Ornis Fennica 80:159–171. 2003

Changes in distribution and numbers of the breeding population of the Common Crane *Grus grus* in Estonia

Aivar Leito, Jaak Truu, Agu Leivits & Ivar Ojaste

Leito, A., Estonian Agricultural University, Environmental Protection Institute, Akadeemia 4, 51003 Tartu, Estonia. (E-mail: leito@envinst.ee)
Truu, J., Tartu University, Department of Biology and Geography, Riia 23, 51010 Tartu, Estonia
Leivits, A., Nigula Nature Reserve Administration, Vana-Järve, 86101 Tali, Pärnumaa, Estonia
Ojaste, I., Silma Nature Reserve Administration, Saare küla, 91201 Pürksi, Läänemaa, Estonia

Received 20 February 2003, accepted 31 October 2003

The aim of this study is to analyse population trends and distribution of the breeding population of the Common Crane in Estonia. The population size and density of the Common Crane in Estonia has increased several times over the last 30 years (1970–2001). According to the most recent population estimate, about 5800 pairs were breeding in Estonia in 1999. The mean population density of the Common Crane in Estonia was 17.4 pairs/100 km^2. Most of the Common Cranes are nesting in mires (5300 pairs, 91%), primarily in fens (4200 pairs, 72%). The mean population density in fens, transition mires and raised bogs was 41.3, 38.3 and 15.9 pairs/100 km^2, respectively. Several factors have probably contributed to the recent increase in the Common Crane breeding population in Estonia, e.g. the emergence of new nesting sites connected to human activity, locally higher spring temperatures and conservation activities.

1. Introduction

The Common Crane is a breeding species and passage migrant of wide distribution in Europe. The breeding range extends from lat 50°N to lat 69°N and the wintering areas are located in the Near East, North-eastern and Northern Africa and South-western Europe (Cramp & Simmons 1980, del Hoyo *et al.* 1996, Meine & Archibald 1996, Prange 1999). The breeding range began to narrow significantly during the Middle Ages and this negative trend continued until the middle of the 20th century (Cramp & Simmons 1980). Only during the second half of the 20th century has the population showed signs of increase and begun to re-establish itself in the original area of distribution (Prange 1994, Meine & Archibald 1996, Prange 1999, Wetlands International 2002). Despite these recent positive trends, the Common Crane is still categorized as an SPEC Category 3 species, i.e. a species whose global population is not concentrated in Europe, but which has an unfavourable conservation status in Europe (Tucker & Heath 1994). As a species, the Common Crane is sensitive to human activities. The most important threats to the species are the destruction of and decline in the quality of habitats, disturbance during the breeding season, illegal hunting, unfavourable weather conditions and climate change (Prange 1994, Meine & Archibald 1996).

In Estonia the Common Crane is a common breeding species and passage migrant. The breeding population size has been estimated at 600–700 pairs in Estonia (Prange 1994). Already in 1958 the species was defined as a nationally protected species, and it currently is listed as a category II protected species under the Natural Protected Objects Act. More recently, in March 2003, the Ministry of the Environment approved the Conservation Management Plan for the Common Crane, which forms the basis for the study, monitoring and conservation management of the Common Crane in Estonia during 2003–2007 and onward.

The objective of this study is (1) to analyse the earlier estimates of the distribution and numbers of the breeding Common Crane in Estonia; (2) to provide a recent total population estimate and trend line for the breeding population over the last decades and (3) to analyse the reasons for the changes in the distribution and numbers of breeding cranes in Estonia.

2. Material and methods

This study provides an analysis of all published data on the distribution and numbers of the Common Crane in the wider countryside of Estonia (Kumari 1958, Randla *et* al. 1971, Lilleleht &, Leibak 1993, Renno 1993, Leibak *et al.* 1994; Lõhmus *et al.* 1998; Leito 1999; Nowald *et al.* 1999, Leito 2000, 2002, Leito *et al.* 2003a), and also of unpublished data.

2.1. Census methods

2.1.1. Bird atlas

The occurrence and distribution of the Common Crane throughout Estonia during the breeding season were studied in 1977–1982 (Renno 1993) and in 1997–2001. The territory of Estonia was divided into 567 atlas squares (10 × 10 km UTM-grid squares). To determine the breeding status of the Common Crane, a scale of evidence of nesting was used (Renno 1993). The breeding status was described as follows: possible nesting of the species — species observed in a characteristic nesting biotope in the breeding season; probable nesting — incomplete nest or territorial calls of cranes in a characteristic nesting biotope in the breeding season; confirmed nesting — recently used nest found (also abandoned clutch or destroyed nest) or unfledged young at the nest.

