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Nest site selection of the Eurasian Crane *Grus grus* in Estonia: an analysis of nest record cards

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We describe in detail the nesting habitats of the Eurasian Crane in Estonia and explore relationships between different habitat characteristics and nesting success. We analysed all 161 reported Eurasian Crane nest finds in Estonia. We found that the cranes favorite nesting habitats are different types of mire (71% of all nests), especially fens (44%). We conclude that, despite the fact that the Eurasian Crane breeds in different habitats, nesting sites include the same or similar structural elements (vegetation types, plant species and communities and elements of micro-relief). We found that the date of the beginning of egg laying is significantly related to the size of the nesting habitat and that the annual mean date of the beginning of egg laying in Estonia has advanced considerably during the period 1901 to 2001. We also discovered a significant relation between the distance of neighbouring nests (population density) and the brood size and a negative effect of human activity on nesting success.

1. Introduction

Several studies on the breeding of the Eurasian Crane, including descriptions of nesting habitats, have been conducted (see Blotzheim *et al*. 1973, Cramp & Simmons 1980, Ilyichev & Flint 1987, Prange 1989, Meine & Archibald 1996). However, these studies typically lack a serious analysis of the relations of different characteristics within and between different habitat types, and between habitat characteristics and reproduction. There are several reasons for this lack of analysis. First, in a local study area, it is difficult to locate a sufficient number of nests, especially since the Eurasian Crane is strictly protected in almost all countries, which means that special permission is required in order to actively seek out nests and disturb birds (Prange 1994, Meine & Archibald 1996, Leito *et al*. 2003). Secondly, an integrated analysis of various habitat associations, nesting site characteristics and nesting parameters of a bird species, including the Eurasian Crane, is complicated

Table 1. Nesting habitats of the Eurasian Crane in Estonia and distribution according to habitat of the nests found. Total land area of Estonia without Lake Peipsi and Lake Võrtsjärv is 43,428 km^2 (Mansoo 2001).

Biotope category	Total area (km^2)	Share of habitats of the total area of Estonia (%)	Share of nests of nesting habitats (%)	Number of nests in a habitat type	Distribution of nests in relation to habitats (%)
Raised bog	2,780	6.4	23.6	43	27.0
Transitional mire	1,140	2.6	9.7	9	5.7
Fen	5,150	11.4	43.8	63	39.6
Riverplain	276	0.6	2.3	6	3.8
Coastal lagoon	15	0.03	0.1	7	4.4
Inland lake	243	0.6	2.1	15	9.4
Forest[1]	2,152	5.0	18.3	16	10.1
Total	11,756	27.1	99.9	159	100.0

1. Seven forest site types: *Filipendula ulmaria*, drained swamp, grass swamp, *Equisetum*, *Molina caerulea*, *Molina caerulea-Filipendula ulmaria*, *Carex* and *Carex-Filipendula ulmaria*.

(Prange 1989, Jokimäki & Huhta 1996, Mewes 1996, Lutze *et al*. 1998, Nowald 1999). The process of gathering more-or-less representative data on different characteristics of Crane nests and nest sites and breeding success has a long history in Estonia, and only now are we in a position to make the first analysis.

In our previous study (Leito *et al*. 2003), besides territorial distribution and numbers, we also analysed the distribution of Eurasian Crane breeding pairs in Estonia according to main habitat types, based on censuses of territorial pairs. We found that most cranes (91%) were breeding in different type of mire but there were no significant differences in mean population density values between the landscape regions. We also found a significant relationship between population density and mire size, and that, in the case of small mires (less than 10 km^2), population density correlates negatively with size of nesting habitat. However, our previous analyses include only a (rough) location of breeding territories of Crane pairs.

The most important threats to the Eurasian Crane are the destruction of and decline in the quality of habitats, disturbance during the breeding season, illegal hunting, unfavourable weather conditions and climate change (Cramp & Simmons 1980, Prange 1994, Meine & Archibald 1996). All these factors are also important for the conservation and management of species in Estonia. In this study, we discuss different types and qualities of habitats occupied by cranes and the influence of different habitat characteristics on nesting success by using nest record cards.

The objectives of our study were to (1) describe in detail the distribution of nesting sites of the Eurasian Crane in Estonia according to habitats; (2) find the relationships between habitat characteristics and nest site location, and (3) analyse the effect of different habitat characteristics on nesting success on the basis of nest record card data.

2. Material and methods

2.1. Nest cards

All Eurasian Crane nest finds reported in Estonia before 2001 (n = 161) have been analysed in this study. The nest finds cover almost the whole of Estonia; the largest numbers of nests have been found in the West – in Saare (n = 43), Pärnu (n = 34) and Lääne (n = 18) counties. The oldest reported Eurasian Crane nest finds in Estonia date back to the 1880s, but most of the data originate from the middle and end of the 20th century (61%) and from the years 2000 and 2001 (27%).

