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Māris Strazds

Conservation Ecology of the Black Stork in Latvia

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Conservation Ecology of the Black Stork in Latvia

Māris Strazds

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- II Strazds, M. (1993d). Horstschutzzonen für den Schwarzstorch in Lettland — eine wichtige Maßnahme für den Biotopschutz. In: Schutzstrategien für Schwarzstorch und Rauchfußhühner. Naturschutzzentrum Vasserschloß Mitwitz e.V.: 39–45.
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- VI Strazds, M., J. Ķuze, S. Reine (2006). Evaluation of Black Stork *Ciconia nigra* Nest Inspections in Latvia. 2003–2005. Biota 7/1–2: 93–101.
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Supervisors

Hans-Günther Bauer, Dr. Biol., Max Plank Institut für Ornithologie, Radolfzell, Germany

Jānis Priednieks, Assoc. Professor, Dr. Biol., Department of Zoology and Animal Ecology, Faculty of Biology, University of Latvia

Reviewers

Guntis Brūmelis, Professor, Dr. Biol., University of Latvia

Jānis Vīksne, Full Member of Latvian Academy of Sciences, Dr. Biol., Institute of Biology

Ola Olsson, Assoc. Professor, PhD, University of Lund, Sweden

Doctoral committee

Guntis Brūmelis, Professor, Dr. Biol., University of Latvia — chairman

Tatjana Zorenko, Assoc. professor, Dr. Hab. Biol., University of Latvia

Juris Imants Aivars, Professor, Dr. Hab. Biol., University of Latvia

Voldemārs Spunģis, Assoc. professor, Dr. Biol., University of Latvia

Indriķis Krams, Dr. Biol., University of Daugavpils

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Annotation

The author studied the breeding ecology of the black stork and factors affecting breeding performance in Latvia between 1979 and 2010. The analysed data are based on 1,634 controlled nests, and the reasons for nest abandonment were studied on the basis of data from 301 nests in 257 territories. In order to study the impact of DDT on breeding success, data related to egg measures and organochlorine content were also gathered in Estonia, Poland, the Czech Republic, Germany and Belgium. The dissertation contains 39 tables and 26 figures.

Breeding success of the black stork has declined significantly during the study period, and the main objective of the study was to elucidate the factors which could be responsible for this decline. The most important feature of the breeding habitat is the presence of large oaks, pines or aspens. The position of a nest is a trade-off between predation security, access and nest-site stability. Although predation levels increased significantly during the period of study, they do not exceed the level in undisturbed natural forests. Forestry disturbance, particularly during the spring, was found to be the most significant factor affecting breeding success, resulting in breeding failure of up to some 70% of affected pairs. The role of chemical contamination (DDT) has been increasing during the last years, causing an increased rate of egg loss, delays in the breeding season and reduced juvenile survival. Recommendations for changes in forestry practice and legislation are suggested and discussed.

Keywords: black stork, forestry impact, disturbance, habitat quality, DDT, predator impact

Anotācija

Autors pētīja melnā stārķa ligzdošanas ekoloģiju un ligzdošanas sekmes ietekmējošus faktorus Latvijā 1979.–2010. g. Analīzei izmantotas 1634 ligzdu kontroles, ligzdu pamešanas iemesli analizēti, izmantojot datus par 301 ligzdu 257 teritorijās. DDT ietekmes noskaidrošanai materiāls ievākts arī Igaunijā, Polijā, Vācijā, Čehijā un Beļģijā. Darbā ir 39 tabulas un 26 attēli.

Melnā stārķa ligzdošanas sekmes pētījuma veikšanas laikā ir būtiski pasliktinājušās un darba galvenais mērķis bija noskaidrot, kādi faktori nosaka šo pasliktināšanos. Ligzdošanas dzīvotnes derīgumu nosaka iepriekšējās paaudzes priežu un ozolu, bet mežos, kur ozolu nav, lielu apšu klātbūtne. Ligzdas vietas izvēle ir kompromiss starp ligzdas drošību pret postījumiem, iespēju tai piekļūt un stabilitāti. Lai gan postījumu skaits ir būtiski pieaudzis, tas nepārsniedz dabisku plēsēju ietekmes līmeni netraucētos mežos. Būtiska negatīva loma ir mežsaimnieciskās darbības traucējumiem, it īpaši pavasarī. Tādēļ ap 70% traucēto pāru ir neproduktīvi, kas ir galvenais kopējo ligzdošanas sekmju pazemināšanās iemesls. Pēdējos gados palielinās ķīmiskā piesārņojuma (DDT) negatīvā loma. Šis piesārņojums izraisa ligzdošanas sezonas aizkavēšanos, pasliktina ligzdošanas sekmes un jauno putnu izdzīvotību. Darbā izstrādātas rekomendācijas saimnieciskās darbības izmaiņām un priekšlikumi izmaiņām dabas aizsardzības likumdošanā.

Atslēgvārdi: melnais stārķis, mežsaimniecības ietekme, traucējumi, dzīvotnes kvalitāte, DDT, plēsēju ietekme

Introduction

The black stork is a unique species in many ways. It has the most extensive breeding range of any species of storks (*Hancock et al. 1992*), as well as one of the widest distribution ranges among all bird species – the black stork has been recorded in more than 105 different countries (*Strazds 1995*). At the same time the black stork is not common in any country. At the regional level, it has been considered to be threatened in most of its range countries (*Hancock et al. 1992*). When Luthin (*1987*) was analysing the status of the world's species of storks and the conservation priorities in this regard, he categorised the black stork as being globally vulnerable. Despite this, the bird has never been listed on any official list of globally threatened species. The main reason for this is the huge range which the bird covers, even though the overall size of the population only slightly exceeds the “small population” criterion (fewer than 10,000 mature individuals) of the IUCN/SSC (*BirdLife International 2000*). In Europe, the black stork is classified as rare, and it has been assigned the conservation priority rank of SPEC2 (*BirdLife International 2004*).

The rarity and status of the black stork has attracted the attention of ornithologists ever since the early years of ornithological investigations. In Central European countries, the presence of the species declined significantly during the 20th century, and even single sightings, in many cases, warranted a brief article in a local magazine. This has resulted in a long list of papers which “deal” with this species. There is an incomplete bibliography of texts about the black stork which is mostly made up of papers from Western and Central Europe and contains 1,199 publications (*Krauβ 1990*). Another bibliography related to the black stork in the world consists of 662 papers, approximately half of them being ones that are also mentioned in the aforementioned bibliography (*Coulter & Brouwer 1992*). Despite this, the black stork was one of the least familiar species of large European birds as late as 1980. The entire description of the black stork in the Handbook of Birds of Western Palearctic (*Cramp & Simmons 1978*), for instance, takes up just six pages of text. None of the major reference books that are available at this time provide a global or even European estimate of the black stork population (*Bauer & Glutz Von Blotzheim 1966, Cramp & Simmons 1978, Bezzel 1985, Hancock et al. 1992*).

In 1992, the “Black Stork” project of the Latvian Fund for Nature organised the First International Black Stork Conservation and Ecology Symposium in Ķemeri, Latvia, doing so in partnership with the Latvian Ornithological Society and the ICBP/IWRB/IUCN specialist group of Storks, Ibises and Spoonbills. The population status of the species in the world was one of the main topics of this meeting (*Strazds 2005*). Based on the established network in this area, a comprehensive analysis of the situation was carried out for the 2nd International Black Stork

Conference, which took place in Trujillo, Spain, in 1995. I distributed questionnaires to experts worldwide and received 185 responses with information about the numbers of birds, their distribution, and conservation status. It was found that the black stork was nesting in 44 countries, and its global population was assessed to be between 11,000 and 15,000 pairs. The majority of black storks was thought to be in Europe, with between 8,000 and 10,000 pairs of storks found there (*Strazds 1995*). BirdLife International, for its part, published a European population estimate in 1994 (*Tucker & Heath 1994*) which claimed that there were between 6,500 and 19,000 pairs of storks on the continent. The large difference between the two surveys can be attributed to the fact that there have been very different numbers coming from Russia in this regard. I based my estimate of between 208 and 770 pairs on questionnaires that were distributed to ornithologists in 50 regions of European Russia, while the data provided for BirdLife which indicated that there were between 1,000 and 5,000 pairs was made by a few experts from Moscow who apparently were defining broad limits just to make sure that they “hit” the right number. As for Latvia, it is thought that there are between 900 and 1,300 pairs of black storks in the country (*Tucker & Heath 1994*), which represents between 9 and 12% of the total European population. This makes clear Latvia’s significance in ensuring the worldwide welfare of the species (e.g., *Janssen et al. 2004*).

Population changes in Latvia

During the 20th century, the population of the black stork in Latvia experienced changes of a similar scale as in the rest of Europe, although the relevant trends were quite different during various periods of time. In the late 19th and early 20th century, the black stork was characterised as a comparatively rare or rare species (*Russow 1880, Löwis 1893, Loudon 1895, Sawitzky 1899, Grosse & Transehe 1929*). The authors who performed more detailed investigations, e.g., Stoll (*1904*) noted that the black stork was comparatively common in suitable habitats. A definite increase in the number of black storks in Latvia between 1918 and 1933 was also noted (*Grosse & Transehe 1929, Stoll 1934*). These authors did not, however, provide any data about total numbers. This trend probably reflected a real increase in population numbers in a larger area, as similar trends were also reported in nearby Eastern Prussia (*Tischler 1941*) and Northeastern Poland — the Lake Masuri district and Pomerania (*Tomiałojć 1990*). Elsewhere in Europe, by comparison, the population of the species was declining, in some cases even to the point of extinction (*Janssen et al. 2004*).

The first numerical estimate of the black stork population in Latvia was conducted by N. von Transehe, who was one of the most remarkable ornithologists in the country in the 1930s and

1940. Transehe wrote that “in the Baltic region, they [black storks] are not rare, but they are little known. This is because of their secretive way of life. It is reported in the Great Latvian Encyclopaedia that there should be approximately 500 pairs of breeding birds in Latvia¹. I believe this to be slightly overestimated — no one has counted them. I estimate 300 to 400 pairs” (*Transehe 1965*). Whatever the basis for Transehe’s estimate², it has appeared in later works referring to Latvian avifauna. There, too, most authors estimate the population at “not more than 300–400” pairs (*Лунсберг 1983, Aigare et al. 1985*).