2.1.2. Mapping of territorial calls

Since 1997 the mapping of territorial calls has been one of the main methods used for monitoring the number of breeding Common Cranes in Estonia. For the purpose of carrying out a census of territorial pairs, 10 × 10 km UTM-grid squares are selected and fixed cartographically. A survey square is broken down into four equal 5 × 5 km sub-squares, and these four squares are further broken down into four small squares of 2.5 × 2.5 km. Survey points (listening points) are cartographically fixed in the geometric centre of each small square. The distance between listening points is 2.5 km and there are a total of four listening points on each 5 × 5 km survey square and 16 listening points on each 10 × 10 km square. The cartographically fixed points are then determined in the landscape and these points are used for finding the breeding territories of the Common Crane.

All locations of territorial calls of the Common Crane are fixed at each survey point and marked on the field map according to the defined azimuth and distance. Censuses are conducted in April and May when the breeding (territorial) Common Crane pairs are most vocal. The territorial calls are listened for during the two hours after sunrise and the two hours before sunset. During the breeding season a minimum of three counts are undertaken at each survey point. After the censuses are completed, the observation clusters are analysed according to the classical mapping censuses of breeding land birds (Koskimies & Väisanen 1991).

The main steps in this original census method were developed in Estonia already in the 1980s, although the method was not used until 1997. From 1997 to 2001 censuses of 800 km^2 of different habitats in various parts of Estonia were carried out according to this method.

2.1.3. Single-visit mapping of territorial pairs in mires

The most common census method for counting the Common Crane during the breeding season in Estonia is single-visit mapping of territorial pairs. With this method, censuses are conducted in the early morning for five hours beginning at sunrise from the middle of May to the middle of June. The width of the census transect varies from 200 to 300 metres, depending on the saturation and accessibility of the landscape. The survey plot (a mire) is fully covered with parallel census transects.

This method is very similar to the simplified territory mapping technique used in Sweden for the inventory of birds breeding in mires (Svensson 1978, Boström & Nilsson 1983). The census efficiency of the single-visit mapping method for the Common Crane in Swedish mires is 65% (Bylin 1980, Arvidsson *et al.* 1992). In Estonia the efficiency of this method has been not tested, but it did not seem to differ much from the Swedish estimate.

Censuses according to this method have been regularly carried out in Estonian mires since 1986. During the period from 1986 to 1996 the censuses covered 1024 km^2 (18 mires) and during the period from 1997 to 2001, 1156 km^2 (97 mires).

In 1997–2001, when all three census methods described above were used, censuses were carried out on 107 plots covering 2653 km^2, or 6% of the total area of Estonia. From 1986 to 2001, different censuses of breeding cranes were conducted on 120 plots covering 3089 km^2, or 7% of the total area of Estonia. These censuses included all land cover types and biotopes in Estonia, inhabited and uninhabited by cranes. The size of a survey plot was 0.3–300 km^2 with a mean value of 27.1 ± 43.0 km^2 ($\pm$ SD, $n = 120$). The number of territorial pairs was recorded for all survey plots and the population density was estimated.

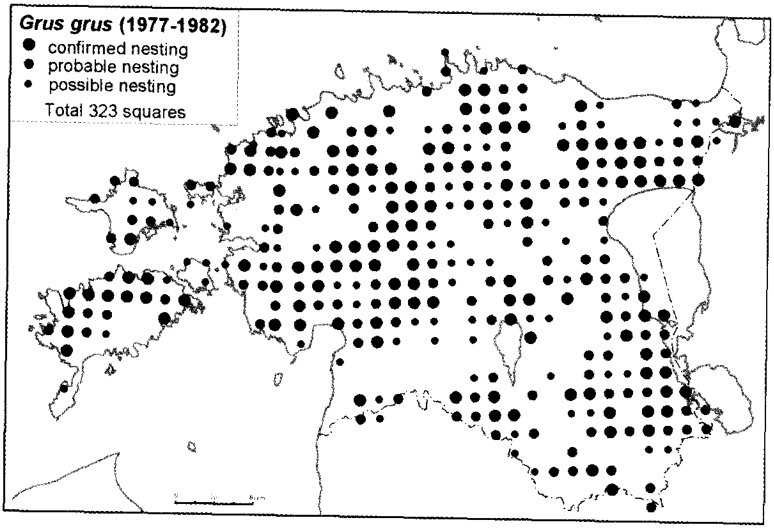
2.2. Data preparation and analysis

The analysis included the following 16 characteristics: the location of the survey plot, the area of the survey plot, the nesting biotope size, the nesting biotope type, the location of a nest, the biotope type around the nest, the level of human disturbance around the nest, the census year, the census date, the number of counted pairs on the survey plot in the census year, the population density on the survey plot in the census year, the mean population density in Estonia in the census year, the mean population density in Estonia in the census period, the mean brood size on the survey plot in the census year, the mean brood size in Estonia in the census year, and the mean brood size in Estonia in the census period.

The calculation of the population size of the breeding Common Crane in Estonia in 1997–2001 was based on the method of stratified mean (Krebs 1999). To do the calculation, the territory of Estonia was divided up into three strata to provide representative samples and to take into consideration the regional differences in the distribution of the Common Crane. The strata were determined according to the natural joint features of the Estonian landscape based on generalised land cover types identified in the CORINE Land Cover nomenclature (Meiner 1999, Arold 2001). Similar landscape types were combined, with a final determination of three main landscape regions, or strata. The stratification method was considered to be the best approximation for estimating the Common Crane population parameters, taking into account the fact that the survey plots were not of equal size.