In 1999, the authors elaborated a Eurasian Crane nest record card on the basis of the standard nest record card of birds being used in the Estonian Ornithological Society. This nest record card is species-specific and characterized by additional features and available on website of the Estonian

Ornithological Society (www. eoy.ee). All new nest finds were registered and previous finds transferred to this record card in the course of the study.

2.2. Nesting habitat

Seven different nesting habitats were provided (raised bog, transitional mire, fen, river plain, brackish-water or fresh-water coastal lagoon, inland lake, and forest) (Table 1). The raised bog is defined as a classic "peat bog" of temperate northwestern Europe, western and north-central Russia and elswhere. The term refers to the convex cupola of ombrotrophic peat raised a few meters above the level of surrounding land. Nutrition – oligotrophic, source of water – precipitation (Gore 1983).

The fen is defined as a minerotrophic or eutrophic mire where the source of water is rock or soil (Gore 1983). The concept "fen" in this paper compasses all eutophic mires i.e. fen and swamp in British usage (Valk 1988). The transitional mire is defined as a medium type of mires between raised bog and fen. The source of water in transitional mire are both the precipitation and ground (Valk 1988). The transitional mire zone lies between raised bog and a mineral habitat, usually forest.

Each habitat is characterized by a potential vegetation type and micro-relief (different type of hummocks). The habitats are distinguished by a six to seven digit code that describes different structural elements of the habitat and the variation in its ecological conditions. Original description of the structure of habitat, demonstrating the ecological variability of habitats, has been provided on the basis of the classification of Estonian vegetation types (Paal 1997) and land cover types (Meiner 1999).

The area of the "nesting site" is defined as a 5 metre radius circle around the nest. "Nesting site characteristic" indicates the location of a nest within the nesting site in terms of its proximity to trees (under a tree or away from trees, in an open area or in a gap), the composition of plant species estimated by geo-botanical analyse, the vegetation type based on geo-botanical analyse, the openness of the nesting site (treeless, dwarf shrubs, shrubs, shrubs/trees, and forest), and its micro-relief (on a hummock or between hummocks; in cases where a nest is located on a hummock, the type of hummock is defined).

"Water regime in the nesting site" indicates the general level of wetness (permanently dry area, permanently wet area but without open water, permanently flooded area, periodically flooded area, permanent water body).

"Landscape around the nest" indicates the distance of nearest neighbouring habitat in terms of the four quarters of the horizon measured cartographically.

"Disturbing factors" indicates the distance of a building or settlement, and main road and foot path from the nest measured cartographically.

"Nesting success" indicates the number of young hatched and number fledged find out by repeated visits of the nesting site. In the case of unsuccessful nesting, the known or probable reason is indicated.

2.3. Data analysis

The main database includes all nest record cards (n = 161). In addition, a sub-database on nest dimensions was compiled and analysed. This database consists of data on the dimensions of 66 nests.

Analysis of databases was carried out using different statistical methods depending on the distribution pattern of characteristics and other specific features. The main statistical methods used were the Spearman rank correlation coefficient (r_s), Mann-Whitney non-parametric U-test, Student t-test, Kruskall-Wallis non-parametric test, and the correlation as well as dispersion analysis of variance. Trends in time series were detected using Mann-Kendall non-parametric test. MS Excel 7.0, Statistics programmes Statistica and Statgraphics were used in computer analyses of data.

3. Results

3.1. Distribution of observed nests according to habitat type

The largest number of Eurasian Crane nests in Estonia has been found in fens, followed by raised bogs, forests and inland lakes (Table 1). A total of 115 nests have been found in mires (fens, transi-

Fig. 1. The hollow-pool-ridge bog is a typical nesting habitat of the Eurasian Crane in raised bogs.

tional mires, and raised bogs) constituting 71.4% of all the nests found. Different types of mires make up about 20% of the territory of Estonia (Valk 1988, Paal *et al*. 1998). Thus, the share of mires as a nesting biotope for the Eurasian Crane is about 77% and the proportion of nests found in mires is about 72%.

Raised bog: The most frequent nesting habitat of the Eurasian Crane in Estonia is the wooded hollow-pool-ridge bog site type (21 nests = 64% of all nests found in bogs) (n = 33) (Fig. 1). The open hollow-pool bog site type is given slight preference compared to the wooded hollow-pool bog type (20 nests to 13 nests, respectively). From various bog vegetation types, Cranes prefer different herb and dwarf shrub complexes. The rest of the nests were located on quaking mires dominated by sphagnum or other vegetation.

Transitional mire: Nests found in the transitional mire (n = 9) were all located in the mire plain, in sites that were either treeless (3 nests) or covered with tree and shrub communities (4 nests). The preferred vegetation type in the transitional mire was the quaking mire community, especially with *Typha* spp. and *Carex* spp.

Fen: The fen was the most frequent nesting biotope of cranes in Estonia, especially in treeless quagmire or paludified grassland. In total, 45 nests have been found in treeless fens, 10 in fens with a shrub-tree community and one nest in a treed fen (total n = 56). Most of the nests were located in the quagmire (48 nests) and 12 nests in paludified grasslands (n = 60).