Only a few remarks about the black stork appear in Latvian ornithological literature from the post-war period. It was considered to be a common species in the late 1940s (*Тауриньш, Вилкс 1949*). In the late 1960s, K. Vilks wrote that a considerable decrease in the population had been experienced during the previous five years. He based this estimate on his 40 years of experience as a field ornithologist and on observations that he made in individual small plots with a diameter of 10–15 kilometres (*Вилкс 1968*). Unfortunately, Vilks did not present the quantity of examined nests, the calculated level of decreases in the numbers, or the possible causes for the decline.³

The first attempt to estimate the total number of black storks in Latvia by using a questionnaire was conducted by J. Baltvilks in 1970. The raw data led to an estimate of between 170 and 192 pairs of storks. Taking into consideration the inevitably inexact nature of the methods, he suggested that there were 150 to 200 pairs, or one pair per 130 km² of forest (*Балтвилкс 1972*). These numbers were used as the standard reference with respect to the black stork in Latvia for quite some time,⁴ but none of the authors who made use of the data ever acknowledged the weakness of the underlying study. The inquiry was conducted not only with respect to the black stork. The questionnaires contained questions about 29 species of birds,

¹ In examining the source cited by Transehe, we did not find any evaluation of stork numbers under the entry „stork.” At the same time, however, all 24 volumes of the Great Latvian Encyclopaedia, which were written in the 1930s, have not been examined in this regard.

² It is possible that Transehe reduced the estimate of breeding pairs provided by the relevant (anonymous) author in the Great Latvian Encyclopaedia on the basis of his own observations, but it is also possible that his estimate was influenced by the rarity of the black stork in neighbouring countries, particularly West Germany in the 1960s, which is where and when he wrote his work. At a distance of time and space, it may have seemed to Transehe that such a large number of birds would not have been possible, given that the black stork was rare even in the 1930s.

³ See “Contamination with DDT” in the discussion chapter.

⁴ Since then the number has been cited by several authors — “at least 150–200 pairs” (*Лунсберг 1983*), or „a maximum of 200 pairs” (*Schröder & Burmeister 1974*). Obviously this depended on each author’s experience with the species. Although not indicated as a source for the data, it is obvious that these indices of population density are also quoted in “The Red Data Book of the USSR” (*Флинт 1984*). This source, in turn, has been used to speak to the total number of black storks or to the population density of the bird in Latvia (e.g., *Luthin 1987*). Figures given by Boettcher-Streim (*1992*) speak to “a maximum of 200 pairs in 1958/1959,” but this is a misquote from Schröder & Burmeister (*1974*) in that the author erroneously combined the survey year in Lithuania with the number of birds from Latvia.

animals, reptiles and amphibians, thus “dissolving” the responses which concerned any specific species. There were two other essential factors which Baltvilks unfortunately did not take into account, and this fact strongly detracts from the credibility of the results. First of all, he did not provide information about the reliability of his inquiry — the number of questionnaires that were circulated, the percentage that were returned, and the percentage that contained noteworthy information. Examination of the original materials from Baltvilks’ inquiry shows that information was lacking for nearly one-half of all of Latvia’s forest districts. Our own experience with questionnaires has demonstrated that a lack of response does not correspond to a lack of available data (*Strazds 1993a*). It is also true that Baltvilks did not check any of his information in the field, and a recent study showed that even trained observers often misidentify black stork nests (*Strazds et al. 2006*). Second, the author did not take into account the fact that his inquiry was conducted just after two major storms in the autumn of 1967 and the autumn of 1969 (*Liepa 2003*). These ravaged large areas of forests, particularly in western Latvia. Most of the known nests at that time were destroyed by the storms. It must be mentioned, too, that these storms apparently had a great impact on the perceptions of foresters even 20 years later (*Strazds 1993a*). This was certainly reflected in the responses which they gave to questions.

Despite all of this, the Baltvilks data, together with an earlier publication from Vilks (*Вилкс 1968*), as well as long-term observations at the Engure Marsh (*Mihelsons 1960*, as well as unpublished data from the Laboratory of Ornithology of the Institute of Biology), were nevertheless the principal source for J. Lipsbergs (*Липсбергс 1983*) when he came to the conclusion that “the total number of black storks in Latvia decreased during the last 30 years and that the decrease had probably continued for a considerable period of time.”

Once again, the work of Mihelsons (*1960*) and the unpublished studies of the Engure Marsh did not involve any *in situ* examination of black stork nests. All of the statements regarding the decline were based on the number of foraging birds observed at the marsh. The possibility that the observed decline in the number of storks visiting the marsh may have been associated with local changes in the marsh habitat or with other factors was not explored. The Engure Marsh, for instance, was the first place where the presence of the white-tailed eagle was noted after a long absence in the early 1970s (*Lipsbergs, Priednieks 1975*). The appearance of the white-tailed eagle could also have resulted in the disappearance of the black stork.

Black storks certainly faced comparatively adverse conditions in Latvia after the storms of 1967 and 1969, because of increased disturbance resulting from the removal of broken trees, etc. Storks had difficulties in finding appropriate trees for nesting. The population could, therefore,

have been smaller than in previous years, but neither the actual population nor the level of decline can be estimated properly due to the stated inaccuracies in the data (*Strazds 1993b*).

Many black stork nests in Latvia were first inspected by ornithologists who were collecting data for the Latvian Red Data Book between 1977 and 1980. The work has been more thorough since 1980, when the Latvian Breeding Bird Atlas project was started. All previously found nests were re-examined during this programme (*Priednieks et al. 1989*). Many new nests were found, and the total number of black storks in Latvia was cautiously estimated as being “not fewer than 200 pairs” in the Latvian Red Data Book (*Aigare et al. 1985*). Partly because of previous perceptions, however, the book also said that the decrease in population numbers was continuing. The “decline impact” was partly caused by the fact that many nests were first identified during forestry operations — nests which were abandoned immediately after their discovery because of those operations (e.g., *Petriņš 1993*). The authors of the Latvian Breeding Bird Atlas were also strongly influenced by the myth about the rarity of the black stork — this despite new evidence which clearly showed that the species was far more common than had been believed. Fears of overestimation, however, still resulted in the conservative estimate in the atlas of 400 to 500 pairs of black storks, although the authors did state that “the real number can be even higher (as many as 700 pairs), as some regions in the country have not yet been sufficiently surveyed” (*Priednieks et al. 1989*).⁵ The next step was to gather data for the European Breeding Bird Atlas (*Hagemeijer & Blair 1997*). New nests of black storks were discovered mostly on the basis of annual interviews of foresters, as well as follow-up investigations. Only a few years later, the breeding population in Latvia was estimated to be “not fewer than 500 pairs” (*Strazds et al. 1989*), while the next evaluation that was carried out in the early 1990s said that there were 900–1,000 pairs (1,200–1,300 territories). This would have represented approximately 10% of the known global population of black storks (*Strazds 1993b*). However, this steep increase over such a short period of time reflected a change in our knowledge, as opposed to the speed of increase in the population itself. The increase, however, did take place.

There were two major factors in the increased number of black storks. First, there was the fact that between 1935 and 1983, forest cover in Latvia expanded from 24.9% to 41.1% of the territory (*Matīss 1987*). Better foraging conditions could have been a second factor. An increase in the number of fish-breeding farms and the development of hydrographical systems in forests have benefited the black stork. The network of forest drainage ditches increased dramatically from 4,744 km in 1949 to approximately 32,800 km in 1990 (*Bušs et al. 1973*, unpublished data

from the State Institute for Hydromelioration). These irrigation ditches are full of water because of the building of ponds by beavers *Castor fiber*. Analysis of the foraging habits of the black stork have shown that forest drainage ditches constitute a great deal of the bird's foraging habitat (42.7% of observations, n = 625, in ditches and regulated rivers; *Strazds 1993c*). They are particularly important during years when weather conditions are poor (*Strazds et al. 1989*). There has been a dramatic increase in the number of beavers in Latvia since the mid-1970s. There were some 1,000 beaver settlements in 1988 (*Озолиньи, Балодис 1989*), with some 50,000 animals in all. The relationship between the black stork and the beaver is supported by the fact that the regions with the highest breeding density of black storks were also the regions with the highest density of beaver settlements.

The economic situation in Latvia changed rapidly after the recovery of the country's independence in 1991, but legislation related to environmental conservation was adjusted rather slowly. As a consequences of this, the number of protected nesting sites dropped by a significant number. There were 208 protected nesting sites in 1990, but only 146 remained in 1995. The abandonment rate of nests was strengthened by the significant increase in forestry operations and by an increasing number of predators (*Strazds 2005*). A new evaluation of the stork population in Latvia showed that a major decrease in their numbers had occurred. There were no more than 750 to 900 pairs of nesting storks in Latvia in 1996 (*Strazds 1998a*), which represented the largest known decrease in the number of storks anywhere in the world. The decrease continued later, as well, and the latest estimate shows that no more than 500–700 pairs of black storks were nesting in Latvia between 2000 and 2004 (*BirdLife International 2004*). Since the early 1990s, the total size of the population was at approximately 45% of the maximum size. Similar negative trends have been reported in neighbouring Estonia (*Sellis 2000*) and Lithuania. This ran counter to positive trends elsewhere in Europe (*BirdLife International 2004*), which suggests that the stork population in the Baltic States may be suffering from common problems, as opposed to the idea that it is based only on negative developments in Latvia.

Factors affecting population size

These negative developments may have been caused by many factors. Analysis of former decreases between the late 19th century and the first half of the 20th century may offer clues about this. The fact is, however, that changes in the range and numbers of black storks in Central Europe have been documented quite well (e.g., *Bauer & Glutz von Blotzheim 1966, Schröder &*

⁵ The actual year when this estimate was made was 1986.

Burmeister 1974), while possible or actual reasons for the decline have not been documented very well at all.