The Mann-Kendall test was used to detect trends in time series. One advantage of the Mann-Kendall test is that the standard normal distribution of time series for the estimation of a linear trend is not needed. The Mann-Kendall test is a non-parametric test allowing for analysis of time series that are not characterized by standard normal distribution. The second advantage of the test is its relatively low sensitivity to omissions in data resulting from the non-homogeneous character of the data. The relationship between the population density and biotope area was fitted by the inverse first order model using non-linear regression with the Marquardt-Levenberg algorithm. The best-fit parameter values of the model were compared using a one-way analysis of variance (ANOVA), followed by Tukey's and Scheffe's tests for group mean comparisons.

a)



b)

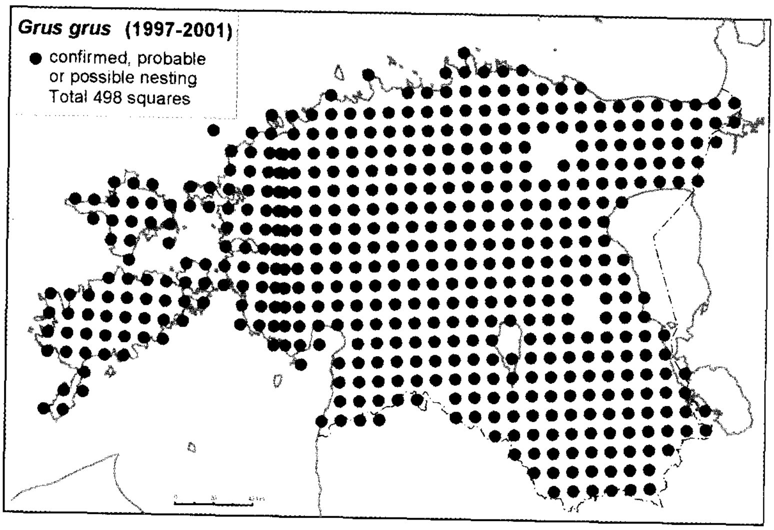


Fig. 1. Distribution of the Common Crane during the breeding season in Estonia in 1977–1982, according to the Estonian Bird Atlas (Renno 1993): (a) in 1997–2001 and (b) on the UTM-grid map of 10 × 10 km squares.

3. Results

3.1. Changes in distribution

According to the Estonian Bird Atlas 1977–1982, the Common Crane was breeding in 323 atlas squares (total number of squares observed was 567), with confirmed breeding in 121, probable breeding in 120 squares and possible breeding in 82 squares (Fig. 1a). According to our data in the period 1997–2001, breeding cranes were detected in 498 squares (total number of squares observed was 567 (Fig. 1b)). Confirmed breeding was observed in 204 squares, probable breeding in 242 squares and possible breeding in 52 squares. Thus, the total number of squares where cranes were detected increased from 323 (57% of atlas squares) in 1977–1982 to 498 (88% of atlas squares) in 1997–2001.

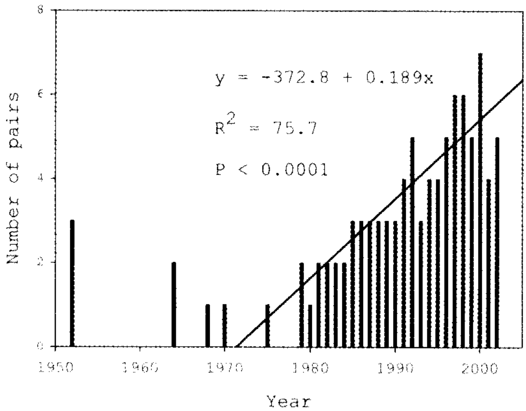


Fig. 2. Number of territorial pairs of the Common Crane at the Nigula bog (area 20 km²) in 1952–2002. The trend line is fitted for the period of 1971–2002; the increase in numbers is statistically significant (Mann-Kendall non-parametric test, $P < 0.0001$).

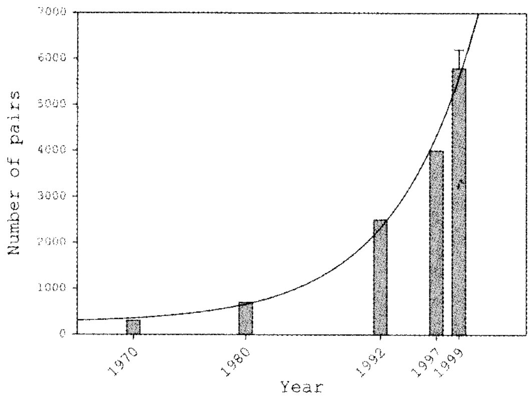


Fig. 3. Estimated population size of the breeding Common Crane in Estonia in 1970–1999. Earlier estimates have been reviewed. The exponential growth curve was fitted to the data ($R^2 = 98.2$, $P < 0.01$). A 95% confidence interval for the estimated population mean is shown for 1999.