If fens with different water regime were compared, the greatest number of nests have been found in fens with high ground water level (34 nests), followed by floodplain fens (20 nests) and spring fens (6 nests). In terms of different fen vegetation types, the greatest number of Crane nests have been found in the sedge-reedbed mosaic community.

River plains: Only six Eurasian Crane nest finds on river plains have been described in Estonia (Table 1). Three nests were located in sparse reedbeds of the alluvial fen and two in alluvial meadows. Four nests were located in an open area and one in a sparse shrub community. There are no reports of Eurasian Crane nests located in the typical saline coastal meadow in Estonia.

Coastal lagoons: Seven nests have been recorded in coastal lagoons. All the nests were situated in treeless areas and none of them on lagoon

Fig. 2. The rich paludified forest with a majority of alder is a common nesting habitat of the Eurasian Crane in Estonian forests.

mineral islands. In terms of water regime, 6 nests were located on the floodplain and one in an area with a stable water regime (n = 7). Most of nests were located in the reedbed and only one in the Greater Tussock-sedge community. As for the different types of reedbed, 3 nests were located in reedbeds of watercourses and 3 nests in reedbeds of temporary floodplains; nests have not been found in terrestrial reedbeds (n = 6).

Inland lakes: A total of 15 crane nests have been found on inland lakes. 12 of the described nests were located in treeless areas and 2 in shrubs along the shore (total n = 14). Nests have not been found on mineral islets in lakes. In terms of water regime, most of the nests were located in areas of permanent innundation (10 nests), however, four nests were found in areas of periodical flooding. Treeless shore quagmire with herb or moss community in the inland lake`s vegetation type was most frequently used by cranes for nesting. The second most frequently occupied vegetation type is the reedbed, followed by the Greater Tussock-sedge community.

Forest: A total of 16 crane nests have been found in forests. In terms of the age of stands, more nests have been found in premature stands (6 nests) than in mature stands (3 nests) (n = 9). Nests have not been found in young growth and young stands. According to dominant tree species, decidious forest with a majority of birch or alder (both, black and gray alder) is the most frequent nesting site for cranes (Fig. 2). In terms of water regime, the majority of nests (75%, 12/16) were located in rich paludified forests or wooded meadows. Three nests were found in floodplain forests and one in a poor paludified forest. Nests have not been found in dry forests on mineral soil.

3.2. Size of the nesting habitat

The area of the nesting habitat of the Eurasian Crane in Estonia varies from 0.5 to about 10,000 ha. For the recorded nests, a habitat size of 1–10 ha was most frequent (40%), followed by a size of 101–1,000 ha (25%), more than 1,000 ha (18%), 11–100 ha (14%) and less than 1 ha (9%) (n = 159). The smallest nesting habitats used by cranes are small fens and lakes in the forest and the largest habitats are large mire expanses. The habitat size differ significantly between the different habitat types (Kruskal-Wallis non-parametric test, $P < 0.0001$, n = 159). On the average, the largest nesting habitat is the raised bog, compared to fen, coastal lagoon, inland lake and forest.

There is also a significant correlation between the size of the nesting habitat and the beginning of egg laying (Kruskal-Wallis non-parametric test, $P < 0.01$, n = 91). The earliest date of egg laying was observed in the habitat size category of 1–10 ha (mean date 21 April), followed by size under 1 ha (25 April), 11–100 ha (26 April), 101–1,000 ha

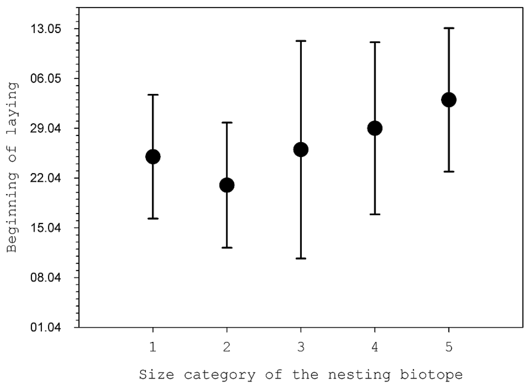

Fig. 3. Relationship between the beginning of egg laying (mean annual date ± SD) and the size of the nesting habitat of the Eurasian Crane in Estonia. Habitat size categories: 1 = less than 1 ha; 2 = 1–10 ha, 3 = 11–100 ha, 4 = 101–1,000 ha, 5 = more than 1,000 ha.

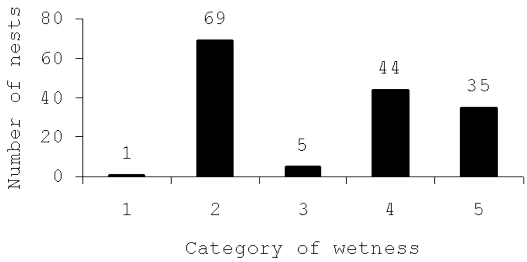

Fig. 4. Distribution of Eurasian Crane nests found in Estonia, according to wetness of the nesting site (n = 154). Categories of wetness: 1 = permanently dry area, 2 = permanently wet area but without open water, 3 = permanently flooded area, 4 = periodically flooded area, 5 = permanent waterbody.