The major problem, insofar as specialists have recently concluded is the destruction of habitats and the degradation of forests, both of which have a serious effect on reducing the range of suitable breeding habitats (*Tucker & Heath 1994*). Other factors that have been cited as a threat against the species include shooting, electrocution, nest robberies, and disturbances (*Boettcher-Streim 1992, Tucker & Heath 1994*). Pesticides have been another problem (*Hancock et al. 1992*).

Disturbances

Despite historical calls from early conservationists to protect certain rare species as natural monuments in Latvia (*Transehe 1924*), the black stork has been considered by others as a very harmful bird, especially in terms of fish farming. The black stork “destroys more fish than any other species, and so it is persecuted in all possible forms” (*Kalniņš 1924*). The “harmful” nature of the black stork was accepted even by those people who supported the protection of the species and stressed its rarity (*Mežulis 1924*). There is literature to indicate the persecution (shooting) of the black stork. For instance, at least six birds were shot on the Sloka Estate in 1901, and another one was shot there in 1902. After that, the black stork did not nest on the grounds of the estate anymore. Also in 1902, five birds that were probably locally fledged were shot on the Kaleti Estate (*Stoll 1904*).

Oscar von Löwis⁶ was one of the most prominent ornithologists in the Baltic region during the late 19th century, and in a book that he published about birds in Latvian (the first book about birds in the Latvian language, in fact), he wrote that the black stork was, indeed, harmful to fish farmers, but at the same time, interestingly, von Löwis insisted that the black stork “is very shy. The hunter may get it in his hands very rarely or occasionally. Its meat is not edible, it has an awful stench, and its fat is horrible, rusty-tawny in colour” (*Löwis 1893*). Irrespective of the gastronomic quality of the bird, von Löwis’ description of the stork’s attitude toward people tells us a lot about what people thought about the stork at that time.

As late as in 1925, a local hunters’ club which was announcing prizes for the shooting of “pest birds” listed the black stork along with “pests” such as the buzzard, the carrion crow, the magpie

⁶ One of the co-authors of the monumental second edition of “Naumann’s Naturgeschichte der Vögel Mitteleuropas” (see *J.R. 1897*).

and the white stork, offering LVL 0.10 per head (*Nātra 1925*).⁷ Other sources offer the same kind of information. Siewert (1932) writes that “not so long ago,” prizes for the shooting of black storks were also offered in Germany, and no fewer than one-quarter of the 112 juvenile storks that were ringed in Denmark were shot in France and Germany during their first autumnal migration to Africa. This was true despite the fact, according to Siewert, that the bird was protected in Germany. The shooting of adult birds and the stealing of eggs from nests by collectors are claimed to be the main reason for the disappearance of the black stork from certain parts of Germany at the end of the 19th century (*Stengel 1883*) and from Sweden, where an additional problem was the drainage of feeding grounds during the same period of time (*M. Forsberg, pers. comm.*). The last pair was shot near a nest in Luxembourg in 1860, in Hessen in 1909, etc. (*Schröder & Burmeister 1974*). Collectors paid “an initial sum of one mark, 30 shillings” per juvenile stork, while later the price reached the sum of 6 to 10 marks per bird (*Stengel 1883*).⁸ This was certainly a sufficient sum of money to interest people in removing eggs or juveniles from all accessible nests, and/or to shoot the birds as soon as possible. All of these sources show that there was direct persecution of the black stork during this period in time.

In 1934, F. Stoll wrote about a significant increase in black stork numbers in Latvia between 1920 and 1934 (*Stoll 1934*), associating this exclusively with changes in the attitude of foresters. In other words, he linked it indirectly to conservation measures. In Eastern Prussia, which was not far from Latvia, Otto Steinfatt wrote that in the Rominetner Forest, where “some 25 pairs are currently nesting,” the black stork population was stabilised and also expanded thanks exclusively to conservation measures (*Steinfatt 1940*).

The quality of habitats

The description of black stork habitats that was provided by Löwis was similar to that of most authors at that time: “They can be found in pairs only in remote forests interspersed by larger rivers and lakes; they like to reside near the water.” The author added that the stork “breeds in primeval forests not far from water on 2/3 height of strong trees, yet not on the tree itself, but on branches” (*Löwis 1893*). Apart from old pine trees, oaks, black alders, aspens and birches were also mentioned as nesting trees (*Stoll 1904*). The publications did not, however, give a precise definition of the concepts of “a primeval forests” or of “large, old, strong trees” (e.g., *Mežulis 1923, Stoll 1934*). More explicit information was given only in a few cases. For instance, F.

⁷ For comparison, we can note that the cost of mailing a domestic postcard in 1925 was LVL 0.04.

⁸ This sum was slightly higher than that which would have been paid at that time for a newborn lamb. The price of a dairy cow was 120 marks. *H.-G. Bauer, pers. comm.*

Stoll (1904) reported that a nest was found on a bend of a 1.5 foot (~47 cm) strong pine, supported by a strong side branch. This nest deserves particular attention, as the author also cited the size and age of the nest itself. He wrote that it had been occupied annually for more than 30 years and had a diameter and also height of nearly 1 metre (Stoll 1904). In neighbouring territories, Siewert (1932) wrote about nesting trees “well over 150 years old.” Stengel (1883), when listing nests from which eggs were regularly stolen, cited a pair which nested in a “pine that was so thick that it was considered inaccessible”. Taken together, these fragmented descriptions shape a picture which very much resembles contemporary long-lived nesting territories, as well as the best nesting trees.

As early as in the 1940s, some foresters began to insist that storks cannot build a nest in just any tree. Given the size of the nest and the wingspan of the bird, the nest cannot be positioned in the canopy of a tree, so storks instead use broken treetops or the tops of dry side branches where nests are sensitive to collapse. Such trees can seldom be found, because they are removed during thinning or sanitary cuttings as “diseased” trees (Ūdris 1940). Some authors (e.g., Stengel 1883) have written about former nesting trees that have collapsed or have been cut down when discussing the decline of the black stork population in Central Europe. None of them, however, analysed the issue of whether the availability of suitable trees was a factor in triggering or supporting the decline. It is likely that the role of direct disturbance and shooting of birds at that time was so extensive⁹ that other factors seemed insignificant, at least to observers at that time. Researchers at that time devoted far more attention to when birds arrived and departed (e.g., Stoll 1934, Steinfatt 1940) than to any detailed description of their breeding habitat. It was only much later that a single study in Poland showed that the presence of old and large trees is more important feature of a breeding site than the age of the surrounding forest (Bednorz 1974). Most other research papers and even monographs (e.g., Schröder & Burmeister 1974) do not deal with the particular aspects of breeding habitat features such as the age of the stand or the nesting trees at all. Similarly scarce is information about the longevity of the nests. Researchers usually cited only the greatest longevity in the nearby vicinity, often without any quotes to provide a broader context for the content of what they wrote. The consequence of this is that very different extremes can be found even in terms of neighbouring countries at the same time. One report said that in eastern Germany, for instance, black storks “seldom use their nests for longer than 10 years,” with the authors citing exceptional cases of 17 and 40 years of nest occupancy (Schröder

⁹ In one case, for instance, eggs were removed from the nest six years in a row, but in order to keep the pair in the relevant nest, eggs laid by domestic chickens or geese were put into the nest instead. In four of the five described nests, in turn, the adult birds were shot (Stengel 1883).

& *Burmeister 1974*). In neighbouring Poland, by contrast, *Bednorz (1974)* reported that storks “use their nests for many years,” citing “known nests that have been occupied for more than 50 years” and “several dozen nests which have been occupied for a period of 25–40 years”. These differences may also point to true variations caused by environmental factors,¹⁰ but neither of the aforementioned papers analysed the conditions that are essentially for long use or the factors which led storks to change their nesting sites.

The level of knowledge about the breeding habitat of the black stork and about factors which affect its breeding success remained quite similar until the late 1980s. Because the stork population in Latvia has obviously reached its peak at that time, the initial purpose of this study was to understand the true size of the population, along with basic habitat requirements and limiting factors therein. We began to assess the geographic characteristics of the habitat (e.g., length of ditches, forest cover, etc.). We also looked at the peculiar aspects of nest location, including the microhabitat of the surroundings of the nest, shadowing of nests, etc. (*Strazds et al. 1993*). At the first Black Stork Conference in Ķemeri, Latvia, in 1993, participants agreed to launch an internationally co-ordinated colour ringing programme. This provided us with plenty of new knowledge about the timing, directions and other properties of black stork migration (*Van den Bossche 2003*) in all of Europe. Annual inspections of nests with the purpose of ringing did make it possible to discover changes in the survival of juveniles in different nests (*Strazds 1998a*), and it also outlined the role of predators in this process. Because the proportion of unproductive nests grew rapidly in the mid 1990s — a period of time when there was an increasing number of cases in which forestry work was a disturbance — I formulated my initial hypothesis about the negative role of forestry. After the detection of chemical contamination, of course, the hypothesis was supplemented with this factor.

The initial hypotheses:

The decrease in the black stork population in Latvia has been caused by a number of factors, among which the most significant ones are:

- 1) Changes in the quality of the habitat;
- 2) Disturbances caused by forestry and other factors;
- 3) Changes in the rate of predation;
- 4) The role of DDT and other chemical contamination.

¹⁰ Or, more likely, they manifest a lack of good contacts and/or of knowledge about neighbouring territories.

The objective

The objective of the study has been to discover reasons for the decline in the black stork population in Latvia.

The following tasks were defined in relation to the objective:

- 1) To identify the essential characteristics of the quality of the breeding habitat, also analysing changes in the availability of same;
- 2) To analyse the significance of disturbances caused by forestry and other factors;
- 3) To assess changes in the impact of various groups of predators;
- 4) To analyse the impact of chemical contamination on the breeding performance of the black stork;
- 5) To propose changes in legislation related to conservation and forest management where appropriate.

Thesis to be defended

A number of factors relate to the decline in the black stork population in Latvia — the impact of forestry, the role of predators and, during the last decade, the increasing problem of chemical contamination. In the long run, the most important of these will be forestry, because it affects the stork population both directly (by causing significant breeding failures) and indirectly (by reducing the available habitat and enhancing the impact of the other contributory factors).

Methods

Definitions

A proper description of specific phenomena related to nesting behaviour — e.g., the lifespan of the nest or the issue of nest abandonment — requires the use of relevant terminology. Some of the terms used in this dissertation for purposes of analysis may differ from the traditional use of similar terms elsewhere (Table 1).