3.2. Changes in numbers

At the local level of the Nigula bog, the number of breeding pairs varied between 1 and 7 pairs in 1952–2002. The number decreased from 1952 to 1970, then increased significantly from 1971 to 2000. Because of the lack of observation data in the early period, the trend line was fitted only for the period of 1971–2002 (Fig. 2; $R^2 = 75.7$, $P < 0.0001$).

Based on the surveys made in 1970, 1980, 1992, 1997 and 1999, the Common Crane population in Estonia has increased significantly from 300 breeding pairs in 1970 up to 5800 pairs in 1999 (Fig. 3; $R^2 = 98.2$, $P < 0.01$).

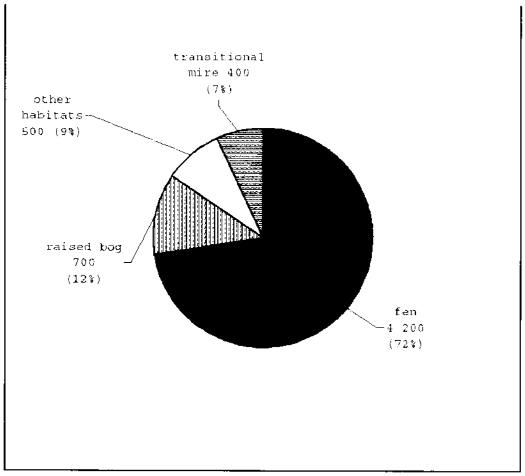


Fig. 4. Mean distribution of the Common Crane breeding pairs in Estonia by main habitat type in 1997–2001 (n = 5800).

3.3. Number and density of cranes in different habitats

In terms of different nesting biotopes, the use of the stratified random sampling approach provided statistically reliable information only for the number of pairs breeding in fens and raised bogs. The Common Crane population size in 1997–2001 was between 2500 and 5900 territorial pairs in fens, with a mean value of 4200 pairs, and between 500 and 900 pairs in raised bogs, with a mean value of 700 pairs, at the 95% confidence limit. In transitional mires there were about 400 breeding pairs and in all other habitats about 500 breeding pairs (Fig. 4).

The Common Crane population density in fens varied from 0 to 250, with a mean value of 41.3 pairs/100 km² (n = 22, area 150 km²). The highest density in Western Estonia was seen in small quagmires with a mosaic of sedge-reed-bed communities. The smallest fens occupied by the Common Crane were only 0.5–1.0 ha (n = 4). The relationship between the population density of the Common Crane and the fen size was statistically significant (non-linear regression with the

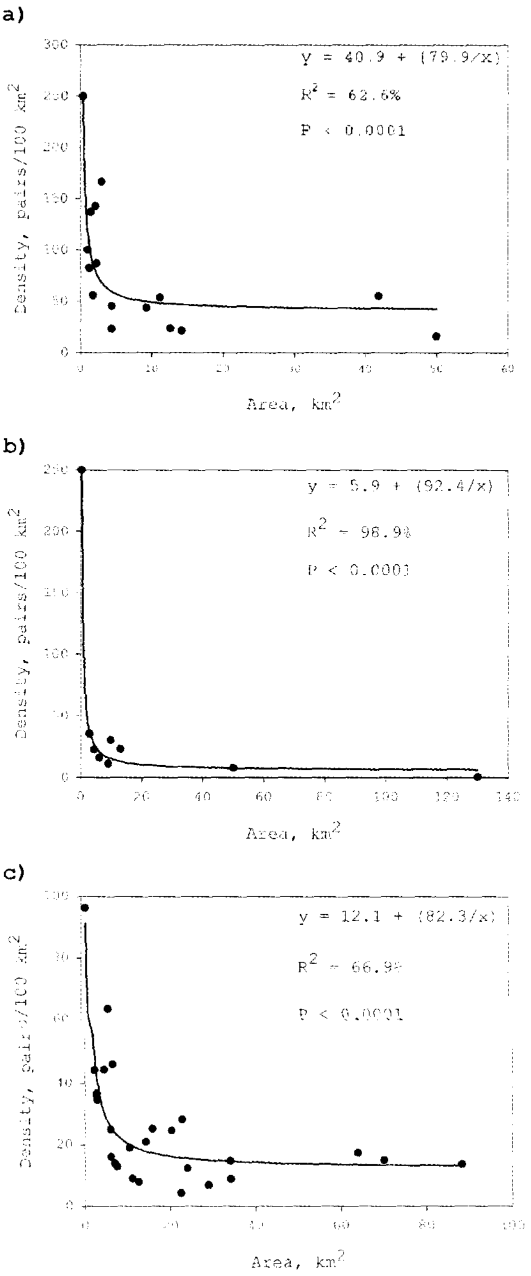


Fig. 5. The relationship between the Common Crane population density and the size of the breeding biotope in (a) fens, (b) transitional mires and (c) raised bogs. The difference between the population densities in different biotopes is statistically significant (Kruskal-Wallis non-parametric dispersalanalysis, $P < 0.001$, $n = 53$).

