. and Simmons, K. E. L. (1980) Handbook of the birds of Europe, the Middle East and North Africa, vol. II. Oxford: Oxford University Press

Crockford, N., Green, R. E., Rocamora, G., Schäffer, N., Stowe, T. J., & Williams, G. M. (1996). European Action plan for the Corncrake (Crex crex) in Europe.

Deceuninck B, Fantin Pierre, Jolivet Christophe, Loir Olivier, Hermant Didier, F. M. & M. S. (1997). Chronologie de la reproduction du Râle de genêts Crex crex en France : Particularités régionales et évaluation des mesures de conservation. Alauda, 65 (1), 91–104.

Deceuninck, B. (1999). The Corncrake (Crex crex) in France. In Proceedings International Corncrake Workshop 1998.

Del Hoyo, J., Elliott, A. & Sargatal,J. (1996). Handbook of the Birds of the World. Vol 3. Lynx Edicions, Barcelona.

Demongin L. (2015). Guide d'identification des oiseaux en main. Les 250 espèces les plus baguées en France. Beauregard-Vendon

Direktoratet for naturforvaltning (2008). Handlingsplan for åkerrikse Crex crex. Report.

Donaghy, A. M. (2007). Management of habitats on the Shannon Callows. Thesis

Donaghy, A. M., Green, R. E., O'Halloran, J., & O'Halloran, J. (2011). Timing of autumn migration of young Corncrakes Crex crex: Migration of young Corncrakes. Ibis, 153(2), 425–428.

DOPPS - Birdlife Slovenia (2003). Layman's report "Establishing Long-Term Protection of Crex crex in Slovenia."

Dorresteijn, I., Teixeira, L., von Wehrden, H., Loos, J., Hanspach, J., Stein, J. A. R., & Fischer, J. (2015). Impact of land cover homogenization on the Corncrake (Crex crex) in traditional farmland. Landscape Ecology, 30(8), 1483–1495.

Eason, P., Rabia, B., & Attum, O. (2016). Hunting of migratory birds in North Sinai, Egypt. Bird Conservation International, 26(1), 39–51.

Fourcade, Y., Engler, J. O., Besnard, A. G., Rödder, D., & Secondi, J. (2013). Confronting expert-based and modelled distributions for species with uncertain conservation status: A case study from the corncrake (Crex crex). Biological Conservation, 167, 161–171.

Fourcade, Y. (2014). Approche intégrative de la stratégie de conservation du Râle des Genêts. Thèse - Université d'Angers.

Fourcade, Y., Keišs, O., Richardson, D. S., & Secondi, J. (2014). Continental-scale patterns of pathogen prevalence: a case study on the corncrake. Evolutionary Applications, 7(9), 1043–1055.

Fourcade, Y., Richardson, D. S., Keišs, O., Budka, M., Green, R. E., Fokin, S., & Secondi, J. (2016). Corncrake conservation genetics at a European scale: The impact of biogeographical and anthropological processes. Biological Conservation, 198, 210–219.

Fourcade, Y., Richardson, D. S., & Secondi, J. (2019). No evidence for a loss of genetic diversity despite a strong decline in size of a European population of the Corncrake Crex crex. Bird Conservation International, 30(2), 260–266.

Green, R. E., Tyler, G. A., Stowe, T. J., & Newton, A. V. (1997). A simulation model of the effect of mowing of agricultural grassland on the breeding success of the corncrake (Crex crex). Journal of Zoology, 243(1), 81–115.

Green, Rhys E, Rocamora, G., & Schäffer, N. (1997). Populations, ecology and threats to the Corncrake Crex crex in Europe. Vogelwelt, 118(April), 19.

Green, Rhys E. (1999). Survival and dispersal of male corncrakes Crex crex in a threatened population. Bird Study, 46, S218–S229.

Green, Rhys E. (2004). A new method for estimating the adult survival rate of the Corncrake Crex crex and comparison with estimates from ring-recovery and ring-recapture data. Ibis, 146(3), 8. https://doi.org/10.1111/j.1474-919x.2004.00291.x

Green, Rhys E., & Tyler, G. A. (2005). Estimating the age of Corncrake Crex crex chicks from body weight and the development of primary feathers. Ringing & Migration, 22(3), 139–144.