Table 1. Terms used in this dissertation

Term	Definition	Location†
1	2	3
Terms related to landscape		
Flatness index	The ratio of elevation contour lines (each 10 m) within a 3 km radius versus the diameter of the circle. The longer the elevation lines (i.e., the value of the index is higher), the more expressive is the terrain.	Fig. 5, Page 32
Fragmentation index	The ratio of the borderline of the undisturbed part of the 3 km circle (Fig. 6), versus the perimeter of that circle; if the analysed range does not contain any “disturbing” landscape, then these lines are identical, and the value of the index is 1; the larger the index, the more fragmented the landscape.	Fig. 5, Page 32
Undisturbed landscape	The theoretically disturbance-free part of the surrounding landscape, encompassing forests, bogs and larger bodies of water. This identification is based on topographic maps (<i>LGIA 2008</i>) which show the situation in the early 1990s.	Table 7, Page 33
Terms related to breeding habitat		
Nesting location	The term “location” is used to define one and the same nesting tree. I use it in order to distinguish those cases in which I discuss the nesting tree as a geographic spot, as opposed to cases in which I discuss or analyse a nesting tree as a tree (e.g., its species, age, strength, etc.).	Page 40
Replacement nest	Another nest in the same home range.	Page 42
The age of the tree at first nesting	The age of the nesting tree in the first year when the stork is nesting in it.	Page 36
Nest-holding age	The age of the nesting tree at each nesting attempt (see nesting attempt).	Page 23
The tree selection preference index	The ratio between the frequency of choice and the availability of the respective species in stands of trees (<i>Strazds et al. 1993</i>).	Fig. 7B, Page 35
The lifespan of the nest	The lifespan of the nest refers to the number of years during which a bird uses the same nest without rebuilding it completely.	Page 40
The lifespan of the nesting location	The lifespan of the nesting location refers to the length of time during which the same nesting tree is being used.	Page 40
Visibility range from the air	The calculated area at a level of double tree height from which the nest can be seen.	Fig. 3, Page 24
Terms related to the breeding performance of storks		
Breeding success indexes	The trend shows the actual value of the respective parameter changes with respect to the value of the year of reference. 1978 is the year of reference for trend indexes (the value for the year is 1).	Page 32
Occupied nest	An occupied nest is repaired in the spring and lined with fresh green moss and/or grass. The birds attend such a nest regularly during the entire season.	Page 22
Nesting attempt	Nest with at least one egg laid.	Page 28

Table 1. Terms used in this dissertation (continued)

1	2	3
Successful breeding	Only those nests with successfully fledged juveniles were considered to be successful. The only exception is described on page 28.	Page 28
Unproductive nest	An unproductive nest is one which is inhabited by storks which do not have offspring in a given year. This can be due to a lack of a partner, the disappearance of a clutch, a case of predation, etc.	Page 43
Nest abandonment	A nest is considered to have been abandoned if the birds which once nested there have moved elsewhere. If the new territory is nearby, the birds may visit the former nest or use it for sleeping, but the nest itself is normally not restored in the springtime — it has no fresh lining, and during the summer it usually overgrows with grasses.	Page 25
Period of desolation	The term “desolation” refers to years when the nest is not being used by the stork. It is quite common, however, for other species of birds to use the abandoned stork nest for some part of the relevant years. We have recorded the lesser spotted eagle, the goshawk, or the common buzzard doing so.	Table 17, Page 42
Terminal period of desolation	The last period of desolation between the abandonment of the nest and the final collapse of the nest.	Page 42
Mammalian predation	Known mammalian predators in Latvia include the pine marten (<i>Martes martes</i>) and the lynx (<i>Felis lynx</i>), but because I am aware of only four (or, possibly, five) nests which were depredated by the lynx, I am speaking mostly about marten predation.	Page 47

† The first location where the respective term is mentioned in this dissertation.

Nest inventories

Regular inspections of nests of black storks and the collection of data about the annual breeding success began in 1978. To calculate trends related to breeding success and other demographic parameters, however, I am using data beginning with 1979, because the number of inspected nests in 1978 was quite small. Because of the long period of data collection, it is important to ensure that all of the information is comparable. A lack of appropriate experience in this regard may result in, e.g., the incorrect identification of nest ownership (species breeding) or an incorrect evaluation of breeding success in almost one-half of all cases (*Strazds et al. 2006*).

To minimise the presence of such possibly erroneous data, I only used information that was collected by myself (in most cases, working together with colleagues or foresters), or by other experienced ornithologists (Fig. 1). These data were checked against original sources such as field notes, photographs, etc., using the same approach in 2010. I only collected data and information from such foresters and birdwatchers whose knowledge in terms of identifying black stork nests was field-tested, and only with reference to nests which could be monitored from the ground. In most cases, control over nests was conducted by climbing straight up the relevant tree or a nearby tree (*Strazds et al. 2006*).

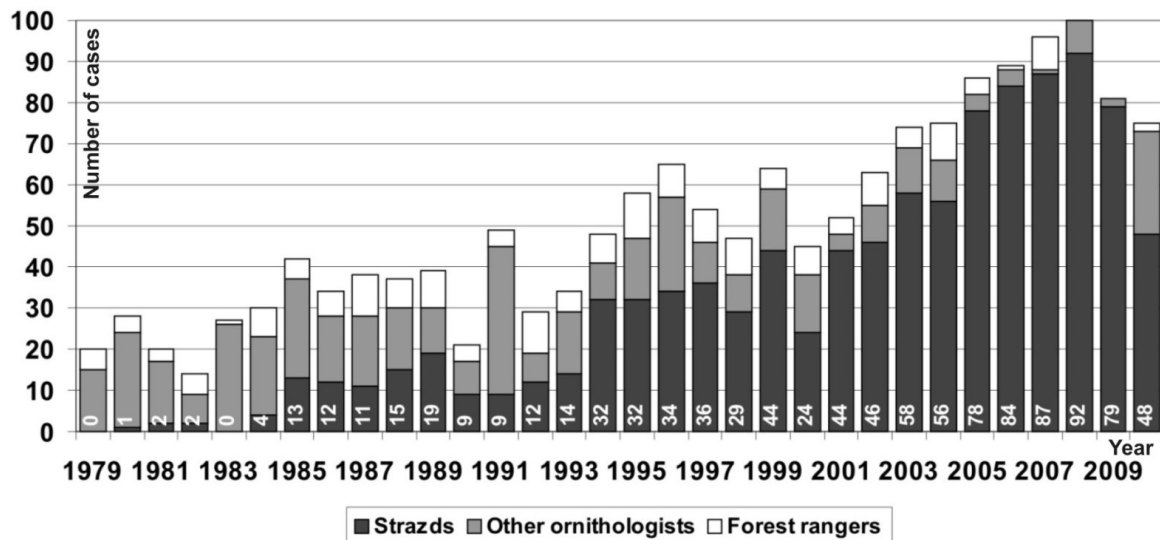


Figure 1. Nest monitoring used to analyse trends in breeding success, 1979–2010 (1,634 in all). Strazds: Cases in which the author took part in inspecting the nest and evaluating breeding success (white numbers; 1,206; 62.85%). Other ornithologists: Nests inspected by other experienced ornithologists, usually J. Lipsbergs, A. Petriņš, M. Čauns, J. Ķuze, and H. Hofmanis (427; 26.1%). Forest rangers: Data collected from foresters and individual amateur ornithologists (181; 11.1%).

Inspections of nests were usually carried out from late May until the end of July, when juvenile birds are in their nests (*Strazds et al. 2006*). Where nests were accessible, most juveniles were ring-marked both with metal and with colour rings (Table 32 in the Appendix). Along with this, the nest itself was measured on the basis of a protocol elaborated by P. Sackl and myself (Fig. 25 and 26 in the Appendix). The micro-habitat of each nest was measured only once, mostly between 1994 and 1996 (*Strazds 1997*).

Determination of the breeding season

In most cases, the start of the breeding season was calculated on the basis of the age of juveniles at the time of ring-marking. During this process, nearly all of the juveniles (833 of 843, or 98.8%; Table 28 in the Appendix) were photographed (the face and body in most cases) and measured (the length and height of the beak and the length of the longest primary). I estimated the age of juveniles on the basis of these measurements and of the overall development of their plumage. As a control marker for age estimations, I used published data about plumage development (*Heinroth & Heinroth 1927; Janssen et al. 2004*), as well as analysis of photographs from a nest photographed via Web cam in Estonia during the “Eagle-Life” project (a snapshot once every five minutes during the entire breeding season, *data received from U. Sellis*). I used the estimated age of the oldest juvenile to calculate the date when the first egg was laid, assuming that incubation requires 30–32 days (from *Janssen et al. 2004*). The adequacy of these estimates was always verified via observations that were made near the nests during the breeding season (e.g., when incubating adults have been observed in the nest). In some cases, I was aware of the

exact dates when eggs were hatched or laid. To determine the most probably date when the first egg was laid, I used the mean value between the earliest and the latest calculated laying date. The average precision of our estimate varied between 2.1 and 4.3 days. The precision of the estimate for inaccessible nests where juveniles were not measured, but were instead only photographed or had their plumage development described, was 5–10(16) days (Table 28 in the Appendix).

Locating and determining the age of nests

The location of nests was initially registered by measuring the distance between the nest and other natural landmarks (roads, compartment lines, power lines, etc.). The nests were indicated on a map with a scale of 1:10,000 (Fig. 26 in the Appendix). Beginning in 2001, nests were mapped with the use of portable GPS receivers. Most of the nests were mapped with the Garmin GPS76 receiver, which has a precision rate of 4.5 metres. Some nests have been mapped with the help of other, more precise devices. I analysed the position of various nests in the landscape with the help of digital maps. There were nesting sites which I could not place on the map because they were gone, and I transferred these onto digital maps with the use of my former measurements, with precision of 10–20 m. The mean precision of the location of analysed nests ($n = 301$) was ± 8.0 m.