Marquardt-Levenberg algorithm, $P < 0.001$, $n = 16$) (Fig. 5a).

In transitional mires the population density varied from 0 to 285, with a mean value of 38.3 pairs/100 km^2 ($n = 9$, area 60 km^2). The highest population density was recorded in transitional mires located around raised bogs. The relationship between the population density and the size of the transitional mire was statistically significant (non-linear regression with the Marquardt-Levenberg algorithm, $P < 0.001$, $n = 9$) (Fig. 5b).

The population density in raised bogs varied from 0 to 96, with a mean value of 15.9 pairs/100 km^2 ($n = 48$, area 734 km^2). The relationship between the population density and the size of the raised bog was statistically significant (non-linear regression with the Marquardt-Levenberg algorithm, $P < 0.001$, $n = 28$) (Fig. 5c). Hollow-pool bogs were the most common breeding site in large treeless raised bogs, while treed hollow-pools with ridges were the most common in small raised bogs. The Common Crane did not occupy small treed raised bogs.

To test the differences between the population densities in different habitats, the best-fit values of regression curves were compared using a one-way analysis of variance (ANOVA). The asymptote (y_0) of the model could be interpreted as a typical population density for cranes in large areas (> 10 km^2) for certain biotope types. The comparison of these values between biotopes showed significant differences ($P < 0.0001$) in population density. According to the calculated asymptote values, the population density was highest in fens ($y_0 = 40.9 \pm 12.0$) and lowest in transitional mires ($y_0 = 5.9 \pm 2.7$). In raised bogs this value ($y_0 = 12.2 \pm 2.8$) was two-fold higher compared to transitional bogs. At the probability level $P = 0.05$, all three asymptote values differed from each other (Tukey's and Scheffe's least significant difference values were 4.76 and 5.97, respectively).

The second component of the regression model also varied significantly between biotopes ($P < 0.05$, ANOVA). However, in the case of transitional mires the number of observations is low, and, in fact, for population densities above 50 pairs/100 km^2 there is only one sample, making the calculated best-fit value ($a = 92.4$) unreliable. Fens and raised mires did not differ by best-fit values of 'a'. The second component of the applied regression model may reflect a difference in population density values between studied habitats in small biotope areas (< 10 km^2). In order to verify this assumption additional data on transitional mires are needed.

In terms of landscape regions, the mean population density of the Common Crane on coastal lowlands and islands was equal to 18.5 pairs/100 km^2 (s^2 = 0.235, n = 308), on inland swampy lowlands and depressions, 18.0 pairs/100 km^2 (s^2 = 0.152, n = 136) and on uplands and plateaus, 7.3 pairs/100 km^2 (s^2 = 0.523, n = 17). There were no statistically significant differences between population density mean values of the landscape regions (ANOVA, $P > 0.05$). The mean population density of the Common Crane in Estonia was 17.4 pairs/100 km^2 (calculated as the arithmetic mean of the total number of surveyed territorial pairs (n = 461) and the total area of survey plots (2653 km^2)).

4. Discussion

4.1. Changes in distribution area

A comparison of the distribution map of the Common Crane in 1977–1982 (Renno 1993) with the distribution map of CORINE Land Cover types (Meiner 1999) shows strong overlap of the distribution of cranes and the distribution of natural habitat types in Estonia. On the other hand, the Crane rarely occupied coastal areas and was absent in some regions of central and southern Estonia. The cranes were totally absent from artificial and agricultural landscapes.

In 1997–2001 the Common Crane was found throughout all regions of Estonia, occupying also in some artificial landscapes.

As in Estonia, the Common Crane has expanded its range throughout Europe during the last three decades (Prange 1994, 1999, Tofft 1999, Hagemeijer & Blair 1999, Salvi & Moreau 2000, Miikkulainen 2001). In this connection, the Crane's expansion of its range in Estonia reflects the much larger process of the expansion of the species throughout its breeding range during 1970–2000.

4.2. Changes in numbers

According to E. Kumari (1958), there were more Common Cranes in the 18th and 19th centuries in the Estonian mires and grasslands than in the middle of the 20th century. The estimate was based on an analysis of the first recordings of the Eastern Baltic avifauna and on changes in climate and landscape in these time periods in general. Unfortunately, the total population estimate for the Common Crane in the wider countryside was not provided and the earlier numbers of the Common Crane in Estonia are unknown.

The first numerical total population estimate for the breeding Common Crane in Estonia was made in 1970 (Randla *et al.* 1971), based on the answers to a questionnaire covering different forest management units. Data were obtained on 110 Common Crane pairs, and the total number of the breeding population was estimated at 200 pairs. Considering the low level of coverage (recovery rate 59%, n = 22) of the survey, especially in inaccessible mires where the population density is the highest and where about 90% of cranes are breeding, we suggest that the population size was underestimated. Based on our calculations, and taking into the account the coverage of the survey and the relative importance of mires not surveyed, the actual population size was about 300 pairs in 1970.