(29 April) and more than 1,000 ha (3 May). Variation in the beginning of egg laying is greatest in the habitat size category of 11–100 ha (Fig. 3).

3.3. Openness and wetness of the nesting site

In terms of openness around the nesting site the greatest number of nests have been found in an open area (89 nests = 61%), 24 nests (16%) have been both in sites surrounded by shrubs as well as in those surrounded by shrubs and single trees, 12 nest sites (8%) in shrubs, and 5 nest sites (3%) in sparse forest (n = 154).

No statistically significant correlation between openness and other single characteristics, other than the combined nesting site characteristic (both openness and hummock type ($r = -0.27$, $P < 0.01$, n = 154) was found. The majority of nests have been found in an open space (137 nests), followed by those in a gap (5 nests) and those under a tree (4 nests) (n = 146).

In terms of micro-relief and hummock type, most of the nests were located on a grass hummock (88 nests), followed by nests on level ground (46 nests), on a moss hummock (4 nests), between hummocks (3 nests), on a waste hummock, and stump tussock (2 on each) and on a stone hummock (one nest) (n = 146).

Most of crane nests were situated in permanently wet (watery) areas without open water in the nesting site and only one nest was found in an almost dry area (Fig. 4). Most of the nests (97 nests = 64%) were located in sites where the depth of water at the nest was only 0–15 cm (usually a permanently wet area but without open water), followed by those a water depth of 16–30 cm (29 nests), over 50 cm (19 nests), and 31–50 cm (6 nests) (n = 151).

3.4. Distance between nests

Most of the neighbouring crane nests were located at a distance of more than 1.0 kilometre (65 nests), followed by a distance of 0.5–1.0 km (41 nests), a distance of 0.3–0.5 km (14 nests), a distance of 0.2–0.3 km (4 nest), and a distance of less than 0.2 km (4 nests) (n = 120). 120 metres is the smallest distance measured between two occupied neighbouring crane nests in Estonia.

Mean brood size (1.65 nestlings, n = 20) in cases where the distance between neighbouring nests was 0.5–1.0 km was significantly larger than in cases where the distance was more than 1 km (1.16 nestlings, n = 32) (Student t-test, $P < 0.05$, and the Mann-Whitney U-test, $P < 0.05$, n = 52).

3.5. Nest size and material

The height of the found nests varied between 1 and 45 cm, with a mean value of 14 ± 9 cm (± SD, n = 60). The 1–10 cm height category contained the greatest number of nests (33 nests), followed by

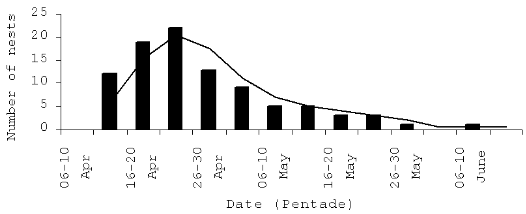

Fig. 5. Timing of the beginning of egg laying of the Eurasian Crane in Estonia, according to nest record cards (n = 93).

categories 11–20 cm (19 nests) and 21–30 cm (5 nests) (n = 60). The outside diameter of nests varied between 40 and 130 cm, with a mean value of 78 ± 19 cm (± SD, n = 64); however, the majority of nests had a diameter of 51–100 cm (57 nests = 89%). No significant correlation between the height and diameter of a nest was found.

Crane nests made of withered grass (hay) were most frequent (83 nests), followed by nests made of reed (30 nest), moss (16 nests), and mixed material (12 nests) (n = 141). The type of nest material depends on the habitat because cranes build their nests from vegetative material growing in the vicinity of the nest. Nevertheless, an analysis of variance indicated that the number of fledglings is significantly higher in nests made of hay than in nests made of reed (Mann-Whitney U-test, $P < 0.01$, n = 113).

3.6. Human activity and disturbance

Most of Crane nests were located in the zone of weak human disturbance (a distance of more than 0.5 km to the nearest building or settlement, main road or path from the nest more than 0.5 km) (104 nests), followed by nests in areas with medium human disturbance (distance 0.1–0.5 km) (45 nests) and in the zone with strong disturbance (distance less than 0.1 km) (6 nests) (n = 155).

Because of the few number of nests found in the zone of strong human disturbance, it was possible to find a statistically reliable relation only by comparing nesting success (brood size) for nests exposed to strong or medium human disturbance (0.81 ± 0.81 (SD) juveniles) (n = 21) and weak human disturbance (1.41 ± 0.80 (SD) juveniles) (n = 46). The mean number of juveniles in the nests subject to weak human disturbance was significantly larger than in the nests located in the zone of medium human disturbance. (Student's t-test, $P < 0.01$ and Mann-Whitney U-test, $P < 0.01$, n = 67). The number of nestlings correlated significantly with the number of fledglings in the brood (Spearman rank correlation coefficient, $r_s = 0.91$, $P < 0.01$, n = 36).