I evaluated the age of each nest the first time that I inspected it. This estimate was based on the nest's dimensions, its density (newly built nests are loose), and the state of vegetation right under the nest. Additional information was based on observations of birds prior to the discovery of the nest — adults flying toward the nest with building materials, birds circling above the nest or nearby, recently fledged juveniles, etc. For older nests, I considered the withering rate of undergrowth spruce (it begins to dry out during the 2nd or 3rd year after the nest is built), and the extent to which the trunk of the nesting tree was covered with green algae (it appears no sooner than 10 years after the nest is built; *author's data*). I also considered the year when previously known nests in the same home range collapsed. The mean age of analysed nests at the time of their discovery and first inspection was 2.7 years (1–22, $n = 301$).

The lifespan of a nest encompasses the period between its erection and its final collapse, irrespective of whether the nest is occupied. Nests which are abandoned for a longer period of time and are slowly disintegrating are considered to be collapsed if less than $\frac{1}{4}$ of the initial volume of the nest is left at the site. If a nest was restored at the same place after a collapse caused by wind or snow, then the nest was counted as a new one in the same location (Table 1), while a new nest presumed to have been established by the same pair, but in a different tree, was seen as a new location in the same home range. All movements of pairs of storks from one

location to another can be analysed only on speculative terms, because in no instance has the identity of adults moving from one nest to another been known definitively (e.g., by genetic means related to feathers collected under nests or to rings).

Characteristics of the home range

Satellite maps of Latvia (*LR VZD 1998*) were our main reference tool when it came to the general surroundings of the various nests. There were individual instances in which the data could be corrected on the basis of our own observations in the field (e.g., excluding from the potential sources of disturbance abandoned homesteads which were still shown as occupied on the map (*Strazds 2006a*)). Forest cover (i.e., the rate of non-disturbance) of nest surroundings were calculated on the basis of newer and more precise topographic maps (*LGIA 2008*). Some of the evaluation of habitats (the position of the nest in the terrain and forest cover according to maps from the Jāņa Sēta company) was carried out by Agris Puriņš. Forestry operations in the surroundings of nests and areas of forest with stands of trees of different ages were analysed on the basis of the National Forest Resource database (digital maps and an adjacent database which I obtained especially for this study; current as of January 2009). Updated descriptions of forest inventory were also used to characterise the stands with nests (as of September 2010).

The size of foraging territories (home ranges)

We have not yet studied the size of home ranges in Latvia. Storks prefer to forage in an area close to their nest, although feeding flights in some cases can be very long. In Estonia, birds tracked by satellite telemetry spent most of their time foraging at a distance of 5–10 km, with the longest flights reaching 40 km (*Nellis et al. 2008*). In Latvia, the longest visually recorded feeding flight was just 7.2 km long, with the specialist remarking that “it may have actually been longer” (*Strazds et al. 1989*). In Belgium in 1998, the home range of a pair of storks which were monitored by means of telemetry encompassed around 80 km² around the nest, with the area being 12.5 km long and 6.25 km wide (*Mahieu 2001*). For survey purposes, I used the closest round value of half of the distance between simultaneously occupied nests, as discovered during the first years of black stork studies in Latvia — 3 km as a surrogate for foraging territories (*Strazds et al. 1993*). I chose to ignore the fact that actual home ranges are very different. Other studies have used the same radius when analysing the habitat of black storks (e.g., *Lõhmus et al. 2005*).

The age of nesting trees

In order to identify the age of the Scot's pine (*Pinus sylvestris*), the aspen (*Populus tremula*), the black alder (*Alnus glutinosa*), the Norway spruce (*Picea abies*), and the birch (*Betula*

pendula / *B. pubescens*), we used a 40-cm two-thread increment borer with a diameter of 5 mm (manufactured by *Suunto*). Considering different growth conditions and the fact that some trees may grow very slowly during their first years of life, we sought to obtain the best possible level of precision, repeating the boring procedure if necessary. All of the increment sticks were collected and labelled. Once they were dried, they were polished. Annual growth rings were counted with the MBS-1 binocular magnifier, with magnification of 12.5x.

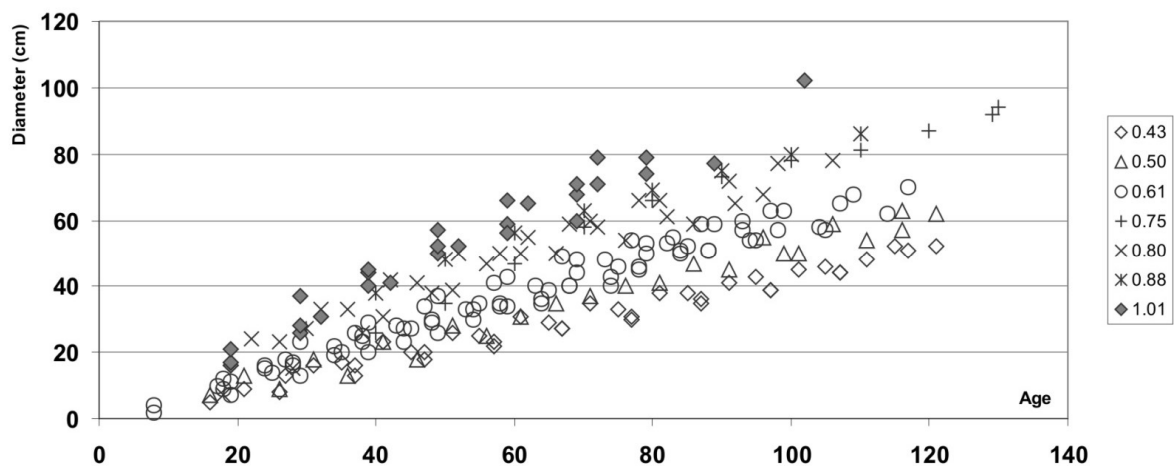


Figure 2. The growth rate of the aspen (axis X = age in years, axis Y = the diameter of the tree in centimetres). The trees are grouped in accordance with their average annual increment (cm).

When dealing with aspens with a rotted central part of the trunk, or with trees that were so thick that our borer could not reach the centre, I calculated the theoretical centre of the tree at the incremental boring height. The missing part of the increment stick was extrapolated, always making use of the fastest annual growth of that tree. From the trees from which I extracted high-quality increment data, I could construct a growth diagram for the aspen (n = 28, Fig. 2).

For various reasons, many nest aspens, have not been bored. There were many cases in which I had a series of diameter measurements which allowed me to estimate the age on the basis of the actual increment and the aforementioned diagram. If I only had a single measurement, I compared the specific tree with those measured trees that were closest to it, taking into account factors such as soil quality, the density of the stand, and the type of forest site in question. Among the alternative options, I always selected the fastest growth rate. In this sense, all of the calculated ages of the aspen must be seen as the minimal ones.

The age structure of the Scot's pine was analysed only on the basis of bored trees (n = 68). I have had too little in the way of data to estimate the age of the oak (*Quercus robur*). In order to assess the importance of the age of nesting trees properly, I used the "nest-holding age" of the tree for purposes of analysis, as opposed to the age of each individual tree. Each case of nesting

was considered as a separate unit. This means that if there was a nest which the bird occupied for 10 years in a row, that nest was listed in the data set ten separate times, adding one year to the age each year and starting with the first year of use (Table 1).

Visibility of nests from the air

To assess the visibility of stork nests from the air, I calculated a “visibility range” — the possible area (L, Fig. 3) from which the nest can be spotted from a certain height.

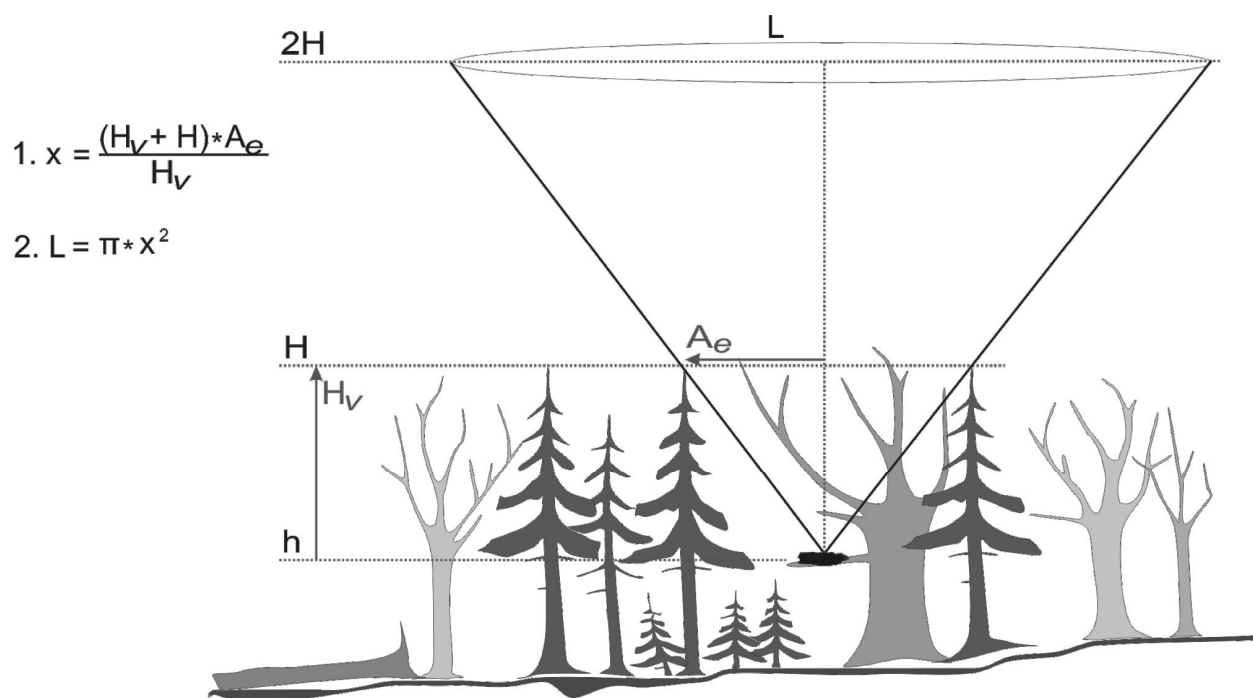


Figure 3. The calculation of nest visibility.