According to the Estonian Bird Atlas (Renno 1993), the Common Crane breeding population in Estonia in 1977–1982 was estimated at 350 pairs. However, in a number of cases more than one pair of cranes was detected per Atlas Square and pairs exhibiting possible breeding behaviour were found in 80 squares. In addition, as in 1970, the large mires were poorly surveyed. Taking a mean population density of 10 pairs/100 km^2 as a basis, as calculated for the Nigula bog, the estimated population size of the Common Crane in mires (total area about 9000 km^2; Valk 1988, Paal *et al.* 1998) could have been close to 900 pairs in 1977–1982. Assuming that the population density in the Nigula bog was probably higher than the average, the actual number of Common Cranes breeding in mires was about 600 pairs and the total population was about 700 pairs. This number demonstrates that the population size of the Common Crane was considerably higher than estimated at that time and that the number of cranes in Estonia had increased already in the 1970s.

In 1992 the Common Crane population in Estonia was estimated at 600–700 pairs (Lilleleht

& Leibak 1993, Leibak *et al.* 1994). The population estimate was obtained by means of direct extrapolation of the mean population density, calculated on the basis of the survey plots, to the wider countryside of Estonia. In terms of trend, it was stated that the population size of the species increased during the period of 1941–1970, as well as in 1971–1990.

We suggest that the method used for calculating the total population of the Common Crane in Estonia in 1992, and in 1997 and 2000, before this study, was not correct and did not allow for direct extrapolation of numbers in the wider countryside, because the size and distribution of the study plots were unequal and the mean population density used was not representative of all Estonia. We used the stratified mean method (Krebs 1999) and the fitted trend line and, based on this method, have re-estimated the total population to be 2500 pairs in 1992. We also found that the population increase in 1970–1990 was much more rapid than previously considered.

In 1997 the Common Crane population in Estonia was estimated at about 1500 pairs (Leito 2002). In terms of trend, it was stated that the periods of 1971–1990 and 1991–1997 reflected a moderate increasing trend (ranked as 10%–50%) (Lõhmus *et al.* 1998, Leito 2000, 2002). By our estimate, the total number of breeding cranes was about 4000 pairs in 1997. In 2000 the population size was estimated at about 2000 pairs (Leito 2002). According to our calculations, the total population was between 5400 and 6200 pairs, with a mean value of 5800 pairs in 1999, at the 95% confidence limit.

Thus, by our estimation, the total population of the Common Crane in Estonia has increased roughly twenty-fold during the last three decades (1970–2000) from about 300 pairs in 1970 to 5800 pairs in 1999. The rate of increase has been the highest during the last two decades, 1980–2000, approaching exponential growth. In recent years, however, based on long-term censuses in the Nigula bog and in some other monitoring areas, we suggest that at the beginning of the 2000s the population increase was probably levelling out and the number of breeding Common Cranes in Estonia has probably stabilized at around 6000 pairs.

The high population density in mires, especially in fens, indicates that the Common Crane prefers these habitats because they offer the best features for nesting sites, e.g. low relief, a suitable plant community, preferred water conditions, openness and a low-level of disturbance (Leito *et al.* 2003b). The availability of food resources around the nest site is probably not so important (not limiting) because, to a large extent, the breeding pairs and pairs with young feed outside of the mires, up to several kilometres away from the nest (Nowald 1999, Peske *et al.* 2003, Leito *et al.* (in prep.)).

The increase in the Common Crane population in Estonia coincides well with the increase in numbers of cranes throughout Europe (Prange 1994, 1999, 2003). Compared to Estonia, the trends in the total population of the Common Crane in Finland (Merikallio 1958, Väisänen *et al.* 1998, Miikkulainen 2001) have probably been less marked, although the trend line is very similar — a decline from the 1950s to the 1970s and an increase from 1980 to 2000, especially in the 1990s. Although the precision and validity of the census methods used in Finland, as in most other cases, are not known and the results may be biased, a general increasing trend in the population size is evident. The increase in the European breeding population has also been confirmed by higher counts of staging cranes at migration stopover sites in France, Germany, Finland and Hungary (Rinne 1995, Salvi 1996, Prange 1999, Le Roy 2002, Végváry & Tar 2002).

4.3. Reasons for changes

4.3.1. Nesting habitats

In Estonia the emergence of new nesting sites connected to human activity has been one reason cited for the increase in the Common Crane breeding population. As a result of reforestation and a large part of the arable land being left uncultivated, forest land has increased in Estonia over the past century more than two-fold (Mander *et al.* 1996, Yearbook Forest 2000, Kohava 2001). Additionally, over the past three decades the number of immature stands has increased and some forests have been thinned, which has resulted in new nesting sites for the Common Crane in the cut areas and thinned forests (Leito *et al.* 2003a, b). The cranes do not breed in dense forest but they will occupy thinned and cut areas of large forests. The increase in the number and distribution of breeding cranes coincided well with the above-described changes in Estonian forests.