3.7. Nesting phenology

According to the nest record cards, the date of the beginning of egg laying of the Eurasian Crane in Estonia varies between 11 April and 6 June, with a mean value of 22 April ± 10 (SD) days (n = 93). The majority of cranes lay their eggs in the period from mid April until the end of May (Fig. 5).

We found that on Saaremaa Island, in the West Estonian Archipelago, cranes start laying eggs at a significantly earlier date than on the mainland (Student t-test, $P < 0.05$, n = 93). The average date of the beginning of egg laying on Saaremaa is 18 April ± 9 (SD) days (n = 23), and 30 April ± 11 (SD) days (n = 70) on the mainland. The difference is 12 days, i.e. almost two weeks.

An analysis of the variation of the beginning of egg laying by cranes over time indicates a significant trend of advancement in Estonia over the whole 1901–2001 period (Fig. 6). The average change for a ten-year period is almost two days.

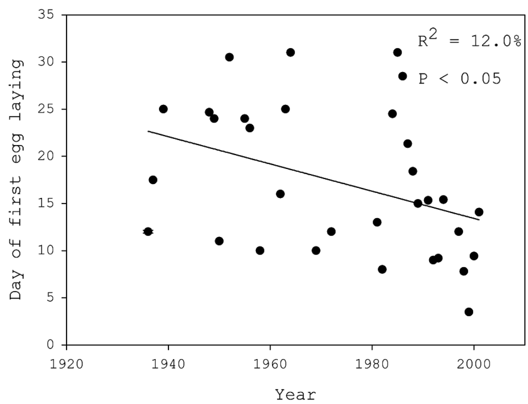

Fig. 6. Relationship between the annual mean date of the laying of the first egg (± SD) and the year, for the Eurasian Crane in Estonia, 1901–2001. Annual mean dates of the laying the of first egg are displayed in days. Cranes started to lay earlier in more recent years ($r = -0.43$, $P < 0.01$, n = 93).

4. Discussion

4.1. Nesting habitat

We analysed characteristics of nesting habitat for the Eurasian Crane on the basis of nest cards. Potentially, the territorial distribution of nest finds can be affected by the actual numbers and distribution of the breeding crane population and by the distribution of birdwatchers. Nevertheless, the spatial distribution of nest finds coincides well with the distribution map of Eurasian Crane occurence depicted in the Estonian Bird Atlas, 1977–1982 (Renno 1993), and with the proportions of breeding habitats determined on basis of censuses of territorial pairs carried out in 1997–2001 (Leito *et al.* 2003). According to the latest population estimate for the period 1997–2001, 91% of cranes nest in mires, primarily in fens (72%) (n = 5,800 pairs) (Leito *et al*. 2003).

Most common Eurasian Crane raised-bog nesting site is a treeless or treed herb and dwarf shrub-rich bog of hollow-pool complex type. In the transitional mire the preferred nesting site is a quaking mire field that is either treeless, or covered with tree and shrub or tree communities. In the fen, cranes prefer a treeless quagmire or paludified grassland with a mosaic sedge-reedbed community and a high ground-water level. In the coastal lagoon, cranes choose the open, sparse *Schoenoplectus tabernaemontanii* dominated reedbeds of watercourses. On the inland, treeless lake shore quagmires with herb communities and reedbeds in watercourses are the preferred nesting sites for cranes, and, in the forest, wet sparse premature rich paludified decidious forests or wooded meadows. Cranes avoid saline habitats like coastal meadows, and reedbeds growing in salty water.

In general it can be stated that, despite the fact that the Eurasian Crane nests in different biotopes in Estonia, all nesting sites include similar structural elements (vegetation types, plant species and communities and elements of microrelief).Our study showed that in terms of plant communitis, identical or similar reedbed and sedge communities occur in fens, river plains, as well as coastal lagoons and inland lakes. Different nesting sites are characterized by similar water regime – flooding or long-term floods in the fen, river plain, coastal and inland lake, and also in swamp and floodplain forests. Occurrence of hummocks is characteristic to all nesting habitats; some difference could be found only in the types of hummock.

In neighbouring Latvia, the most frequent nesting habitats of the Eurasian Crane are similar to those in Estonia – the raised bog, open swampy meadow (fen), reedbeds of inland lakes, alder-birch swamp, marshy clearings in the forest (ranked according to the frequency of occurrence) (Nowald *et al*. 1999). In South-Western Lithuania, the largest number of crane nests have been found in black alder and birch stands (Aleknonis 1983). The nests were located in rich paludified forests, under the trees surrounded by water or on temporarily flooded patches of fens not very deep in the forest.

In Finland, the cranes traditionally mostly breeds in large peatlands of different type (55% of found nests), less frequently by lakes (37%) and on the coast (8%, n = 230) (Karlin 1985, 1995). Extensive drainage in the last decades has caused certain changes in the distribution and biotope use of cranes. An increasing number of cranes breed on lakes and the coast (Karlin 1995).