To obtain this value, I used measurements from the micro-habitat evaluation protocol — the distance from the nest to the top of the canopies of the surrounding stand (H_v), the mean distance to the surrounding spruces (A_e), and the canopy closure rate between the nesting tree and the surrounding trees. The visibility range (L) has been calculated on the basis of the formulas that are presented in Figure 3, and then reduced respectively to the canopy closure rate (%) of the nesting tree, assuming that in those sectors where the canopy of the nesting tree is touching those of neighbouring trees, the nest is not visible. In sectors where there are openings, the nest is assumed to be visible. If, for instance, canopy closure is 75%, then the visibility range is 25% of the initial value of L. I used the double height of trees for this calculation (2H), because the differences among various stands of trees that were compared was insignificant. If comparable stands are of a very different height, however, it is better to use the fixed height above the treetops (e.g., 20 m). The obtained value is a surrogate for nest visibility, but it also encompasses three

important properties which characterise the visibility — the distance to the surrounding canopy tops, the coverage of the nest by surrounding trees, and the canopy closure of the nesting tree.

Reasons for the abandonment of nests

I have analysed reasons for the abandonment of 301 nests in 257 locations, using only those nests which have had three or more valid controls, i.e., nests which were checked during the last year when they were occupied, the preceding year, and the year after abandonment. I also included in my analysis nests which were abandoned after the first year of occupancy — nests which collapsed or were abandoned during the first season or the subsequent autumn/winter. I used these nests if I had two controls — during the year when the nest was built and the next year. Reasons for nest abandonment were divided up into two groups — definitive (i.e., the nest has collapsed or access to it is completely blocked for an approaching bird, which means that the bird has no alternative other to move elsewhere) and probable. Among probable reasons for nest abandonment I listed forestry operations, predation, a lack of partners, etc. This referred to any situation which differed from the “normal, undisturbed state.” When more than one possible factor was registered (e.g., forestry operations have been carried out and observations have suggested the presence of only one bird), the situation was treated as unknown.

The impact of forestry operations

A special study was conducted in 2003–2005 to assess the impact of forestry on the breeding success of the black stork. The stock company Latvian State Forests (LVM) provided us with all of the necessary information about forestry operations within a 3 km radius around all of the nests that were part of the study. For data processing, I added information about when the forestry operation occurred (the date of the contract), the company that was doing the work, the agreed area of operations, and the extracted volume of timber. I entered these data into our forest compartment database, which included some 11,000 compartments in all (Table 2). I also analysed forestry operations in privately owned forests within the same radius from nests. The information about private forests was received from the regional units of the State Forest Service (*Strazds 2006a*).

Many different forestry operations can affect the breeding of the black stork – different types of cuttings, early thinning, and planting of forests. The exact area of cutting may become known only after the next forest inventory, because only a part of the relevant compartment, as opposed to the full area, may be logged. This means that digital maps are almost always out of date and do not represent real areas of operations. The most reliable information about final cuttings is the harvested volume of timber, which was always recorded in the documentation which I received.

Early thinning and forest planting have no such measurable “output,” and data about these operations are based on the number of thinned or planted hectares. Also important is the transportation of timber, although that, too, cannot be expressed in area measurements. In order to make all of the activities “equal,” I transformed either of the available references into disturbance days. The actual amount of time needed for each operation was determined on the basis of interviews with forest company managers, field managers, and experts from the State Forest Service. The values used for the analyses (in most cases referring to the mean value of all data) are presented in Table 36 in the Appendix.

Table 2. Forestry operations in the vicinity of black stork nests in the state-owned forests of Latvia

MS †	Total forest area	Forestry operations except planting		Area affected by hurricane in January 2005		Logged in VIII–II	Logged in III–IV	Logged in V–VII	Early thinnings	Forest planting
	ha (cp.)	ha (cp.)	%	ha (cp.)	%	m ³ (cp.)	m ³ (cp.)	m ³ (cp.)	ha (cp.)	ha (cp.)
AV	5505.95 (2680)	948.9 (440)	17.2 16.4	332.97 (130)	6.0 4.9	13301.9 (81)	12644.7 (70)	3889.07 (43)	416.41 (199)	45.59 (30)
DK	31833.52 (15758)	7989.27 (3739)	25.1 23.7	5399.26 (2493)	17.0 15.8	136042.5 (1437)	49494.03 (738)	51250.99 (758)	1339.81 (697)	431.17 (277)
DL	26199.54 (12693)	3553.84 (1739)	13.6 13.7	850.09 (331)	3.2 2.6	82488.01 (419)	24565.61 (184)	16301.69 (129)	1538.01 (813)	222.1 (152)
RV	6482.91 (3519)	1180.47 (559)	18.2 15.9	320.28 (151)	4.9 4.3	22432.74 (117)	8426.87 (120)	6409.48 (67)	310.38 (137)	49.52 (30)
VD	17132.69 (10043)	2222.3 (1229)	13.0 12.2	906.33 (445)	5.3 4.4	45917.0 (294)	39391.1 (333)	14317.6 (171)	593.46 (350)	98.31 (63)
Z	14774.18 (7621)	3464.96 (1486)	23.5 19.5	2097.56 (895)	14.2 11.7	71477.18 (588)	18306.41 (228)	34593.93 (291)	706.0 (328)	100.67 (56)
ZK ‡	20173.7 (13395)	2649.09 (1542)	13.1 11.5	1232.71 (718)	6.1 5.4	19947.2 (330)	4107.87 (250)	13103.0 (219)	624.66 (372)	186.73 (119)
ZL	14539.76 (6937)	2408.93 (1135)	16.6 16.4	432.95 (181)	3.0 2.6	55507.0 (276)	15029.26 (111)	16198.06 (111)	956.78 (460)	182.8 (110)
Σ	136642.3 (72646)	24417.76 (11869)	17.9 16.3	11571.85 (5344)	8.5 7.4	447113.5 (3542)	171965.8 (2034)	156063.8 (1789)	6485.51 (3356)	1316.89 (837)

† MS = Management districts of LVM: AV — Eastern Vidzeme, DK — Southern Kurzeme, DL — Southern Latgale, RV — Western Vidzeme, VD — Central Daugava, Z — Zemgale, ZK — Northern Kurzeme, ZL — Northern Latgale. Figures in brackets show the number of compartments (cp.) present (in the 2nd column) or processed (in all other columns).

‡ Due to ongoing forest inventory in the Northern Kurzeme forest district, I could analyse all operations only in 2005 (*Strazds 2006a*).

Because of the sensitivity of the black stork against disturbances during the early stages of the breeding season (*Janssen et al. 2004; Strazds 2005*) and of the high level of forestry operations during the relevant period of time (Table 2), I conducted detailed analysis of the impact, particularly during the first two months of the breeding season. I took into account calculated actual start of the breeding season (see Page 17), regional differences, as well as the arrival of adult birds at nesting sites at least 10–12 days prior to the laying date of the first egg. I defined

the beginning of the critical period in 2004 and 2005 to be between March 25 and April 5. There were nests at which the individual season began much later, and the respective deviation was always considered. Taking into account the amount of time that is needed to process timber and then to transport it, I analysed forestry operations (cutting) as being potentially disturbing if the process began around March 11 and/or the contract for the work was signed on March 1 or later. I considered hatching of eggs to represent the end of the sensitive period. In Latvia, this occurs around the end of May or, if this is “transformed” into the date of issuance of a cutting license — on April 30 (*Strazds 2006a*).

All of the nests with known breeding success were included in the study initially. Next I excluded from this list those nests with respect to which information about breeding success was contradictory or uncertain. I also excluded those nests which may have been a “reserve/past” nest of a pair included in the study. Because my primary aim was to determine the impact of forestry operations, I excluded all of the nests that were in large protected territories (the Ķemeri and Slītere National Parks, the Krustkalni Nature Reserve). These are areas in which no forestry activities at all are permitted.

I analysed all documented operations taking place in any compartment closer than 1 km from the nest. The compartment was listed if only one metre of the corner of the compartment that was closest to the nest was closer than 1 km. I pooled adjacent operations if they had the same operator, if they had the same contract date (or a difference in contract dates of no more than five days), or if they were located in the same direction from the nest. For purposes of simplicity in terminology, planting and thinning sites were also called “cutting units.” For each cutting unit, I measured the closest and the average distance to the nest, and I also calculated the number of disturbance days (Table 3).

Table 3. Variables used in the analysis

Variable	Description
Minimal distance	Minimal distance to the closest corner of a “cutting unit”
Mean minimal distance	Mean value of all minimal distances if more than one cutting unit was
Mean distance	Distance to the geographic center of the cutting unit
Disturbance days abs	Actual number of disturbance days for all cutting units
Disturbance days rel	Value of disturbance days weighted against distance to the nest
Year†	Year of operation

† I did not use meteorological information, because it was not available in adequate form free of charge, and the costs related to the purchase of the relevant information exceeded the budget of this study.

Because many of the analysed compartments were located on or beyond the one-kilometre line, the mean distance often did exceed 1,000 m. I processed more than 450 cutting units, but I

did not calculate the average number of compartments in each of them. The number varied from one unit to dozens of units, particularly in 2005, when sanitary cutting operations after a storm covered tens or even hundreds of hectares in succession. Next I made sure that I had all of the important information about the selected cutting units. I excluded those nesting attempts for which essential information was missing even for a single cutting unit — the date of the operation (these data were missing for most operations in 2003), the machinery that was used, or the precise distance to the nest (for many cutting units in privately owned forests). Once this procedure was completed, there were 94 valid cases which remained — 60 successful, and 34 unsuccessful. Breeding was considered to be successful if the juveniles were hatched. This also included a few cases when juveniles hatched later in the summer were predated by the pine marten (*Strazds 2006a*).

I conducted separate analysis to see whether clear cutting within a one-kilometre radius around nests that was conducted between 2000 and 2009 had any impact on the parameters of reproductive success in the nests — the number of juveniles per successful and occupied nest, the number of fledged juveniles, changes in the failure rate of breeding, and the number of successful breeding cases within this timeframe (Table 4). I considered 151 nests with respect to which I had breeding success data for at least six of the 10 years that were studied.