New nesting sites for Common Cranes have also emerged as a result of the transformation of former quarries into wetlands. From the 1960s to the 1980s a number of gravel and sand quarries were being exploited. Today, these quarries are either depleted or mining has been suspended or terminated for conservation purposes. Consequently, a number of such abandoned quarries have filled with water, become overgrown with vegetation and been transformed into wetlands. Additionally, many former peat mines have been abandoned and are now occupied by the Common Crane.

4.3.2. Warming of the climate and a shorter migration route

The Common Crane's earlier spring arrival in Estonia and the earlier start of egg-laying and hatching of eggs clearly corresponds to a local warming of the climate. The annual temperature cycle in Estonia shows definite signs of change in recent years, with the winter (January, February) and spring (March, April, May) temperatures becoming warmer. The mean spring temperature in Estonia has increased by 1.4 °C from 1876 to 2000, and, most particularly, the mean temperature in March, which is when the Common Crane arrives in Estonia, has increased by 5 °C (Keskpaik *et al.* 1997, Jaagus & Ahas 2000, Jaagus *et al.* 2002).

Because of the earlier spring, the cranes can arrive and nest earlier in Estonia (Keskpaik *et al.* 1997, 2000), which results in a higher survival rate of the young cranes. The reason is that the earlier the hatching date, the stronger the young cranes are by the departure date (which has not changed) of their first migration, as compared to young hatched at a later date. Without a doubt, the higher survival rate of the young contributes to the population increase.

The breeding Common Crane in Estonia uses all three of the most important European migration routes (Leito *et al.* 2000, Leito & Ojaste 2001, Leito *et al.* 2003a, c); however, major changes have taken place with respect to the western route, which is the most important migratory route for cranes breeding in Estonia (Leito *et al.* 2003a, c). Formerly, the cranes using this route migrated to southern Spain and Morocco for wintering (Cramp & Simmons 1980). Recently, more cranes are wintering in France and even Germany, while Morocco is losing its importance as a wintering area, particularly for young birds (Salvi 1996, Prange 1999, 2001, Alonso *et al.* 2000, Le Roy 2001, 2002). A shorter migration route decreases the energy-expenditure and the risks during migration, which also contribute to a higher survival rate and an increase in the population size.

4.3.3. Conservation activities

Though we cannot prove it directly, we believe that conservation activities have also played a role in the recent increases in the Common Crane population in Estonia, as well as in Europe and the whole world. First, it is evident that hunting bans must have had a positive effect on the Common Crane population through a lower mortality rate, as has been seen with different goose species (Ebbinge 1991, Kalchreuter 1991). In Estonia, the hunting of the Common Crane was prohibited in 1958; and it seems that illegal hunting and accidental shooting of cranes is of very small importance in Estonia at the moment. Unfortunately, the actual bag and hunting mortality rate of the Common Crane in Estonia in the earlier open hunting periods is unknown.

Currently, the hunting of cranes is prohibited in all European countries and even though in some areas illegal hunting and accidental shooting are still a problem, the bag rate is essentially less than in earlier times (Prange 1994, 1995, del Hoyo *et al.* 1996, Meine & Archibald 1996, Prange *et al.* 1999). Thus, the ban on hunting activities at many Common Crane breeding, feeding and roosting sites throughout Europe has probably also contributed to the recent increase in the Crane population (Alonso *et al.* 1991, Bautista *et al.* 1992, Meine & Archibald 1996, Prange 2001).

Secondly, the establishment of many new protected areas, where the Common Crane has been breeding, has probably influenced the population increase in Estonia. The proportion of protected areas in Estonia has risen from 4% in 1970 to 12% in 1999 of the total area of the country, according to national law, and from about 1% to 3.5%, according to the IUCN categories, IA and IB (Fammler *et al.* 2000). Besides the areas of relatively small importance to cranes, there are ten protected areas where recently (based on 2001 estimates) 15–50 pairs, and altogether 250–300 pairs of cranes were observed breeding (Lõhmus *et al.* 2001, updated). As in Estonia, the number of protected areas has increased in most of the countries in the distribution range of the Common Crane during the period 1970–2000 (Tucker & Heath 1994, Prange *et al.* 1995, Meine & Archibald 1996, Tucker & Evans 1997, Prange *et al.* 1999, Fammler *et al.* 2000, Heath & Evans 2000).

In addition to the reasons described above, a greater availability of food resources may have played a role in the increase in the breeding population of the Common Crane during the last three decades in Estonia and in other areas. However, we lack specific data to be able to analyse the influence of this potentially important factor on a larger scale.