Green, Rhys E. (2010). Timing of breeding, primary moult and duration of maternal care of chicks by adult female Corncrakes Crex crex: Corncrake timing of breeding and moult. Ibis, 152(4), 826–829.

Green, Rhys E. (2013). Tracking Scotland's corncrakes. Birdwatch.

Green, R. E., Brekke, P., Ward, H., Slaymaker, M., van der Velde, M., Komdeur, J., & Dugdale, H. L. (2019). Use of microsatellite-based paternity assignment to establish where Corncrake *Crex crex* chicks are at risk from mechanized mowing. Ibis, 161(4), 890–894.

Hennique, S., Deceuninck, B., Mourgaud, G. & Chanson, C., (2013). Deuxième plan national d'actions en faveur du Râle des genêts (Crex crex) 2013-2018. LPO, LPO Anjou, Ministère de l'Écologie, du Développement Durable et de l'Énergie, DREAL des Pays de la Loire 140 pp.

Inderwildi, E. (2016). Population trend, time of arrival and altitudinal distribution of the Corncrake Crex crex in Switzerland – the results of 20 years of conservation. Vogelwelt, 136, 107–112.

Inderwildi, E., Heer, L., Maumary, L., Laesser, J., & Müller, W. (2017). Plan d'action Râle des genêts Suisse. BirdLife Suisse, Zurich, 55 p.

Keišs, O. (2005). Impact of changes in agricultural land use on the Corncrake Crex crex population in Latvia. Acta Universitatis Latviensis, 691(January 2005), 18. http://files/755/Keišs - Impact of changes in agricultural land use on the.pdf

Ķerus V., Avotiņš A. jun., Reihmanis J., D. D. (2015). Population change of the Corncrake Crex crex and other farmland bird species in the Dviete floodplain nature park from 2006 to 2015. – In: Restoration and management of river floodplains: experience of the LIFE+ project DVIETE. Latvian Fund for Nature, Ri.

Koffijberg, K., & Van Dijk, A. J. (2001). Influx van Kwartelkoningen Crex crex in Nederland in 1998. Limosa, 74(4), 147–159.

Koffijberg, K., Hallman, C., Keišs, O., & Schäffer, N. (2016). Recent population status and trends of Corncrakes Crex crex in Europe.

Koffijberg, K. (2017). Kansen scheppen voor de kwartelkoning.

Laudelout, A., Ryelandt, P., & Paquet, J.-Y. (2020). Proposals to improve the protection mechanisms of Corn Crake Crex crex in Wallonia [Propositions d'amélioration des mécanismes de protection en faveur du Râle des genêts en Wallonie]. Aves, 57(1), 41–51.

Michalska-Hejduk, D., Budka, M., & Olech, B. (2017). Should I stay or should I go? Territory settlement decisions in male Corncrakes Crex crex. Bird Study, 64(2), 232–241.

Mikhail Grishchenko & Herbert H.T.Prins. (2016). Abandoned field succession in Russia and its potential effect on Corncrake Crex crex habitats -. Vogelwelt, 136, 175–184.

Mikkelsen, G. (2009). Individually characteristic corncrake Crex crex song reveals long-distance movements within the breeding season.

Mikkelsen, G., Dale, S., Holtskog, T., Budka, M., & Osiejuk, T. S. (2013). Can individually characteristic calls be used to identify long-distance movements of Corncrakes Crex crex? Journal of Ornithology, 154(3), 751–760.

Mischenko, A., & Sukhanova, O. (1999). The Corncrake (Crex crex) in Russia (European Part). Proceedings International Corncrake Workshop 1998, 77–82.

Muséum national d'Histoire naturelle - 2003-2021. Inventaire National du Patrimoine Naturel, Site web : https://inpn.mnhn.fr.

National Parks &Wildlife Service. (2015). A Framework for Corncrake Conservation to 2022. pp59

O'Brien, M., Green, R. E., & Wilson, J. (2006). Partial recovery of the population of Corncrakes Crex crex in Britain, 1993-2004. Bird Study, 53(3), 213–224.

O'Donoghue, B. (2019). Corncrake supporting document for Article 12 reporting period 2013-2018. National Parks & Wildlife Service, Killarney.

Paquet, J., & Derouaux, A. (2016). Conservation du Râle des genêts Crex crex en Wallonie : situation 20 ans après un projet LIFE-Nature et propositions d'actions. May 2017.