Table 4. Variables used in the cler-cut impact analysis

Variable	Description
X1kmF010	Logged area in a 1 km circle around the nests over the course of 10 years, 1990–1999
Pull_sum	The total number of fledged juveniles
Succ_N	The number of years with successful breeding
P_succ	The average number of juveniles per successful nest
Pull_year	The average number of juveniles per occupied nest
Succ_loss	The difference between the previous two parameters
KnownS	Years with known breeding success

We registered all signs of past or ongoing forestry operations in the vicinity of nests (closer than 1 km) during each nest inspection — the appearance of new clear cut areas, ongoing or completed building or restoration of roads, the fresh tracks of forest tractors, etc. The time of the operations which were not occurring during the inspection itself was estimated with the precision of one month. Of 86 nests, 61 yielded complete data about the variables of disturbance, type, season and distance (Table 5). To assess the likelihood of nest abandonment after forestry operations, I compared 57 nests for which I had complete information about breeding success during the year of the disturbance and the year before that.

Table 5. Variables used in the nest abandonment analysis

Variable	Description
Disturbance = 4	Variable indicating breeding success. Only those nests with successfully fledged juveniles were considered to be successful
Disturbance = 0.1	Variable indicating nest abandonment
Type	Type of disturbance occurring near the nest. The original seven categories were merged into five. One case of restoration of a drainage system was combined with the cases of road building, and planting of forest was combined with early thinnings
CB	Road building and/or renovation
MEL	Restoration of a drainage system
CL	Transportation of timber along the road or compartment line
JS	Planting of forest
JK	Early thinning of plantations
KC	Clear cutting
SC	Other types of cutting
Season	Variables describing season of disturbance
Winter	Disturbance during the period between December and March
April	Disturbance during April
Other	Disturbance during the other seasons also including cases when the actual season is unknown, described as “summer” (April–June)
MinDist	The minimal distance between the disturbance and the nest

Study of contamination level

Colleagues in Hungary (*Tamás & Kalosca 2008*) warned us that there might be DDT in the failed eggs of the black stork. Beginning in 2008, on the basis of this warning, we began to devote particular attention to crushed eggs or failed eggs in nests (*Strazds & Grīnblate 2009*). In 2008, we found at least 32 failed eggs (14.7% of laid eggs; *Strazds 2008*). We conducted special monitoring of nests during the spring of 2009 to determine the actual rate of egg loss. Because of the sensitivity of storks to early disturbances, we did wait until the end of the incubation period, and we examined ten nests between May 19 and 21. According to the method described by Helander, et al. (*2002*), we measured eggs using the Pesola spring scale (to the closest gram), and we measured the dimensions of eggs with a Protecto electronic calliper (to the nearest 0.01 mm). We selected the nests on the basis of information about their age, their success in previous seasons, and their distance from Rīga. In mid-June, when juveniles were about three weeks old, we conducted another inspection of the nests. We ring-marked and measured the juveniles and collected addled eggs from nests, as well as crushed eggshells from under the nests. We put the collected eggs into refrigeration as quickly as possible, but we did not freeze them.

In total during 2006–2009, we found 33 failed black stork eggs in Latvia. In 2009, working with colleagues from Germany, the Czech Republic, Poland, Belgium and Estonia, we collected another 19 addled eggs outside of Latvia (Table 6). We tested all of these eggs for the presence

of DDT and its metabolites. We used gas chromatography and mass spectrometry methods (*Grinblate 2010*)¹¹ for this purpose.

Table 6. Data used to analyse DDT contamination, 2006-2009 (from *Grinblate 2010*)

Country	Year	Analysed eggs			Chemical analyses	Dead juveniles
		I†	II†	Total		
Latvia	2006	2	-	2	2	-
	2007	2	-	2	2	-
	2008	11	-	11	11	-
	2009	18	2	20	15	4
Total		33	2	35	30	4
Estonia	2009	1	-	1	1	-
Poland	2009	2	-	2	2	-
Germany	2009	8	-	8	8	-
Belgium	2009	2	-	2	2	-
Czech Rep.	2009	6	4	10	6	-
Total		19	4	23	19	-
Grand total		52	6	58	49	4

† I — with or without an embryo which was smaller than half of a normally developed embryo; II — with or without an embryo which was half-grown or larger.

In order to measure the thickness of eggshells, we measured eggs in the collections of museums in Minsk (Belarus), Tartu (Estonia), Stuttgart, Bonn and Dresden (Germany), Tring (UK), Stockholm (Sweden), and Rīga (Latvia). We collected data about egg sizes (n = 324), the thickness of eggshells (n = 212), and the weight of eggshells (n = 303). We used the Ratcliffe Index (*Ratcliffe 1970*) and egg volume (*Grinblate 2010*) to analyse the relationship between the size of an egg and the weight of its eggshell.

Statistical processing of data

Most of the statistical analysis of my data was conducted with SPSS 17.0 software, and I used Arcview 9.1 software to analyse geographic data. To evaluate factors which affect the lifespan of nests we used GLM Univariate Analysis.

We used multivariate analysis of variance (MANOVA, *Krzanowski 1998*) to determine whether clear cuts in a one-kilometre radius around each nest (explanatory variable X1kmF010) affected the breeding success parameters of the nests that we analysed. The explanatory variable X1kmF010 (area) was square-root transformed to obtain a measurement on a linear scale. Then the variable was classified into six classes in order to obtain a factor that could be used as a predictor in a MANOVA. There were six dependent variables which described various breeding

¹¹ Santa Grinblate wrote her master's thesis on the presence and possible impact of DDT on black storks as a part of this study. The author of this dissertation suggested this subject to Ms Grinblate and served as her academic advisor when she was doing the work.

success parameters (Table 5), with the classified X1kmF010 variable used as an explanatory variable. The model was fitted on the basis of the `manova()` function in the R 2.11.1 version of the software (*R Development Core Team 2010*).

The variables related to visibility (area) and distances for the forestry disturbance analysis (the variable MinDist) for the purposes of analysis were log-transformed. The differences in visibility among different species of nesting trees were analysed on the basis of analysis variance (ANOVA), with the log of the visibility as dependent, and the species of tree as predictor.

To analyse the influence of a forestry-related disturbance on nesting success and the probability of nest abandonment during the year before the forestry process and during the year when it took place, we used a paired design, fitting a generalised linear mixed model with binomial error distribution, a logit link function, and the nest as a random effect. To analyse the influence of the type of disturbance, the distance and the season on the probability of nesting success or abandonment at those nests which were disturbed by forestry work, we made use of two separate logistic regressions. Because of imbalanced data and small sample sizes, we did not test interactions, and no selection of models was performed. The quadratic effect of the log of MinDist, however, was tested and omitted if it was not significant. The terms in the model were tested with a likelihood ratio test. The influence of the season on success could not be tested with the logistic regression, because there were no successful nests in April. Therefore, a Fisher's exact test was used to test whether the proportion of success differed among the various seasons. All of these analyses were conducted with the statistical software R 2.11.1 (*R Development Core Team 2010*).

Breeding success trends (number of laid eggs, number of hatched juveniles, date of the first egg) were calculated with the help of Trim 3.54 software.¹² Various parameters of eggs were analysed with the help of the MS Excel and R software (*Grünblate 2010*).

¹² TRend analysis and Indices for Monitoring data, Statistics Netherlands.

Results

Breeding success

The results of annual nest inspections (Table 33 in the Appendix) show that the breeding success of the black stork has declined since 1978. The indexes of laid eggs and fledged juveniles both show moderately negative, but significant trends ($p < 0.01$; Fig. 4). The number of recently abandoned nests is growing (Table 34 in the Appendix) The difference between the number of laid eggs and the number of fledged birds has also increased.

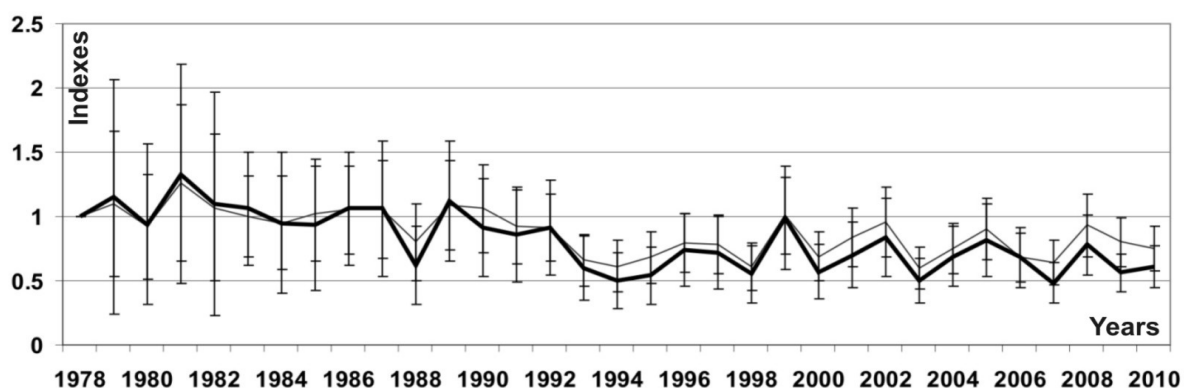


Figure 4. Index of laid eggs (bold line; axis Y) and fledged juveniles (thin line; axis Y) since 1978 (axis X). The black whiskers show the standard errors of the indexes.

Habitat

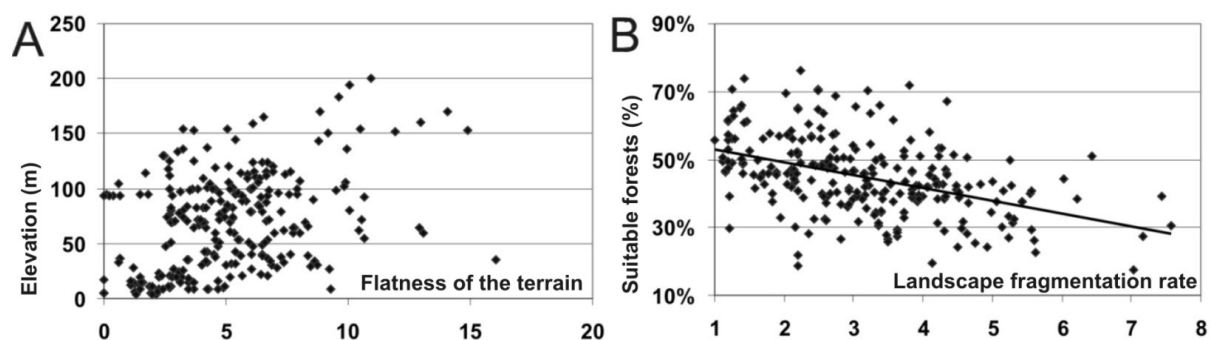


Figure 5. General characteristics of the black stork habitat — nest elevation (axis Y in A) and flatness index (Table 1; Axis X in A) and the share of forests older than 80 years (Axis Y in B), as dependent on the landscape fragmentation index (Table 1; axis X in B; the bold line refers to the trend).