In Germany, which is situated further south than Estonia, the cranes mostly breeds in relatively small wetlands of different types (ponds overgrown with plants, patches of mire and swamp pools), in the forest, or in mosaic agricultural landscape (Prange 1989, Mewes 1996). In Denmark, on the western border of the cranes` breeding range, a small number of pairs breeds in small peat bogs and swampy fresh-water lakes in inland` but also on coastal tundra-like wetlands between dunes with salty and brackish water (Tofft 1999).

To generalize, it could be stated that cranes are well adapted to breed in different types of wetlands available in an area, but prefers mires and other swampy habitats and avoids, whenever possible, saline habitats on the sea coast.

4.2. Breeding biology

We found that the date of the beginning of egg laying of the Eurasian Crane is significantly related to the size of the nesting habitat. The relationship is non-linear and the reasons for this interdependence are not yet known. It may be that the microclimatic conditions (air temperature, water level, ice and snow cover) are significantly different in different sized nesting sites within the same habitat type and in different habitat types, affecting the timing of the egg laying of cranes. Unfortunately, data on micro-climatic conditions of nesting sites were not gathered on the nest record cards, and we cannot therefore test this hypothesis.

It was surprising that, except for the biotope class and the depth of water, no significant relation between the wetness of the nesting site and any other characteristic was detected. One reason for this could be that the predators of the clutch and small nestlings of the Eurasian Crane are mostly the Raven *Corvus corax* and the Hooded Crow *Corvus corone*, for whom water is not a barrier. The most dangerous predators of bigger nestlings and fledglings are the Red Fox *Vulpes vulpes* and the Golden Eagle *Aqulila chrysaetos;* the nesting site has usually become drier by that time, and young cranes are often killed at a distance from the nest as well. Consequently, water cannot provide significant protection against predators.

We found that the mean brood size in neighbouring nests a smaller distance (0.5–1.0 km) apart was significantly greater than for those that were a longer distance (more than 1 km) apart. In our opinion, the habitat quality is one of the reasons for the difference in nesting success and population density of cranes. On the basis of different breeding success by different distances between neighbouring nests we believe that the habitat quality is lower when the distances between nests are longer (or the population density is lower). However, it is also evident that nesting success decreases when the distance between nests becomes too short, because then competition between pairs and families with young increases substantially despite the original quality of a nesting site in terms of other important characteristics (food resources, predators, disturbance and hiding places) remaining unchanged (this concerns the same or very similar nesting habitats).

We have several direct observations of heated boundary quarrels between cranes nesting close to each other. This means, that, if the population density exceeds a critical level, nesting success will decrease just as it does with increasing distances between nests in increasingly low quality nesting habitats. This relationship is similar but not the same as the classical density-dependence relationship between population density and population growth or reproduction described and modelled by many authors (see Schwerdtfeger 1979, Hanski 1990, Holyoak 1994, Cappuccino & Price 1995, Krebs 1998).

Differences and significant dependence of breeding success on distances between neighbouring nests (population density) find out on the basis of detailed analyse of nest record cards in this study coincide well with our previous findings in differences of population densities in different habitats based on a large-scale analyse of habitats occupied by cranes (Leito *et al.* 2003), confirming once more that the quality of different habitats are different for breeding cranes. As the population density was highest in fens (Leito *et al*. 2003), we believe that the cranes prefer the fens because of highest quality of this habitat for breeding.

Surprisingly, nest material had a certain effect on nesting success. The number of fledglings in cases where nests were made of hay was significantly higher than in the cases where they were made of reed. The reason for this is not known, possibly hay has a better mechanical and/or thermoregulatory characteristics for hatching eggs and for nestlings compared than reed.

We found that human activity had a significantly negative effect on the breeding success of cranes in Estonia. The mean brood size in nests close to roads or buildings was significantly smaller than in nests that were further away from human disturbance. This result is not surprising, but it was important to prove that human activity really has a negative influence on the breeding success of cranes, confirming the earlier but often too generalised declarations to that effect (Cramp & Simmons 1980, Prange 1994, Meine & Archibald 1996).

An interesting finding is that the average timing of egg laying by cranes in Estonia has advanced significantly (by 12 days in total) during the period 1901–2001. We suppose that the main reason for this is the warming of the climate, especially the mean spring temperature, in Estonia, as well as in the whole of northern Europe (Jaagus & Ahas 2000, Jaagus *et al*. 2002). Because of the earlier spring, cranes arrive and nest earlier, at least in Estonia (Keskpaik *et al*. 1997, 2000). Earlier nesting has probably contributed to the population increase described in almost all areas of Europe during the last decades (Leito *et al.* 2003, Prange 2003).

5. Conclusions

We conclude that the Eurasian Crane breeds in several types of wetland with similar ecological elements (vegetation types, plant species and communities, and elements of micro-relief, openness and wetness of the nesting site and surroundings). In Estonia, the favourite nesting habitat for cranes is mire, especially fen. They avoid saline wetlands for nesting. In general, the Eurasian Crane is well adapted to occupay different habitats (wetlands) occurring in an area. We have found that the most important habitat-dependent factors affecting nest site selection and reproductivity of the Eurasian Crane in Estonia are the size of the nesting habitat, vegetation type, micro-relief and ground type, openness and wetness, and, more indirectly, nest material, population density, and human activity.