Pedrini, P., Rizzolli, F., Rossi, F., & Brambilla, M. (2012). Population trend and breeding density of corncrake Crex crex (Aves: Rallidae) in the Alps: monitoring and conservation implications of a 15-year survey in Trentino, Italy. Italian Journal of Zoology, 79(3), 377–384.

Peške and Vlček. (2017). Satellite telemetry of Corncrake. Zoological and botanical Garden of the city of Pilsen, contributory organization.

Schäffer, N (1999) Habitatwahl und Partnerschaftssystem von Tüpfelralle Porzana porzana und Wachtelko¨nig Crex crex. Ph.D. thesis. O¨ kologie der Vo¨gel (Ecol. Birds) 21 (1), 1–267.

Schäffer, N., & Koffijberg, K. (2004). Crex crex Corncrake. BWP Update, 6, 57–78.

Schorfheide-Chorin, S. office for environment B. B. reserve. (2019). Documentation of the EU-LIFE Project 2012-2019 "Improvement of the breeding and feeding habitats for the Lesser Spotted Eagle as well as for the Corn Crake and the Aquatic Warbler in the Special Protecte Area Schorfheide-Chorin."

Sklíba, J., & Fuchs, R. (2004). Male Corncrakes Crex crex extend their home ranges by visiting the territories of neighbouring males. Bird Study, 51(2), 113–118.

Rapport LIFE+ Wachtelkönig&Uferschnepfe (2012) - Waterlogging and grassland extensification in Lower Saxony to improve habitats of the Corncrake (Crex crex) and the Black-tailed Godwit (Limosa limosa)

Stowe, T. J. & A. V. Hudson (1991a) Radio-telemetry studies of Corncrake in Great Britain. Vogelwelt 112: 10- 16.

Stowe, T. J. and Hudson, A. V. (1991b) Corncrakes outside the breeding grounds, and ideas for a conservation strategy. Vogelwelt 112: 103–107.

Stowe, T. J., & Green, R. E. (1997). Threats to the Corncrake Crex crex on migration and in the winter quarters. Vogelwelt, 118, 175–178.

Taylor, P. B. (1984). A field study of the corncrake Crex crex at Ndola, Zambia.

Tyler, Glen. (1996). The Ecology of the Corncrake with special reference to the effect of mowing on breeding. Thesis. RSBP, University College Cork.

Tyler, G. A., & Green, R. E. (1996). The incidence of nocturnal song by male Corncrakes Crex crex is reduced during pairing. Bird Study, 43(2), 214–219.

Tyler, Glen A., Green, R. E., & Casey, C. (1998). Survival and behaviour of Corncrake Crex crex chicks during the mowing of agricultural grassland. Bird Study, 45(1), 35–50.

Tyler, G. A., & Green, R. E. (2004). Effects of weather on the survival and growth of Corncrake Crex crex chicks. Ibis, 146(1), 69–76.

Van den Bergh, L M J (1991) Status, distribution and research on Corncrakes in the Netherlands. Die Vogelwelt 112, 78–82.

Verbelen, D., Herremans, M., Derouaux, A., & Paquet, J. (2016). Corncrake Crex crex in Belgium : holding on to the verge of extinction Corncrake Crex crex in Belgium : holding on to the verge of extinction. January.

Walther, B A. (2008). Ringing recoveries of the Corncrake Crex crex in Africa and Sinai. Vogelwelt, 29, 103–108.

Walther, Bruno A., Taylor, P. B., Schäffer, N., Robinson, S., & Jiguet, F. (2012). The African wintering distribution and ecology of the Corncrake Crex crex. Bird Conservation International, 23(3), 309–

Whittingham, M. J., & Evans, K. L. (2004). The effects of habitat structure on predation risk of birds in agricultural landscapes. Ibis, 146(SUPPL. 2), 210–220.

Wichtmann, W., Schröder, C., Joosten, H., 2016. Paludiculture – Productive Use of Wet Peatlands – Climate Protection – Biodiversity – Regional Economic Benefits. Schweizerbart, Stuttgart.

Williams, G., Holmes, J., & KIRBY, J. (2008). Action Plans for United Kingdom and European rare, threatened and internationally important birds. Ibis, 137, S209–S213.