5. Conclusions

We have shown that the distribution range and the breeding population of the Common Crane in Estonia increased considerably during the last three decades, i.e. from 1970 to 2000. We found several factors that contributed to the Crane's population increase in Estonia, but we do not know the relative importance of the different factors. We need more specific data to show how habitat and other external characteristics along with genetic and behavioural processes determine reproduction, survival and mortality of species (Prange 1989, Alonso *et al.* 1991, Meine & Archibald 1996, Mewes 1999, Nowald 1999, Jones 2001, Leito *et al.* 2003a).

Another problem is that because the Common Crane is a timid and strictly protected bird species nesting in solitary pairs of low density, collecting data on the breeding of this species is difficult. Nevertheless, we need a great quantity of long-term observations of many individuals and pairs of cranes to ascertain the spatial-social and age structure of the population, the reproduction, survival and mortality rates in different age classes and the habitat use during the breeding and non-breeding periods. For the identification of individuals, colour-ringing and radio- and satellite-tracking of cranes have been used (Alonso & Alonso 1999, Leito *et al.* 2003 a, c). Nevertheless, the number of birds that can be captured and marked in this way is limited. Additionally, the colour-rings are not easy to read from a distance, which can cause mistakes in the identification of individuals, and the transmitter batteries last only up to five years at a maximum, thus, limiting the study period of individuals.

To get around these problems a new method and technology were developed for the identification and recognition of cranes from a distance, i.e. the use of digital recording and three-dimensional analysis of crane calls (sonograms) (Wessling 2000). This method was first applied in Germany in 1998. In 2003 we imported the technology from Germany to Estonia and, during the next years, we hope to generate sufficient new data on the Common Crane breeding ecology.

Despite the lack of sufficient information, we suggest that, in general, the present status of the Common Crane breeding population in Estonia is favourable and there is no need for specific conservation actions at the moment. Estonia has a management plan for the Common Crane in force for the period 2003–2007 and onward; this plan includes all the most important activities for conservation.

The main goal of conservation management is to maintain a viable Common Crane population in Estonia and support the European and global populations. The minimum limit for the population size in Estonia has been estimated at about 300 pairs. To reach this goal there are plans to create 36 specially protected areas (SPA) for the Common Crane with a total area of 3892 km^2. Currently, about 500–600 pairs of cranes are breeding in these areas. Most of the SPAs are already existing protected areas and some SPAs will be new protected areas established under the Natura 2000 network of the European Union. The SPAs will include proportionally all the Common Crane nesting habitats in Estonia.

Acknowledgements: We would like to express our gratitude to all the people who have actively participated in the Common Crane censuses in Estonia for many years. The Estonian Science Foundation and the Estonian Environmental Investments Centre provided financial assistance for carrying out the Common Crane studies. Within the framework of international co-operation, considerable aid has been given by a number of German nature conservation organisations, research centres and funds (Kranich Informationszentrum, Kranichshutz Deutshland — NABU, WWF-Deutshland), and by the airline company, Lufthansa, and the Spanish Air Force. We would also like to personally thank Günter Nowald, Thomas Fichtner, Volker Günther and Anja Kluge from Germany, and Javier and Juan Carlos Alonso from Spain for the procurement of colour rings, radio- and satellite-transmitters and the radio-receiver, and for their participation in the fieldwork. We are also thankful to Ene Hurt for assistance in preparing the manuscript.

Selostus: **Kurkien levinneisyysalueen ja pesimäpopulaation muutokset Virossa**

Kurkien määrä on Virossa viimeisen 30 vuoden aikana (1970–1999) lähes kaksikymmenkertaistunut (300 parista 5800 pariin). Parimäärän kasvamisen myötä myös kurkien levinneisyysalue on laajentunut. Vuosina 1977–1982 kurkia tavattiin 323:lla (57%) ja vuosina 1997–2001 498:lla (88%) 10 × 10 km tutkimsuruudulla. Valtaosa Viron kurjista pesi ajanjaksona 1997–2001 erityyppisillä soilla (5300 paria eli 91%), pääasiassa minerotrofisilla soilla (4200 paria eli 72%). Keskimääräinen paritiheys oli 17.4 paria/100 km^2.Keskimääräinen paritiheys oli minerotrofisilla soilla 41.3, vaihettumissoilla 38.3 ja korvissa 15.9 paria/100 km^2. Pienilla soilla (pinta-ala < 10 km^2) kurjen esiintymistiheys korreloi negatiivisesti pesintäsuon pinta-alan kanssa kaikissa suotyypeissä. Paikalliset tekijät ovat vaikuttaneet kurkien parimäärän kasvuu ja levinneisyysalueen laajenemiseeen. Tärkeimpiä globaaleja tekijöitä ovat ilmaston lämpeneminen ja kurjen elinympäristöjen aktiivinen suojelu. Virossa kurkien parimäärään kasvuun ja levinneisyysalueen laajenemiseen ovat oletettavasti vaikuttaneet myös metsien ikärakenteen nuorentuminen ja harveneminen sekä entisten maa-aineisten ottopaikkojen muuttuminen kosteikoiksi.

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