The results of our study are useful for the management and conservation of breeding populations of Eurasian Cranes, because the characteristics we have analysed are also important population limiting factors (Prange 1989, 1994, Meine & Archibald 1996, Leito *et al*. 2003). In Estonia, the breeding habitats seems currently to be in a good condition, but human activity has already had a remarkable negative effect, as we demonstrated in this study. One problem lies in the fact that we do not actually know the relative importance of different factors affecting the reproduction and mortality of Crane populations (Alonso *et al.* 1991, Prange 1989, Meine & Arcibald, Mewes 1999, Leito *et al*. 2003). For this purpose, we have already started more massive and integrated study on habitat-dependency relationships in breeding Eurasian Cranes using GIS-based methods.

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Virolaisten kurkien pesäpaikat

Pesälöytöjen perusteella kurki asuttaa Virossa monenlaisia kosteikkoja. Eniten pesiä (yhteensä 161) on löydetty minerotrofiselta suolta (n = 63), sitä seuravaat korpi (n = 43), metsä (n = 16), järvi (n= 15), vaihettumissuo (n = 9), kluuvijärvi (n = 7) ja joen luhtaniitty (n = 6). Erilaisista pesimäbiotoopeista huolimatta pesäpaikoille ovat ominaisia monet yhteiset tai samankaltaiset rakenneosat (kasvilajit ja -yhdyskunnat, kasvillisuustyyppi, pinnanmuoto ja mättäisyys) tai muut ominaisuudet (avoimuus ja vetisyys).

Yleistettynä kurjen tyypillinen pesäpaikka on avoin tai puustoinen, allikkoinen keidasräme, vaihettumissuolla avoin, pensaikkoinen hetteikkö sekä minerotrofisella suolla avoin, ruovikkoinen ja sarainen hetteikkö tai niitty. Kluuvijärvillä tyypillinen pesäpaikka on avoin, vedessä kasvava harva ruovikko, sisämaan järvillä avoin tai puoliavoin sarahetteikkö tai vedessä kasvava ruovikko sekä metsässä keski-ikäinen harva soistuva lehtimetsä tai lehtoniitty.

Kurjen pesimämenestys riippuu olennaisesti naapuripesien etäisyydestä (populaation tiheydestä), pesämateriaalista (kuivalla ruoholla sisustetut pesät tuottavat ruokopesiä paremmin) sekä ihmistoiminnasta (mitä lähempänä pesää on tie, talo tai taajama, sitä alhaisempi on tuotos). Munimisen alku on yhteydessä pesimäbiotoopin pinta-alaan. Virolaisten kurkien munimisen alun vuotuinen keskipäivämäärä on ajanjaksona 1901–2001 muuttunut huomattavasti varhaisemmaksi.

References

Aleknonis, A. 1983: The Eurasian Crane in South Western Lithuania. — In Abstr. XI Baltic Ornithological Conference (ed. Kumari, E., Lilleleht, V. & Renno, O.): 51–53. (In Russian)

Alonso, J.A., Alonso, J.C., Martinez-Vicente, I.S. & Bautista, L.M. 1991: Simulation of o Common Crane Population Model. – In Proc. IVth International Crane Workshop: 277–283. Quiqihar, China, 1–10 May 1987. — International Crane Foundation, Barboo, Wisconsin, USA.

Blotzheim, U.N.G., Bauer, K.M. & Bezzel, E. 1973: Der Vögel Mitteleuropas. Band 5. Galliformes und Gruiformes. — Akademische Verlagsgesellschaft, Frankfurt am Main. (in German)

Cappuccino, N. & Price, P.W. 1995: Population Dynam-

ics. New Approaches and Synthesis. — Academic Press Limited.
Cramp, S. & Simmons, K.E.L. (eds.) 1980: The Birds of the Western Palearctic, Vol. 2. — Oxford University Press, Oxford, U.K.
Gore, A.J.P. 1983: Introduction. — In Ecosystems of the world 4A. Mires: swamp, bog fen and moor. General studies (ed. Gore, A.J.P.): 1–34. Elsevier Scientific Publishing Company.
Hanski, I. 1990: Density dependence, regulation and varialibility in animal populations. — Philosophical Transactions of the Royal Society (London), Ser. B 330: 141–150.
Holyoak, M. 1994: Identifing delayed density dependence in time-series data. — Oikos 79: 296–304.
Ilyichev, V.D. & Flint, V.E. 1987: Birds of USSR. Galliformes and Gruiformes. — Nauka, Leningrad. (In Russian)
Jaagus, J. & Ahas, R. 2000: Space-time variations of climatic seasons and their correlation with the phenological development of nature in Estonia. — Climate Research 15: 207–219.
Jaagus, J., Ahas, R & Aasa, A. 2002: Eesti asub kliimamuutuste keskmes. — Eesti Loodus 11: 6–13. (In Estonian)
Jokimäki, J. & Huhta, E. 1996: Effects of landscape matrix and habitat structure on a bird community in northern Finland: a multi-scale approach. — Ornis Fennica 73: 97–113.
Karlin, A., 1985. Kurkitutkimus. — Lintumies 20: 111–118. (in Finnish)
Karlin, A. 1995. Nesting of cranes in Finland. — In Crane Research and Protection in Europe (ed. Prange, H.): 145–148. Martin-Luther-Universität, Halle-Wittenberg.
Keskpaik, J., Ojaste, I., Peterson, K. & Leito, A. 2000: Spring migration of the Common Crane pairs in Estonia: arrival, occupation of nesting sites and start of laying eggs. — In Linnurada 2000: 23–28. Tallinna Raamatutrükikoda, Tallinn. (In Estonian with English summary)
Keskpaik, J., Ojaste, I. & Rootsmäe, L. 1997: Spring arrival of the Common Crane in Estonia in 1905–1994. — In Nature Observations 1995/96: 193–199. Matsalu Looduskaitseala. Tallinn. (In Estonian with English summary)
Krebs, J.C. 1998: Ecological Methodology, second edition. — Addison-Wesley Educational Publishers.
Leito, A., Truu, J., Leivits, A. & Ojaste, I. 2003: Changes in distribution and numbers of the breeding population of the Common Crane Grus grus in Estonia. — Ornis Fennica 80: 159–171.
Lutze, R., Wieland, R & Schultz, A. 1998: Habitatmodelle für Tiere und Pflanzen – Instrument zur integrative Abbildung und Analyse von Lebensraumansprüchen mit direktem Bezug zur Landschaftsstruktur und zur Landnutzung. — In Umweltmonitoring und Umweltmodellierung: GIS und Fernerkundung als Werkzeuge einer nachhaltigen Entwicklung (ed. Blaschke, T.): 223–236. H. Wichmann Verlag, Hüthig GmbH. (In German)
Maansoo, S. (ed.) 2001: Estonian Statistical Yearbook 2001. — Statistical Office of Estonia, Tallinn. (In Estonian and English)
Meine, C.D. & Archibald, G.W. (eds.) 1996: The cranes: Status survey and conservation action plan. — IUCN.
Meiner, A. (ed.) 1999: Land Cover of Estonia. Implementation of CORINE Land Cover Project in Estonia. — OÜ Mansfield, Tallinn. (In Estonian and English)
Mewes, W. 1996: Habitatnutzung des Kranichs in Deutschland. — Die Vogelwelt 117: 111–118. (In German with English summary)
Nowald, G. 1999: Reviergrösse und Raumnutzung jungeführender Kraniche Grus grus in Mecklenburg-Vorpommern: Erste Ergebnisse einer Telemetriestudie. — Die Vogelwelt 120: 261–274. (In German)
Nowald, G., Drobelis, E., Leito, A. & Vaverins, G. 1999: Brutbestand des Kranich Grus grus in Estland, Lettland und Litauen: Siedlungsdichte, Verbreitung und Brutplatztypen. — Die Vogelwelt 120: 281–284. (In German with English summary)
Paal, J. (ed.) 1997: Eesti taimkatte kasvukohatüüpide klassifikatsioon. — Tartu Ülikooli Botaanika ja Ökoloogia Instituut, Tallinn. (In Estonian with English names of main classification units)
Paal, J., Ilomets, M., Fremstad, E., Moen, A., Børset, E. Kuusemets, V. Truus, L. & Leibak, E. 1998: Estonian Wetlands Inventory 1997. — Eesti Loodusfoto, Tartu.
Prange, H. (ed.) 1989: Der Graue Kranich. — Die Neue Brehm-Büherei 229, A. Ziemsen Verlag, Wittenberg Lutherstadt. (In German)
Prange, H. 1994: Crane Grus grus. — In Birds in Europe: their conservation status (ed. Tucker, G.M. & Heath, M.F.): 234–235. BirdLife International (BirdLife Conservation Series no. 3), Cambridge, U.K.
Prange, H. 2003: The European Crane Working Group in the present and future. — In Proceedings and Abstracts of the Vth European Crane Conference: 11–12. Sweden, 10–13 April 2003.
Renno, O. (ed.) 1993: Estonian Bird Atlas. — Valgus, Tallinn. (In Estonian with English and Russian summaries).
Schwerdtfeger, H.C.F, 1979: Ökologie der Tiere. Bd. 2. Demökologie. Structur und Dynamik tierisher Populationen. — Ferlag Paul Parey, Hamburg und Berlin. (In German)
Tofft, J. 1999: Der Kranich Grus grus als Brutvogel in Dänmark. — Die Vogelwelt 120: 275–279. (In German with English summary)
Valk, U. (ed.) 1988. Estonian Peatlands. — Valgus, Tallinn. (In Estonian with German and English summaries)