In Latvia, black stork nests have been found in large forest tracts, but also in patchy mosaic forests where there is a large number of permanent potential sources of disturbance in the vicinity (single farms, etc.). In such cases, storks tend to choose the least-disturbed locality. The number of single farms within a 1 km radius around nests is, on average, just 1.1. Moreover, 72 of the 125 nests which were analysed were in places where there were no potential sources of

disturbance in a 1 km range (Table 35 in the Appendix). Forest cover nearby the nest is significantly higher than in the overall vicinity of the nest — 82%, on average (*Strazds 2006a*).

Most nests are located on flat or fairly inexpressive terrain in areas where there is a larger share of old forests and a denser network of waterways. None of the 301 analysed nests was higher than 200 m above sea level (Fig. 5 and 6, Table 7 and 8).

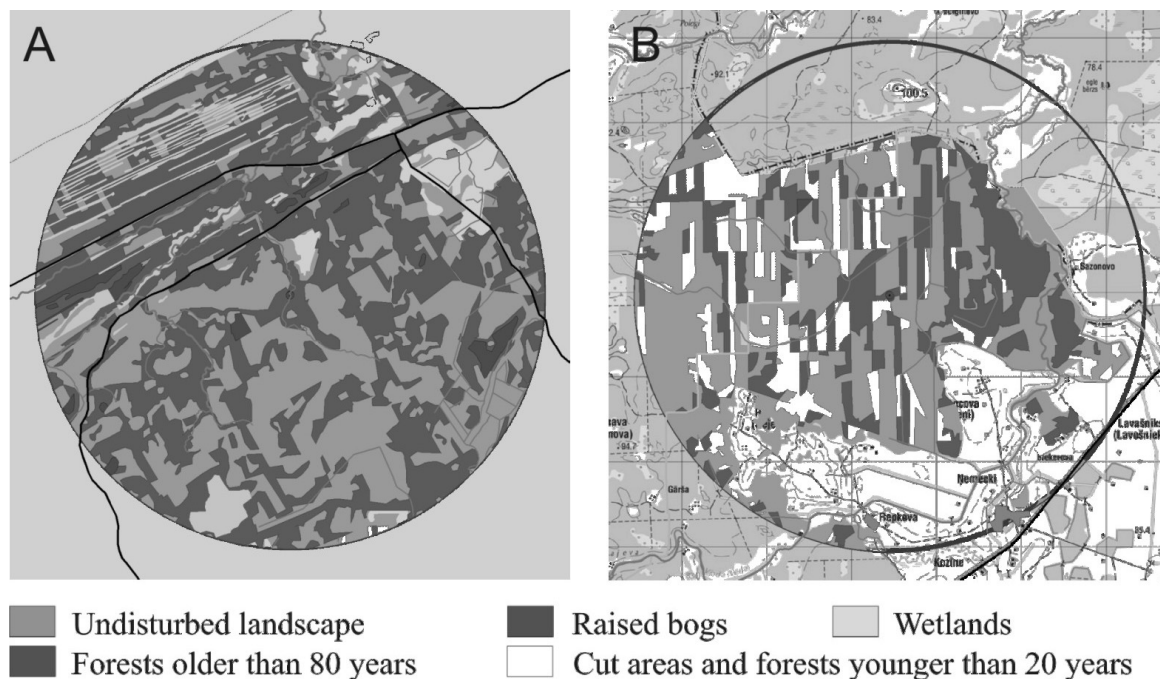


Figure 6. Examples of habitat analysis without (A) and with (B) a topographic map in the background. Black lines represent major roads, while gray lines refer to rivers and ditches. Territories outside of the national boundaries of Latvia (B) have not been analysed in terms of forest age and intensity.

Table 7. The primary characters of the black stork habitat

	Parameter	Avg.	Med.	Moda	SD	Variance	Min.	Max.	N	95%
1	Flatness index	5	4.7	0	2.9	8.2	0	16.1	257	0.4
2	Fragmentation index	3.2	3	1.2	1.3	1.7	1	7.6	257	0.2
3	Elevation (m)	68.8	69	9	44.1	1945.3	4	200	257	5.4
4	Undisturbed landscape	70.0%	71.8%	99.2%	19.2%	3.7%	23.1%	100.0%	257	2.4%
5	Raised bogs (%)	3.5%	0.1%	0.0%	7.2%	0.5%	0.0%	48.8%	257	0.9%
6	Forests‡ (%)	66.1%	66.8%		18.9%	3.6%	20.1%	99.3%	257	2.3%
7	Forest 60y+† (% of 6)	44.9%	44.4%		11.2%	1.3%	17.5%	76.3%	257	1.4%
8	Wetlands†† (%)	1.1%	0.5%	0.0%	1.9%	0.0%	0.0%	16.8%	257	0.2%
9	Ditches in forest (km)	54.479	46.183	111.025	30.566	934284.906	5.445	181.17	257	3.755
10	Rivers within 3 km	9.992	9.137	15.548	5.536	30643.846	0.551	30.371	173	0.831
11	Rivers within 10 km	55.716	54.165	80.922	26.621	708655.87	3.505	128.164	257	3.27
12	Logged % (of 7)	31.2%	30.6%		13.8%	1.9%	0.2%	65.0%	257	1.7%
13	Logged in 10y 1km (ha)	18.2	17.2	0	12.3	1523756.7	0	77.2	257	1.5

† Twenty years ago, consisting of forests which are suitable for stork nesting now (80y+), as well as those forests which, during the past 20 years, have been logged (now they are 0 to 19 years old, but would have been suitable for storks if they had not been logged).

‡ The percentage of forest cover is stated on the basis of maps from the Jāņa Sēta map company, while the proportion of other habitats, the proportion of old forest (row 7), and the impact of forestry operations (rows 12 and 13) are stated on the basis of digital maps from the State Forest Service. The information in

rows 7 and 12 is incomplete because of the unavailability of some information from privately owned forests. The stated data show the minimal values. At the same time, however, the ratio between these two values (%) is correct, because I compared only those properties for which complete data were available.

†‡ Fens, transitional bogs, wet forest meadows and beaver ponds, as registered in the national forest database; these habitats are considered to be suitable for black stork foraging (*Strazds 1993c*), as opposed to a raised bog, which is a harmless (i.e., disturbance-free), but completely useless landscape.

Table 8. Correlation† between various habitat characteristics

Parameters	Flatness index	Density of ditches	Fragmentation	Forest 60y+
Flatness index	1			
Density of ditches	-0.441***‡	1		
Fragmentation index	0.466***	-0.271***	1	
Forest 60y+	-0.263***	0.088	-0.445***	1

† We used the Spearman Rank Correlation (r_s) for density of ditches because it does not comply with the normal distribution (Kolmogorov-Smirnov test, $p = 0.001$). Pearson's Correlation Coefficient (r) was used for other parameters (*Zar 1984*).

‡ The number of asterisks indicates the level of significance: *** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$

Most nests are in mixed-type forests with at least three or four different species of trees in the stand. In the nearby surroundings, spruce trees (both at the first and the second level) dominate in terms of nesting sites. (Table 9).

Table 9. Microhabitat of black stork nests (with changes from *Strazds 1998b*)

Parameter	Average	Median	Moda	SD	Variance	Min.	Max.	N	95%
Nest height above gr.	13	13	14	3.7	14	4.9	23.4	104	0.7
Space over the nest	3.4	2.5	2	3	8.9	0.9	15	85	0.6
Dist. from the trunk	0.5	0	0	1	0.9	0	4	104	0.2
Tree height	25.9	26.6	27	5	24.9	9	36	104	1
Height of the stand†	22.1	22	21.6	4.7	21.7	8.3	42.9	104	0.9
Tree diameter (cm)	69.4	65	53	25.7	659.9	28	166	104	5
Avg. diam. of stand	29.3	29.4	29.6	6.8	45.8	7.7	49.6	104	1.3
Distance to the	3.2	3.6	8.3	3.5	12.5	-7	9.5	104	0.7
Dist. to tree-tops	9.1	8.5	10.1	3.4	11.8	2.7	24.9	104	0.7
Height of the canopy	12.9	12.5	7.4	3	8.8	5.7	29.1	104	0.6
Canopy closure	46.5%	49.0%	0.0%	22.4%	5.0%	0.0%	85.8%	98	4.5%
Number of tree	3.5	3.5	4	1	1	2	6	104	0.2
Unevenness†‡	1.9	1.7	1.3	1.1	1.3	0.1	7	104	0.2
Trees per 100 m ²	4.1	3.9	4	2.1	4.3	0	13.3	104	0.4
Share of spruces (E)	44.5%	43.8%	31.3%	24.6%	6.1%	0.0%	93.8%	104	4.8%
Unevenness of E	1.92	1.70	1.27	1.14	1.30	0.13	6.98	104	0.22
Distance of E	7.3	7.1	7.8	2.3	5.5	4	19.5	97	0.5
Slope of terrain	1.5	0	0	3.8	14.5	0	22	103	0.7

† In this table, a stand is defined as the 15 trees that are closest to the nesting tree and exceed the level of the nest in accordance with the microhabitat description protocol (Fig. 25 and 26 in the Appendix).

‡ The distance to the canopy represents the distance between the nest and the lower edge of the tree's canopy (where this value is negative, the nest is positioned at the respective distance under the canopy).

The distance to tree-tops shows the distance between the nest and the top of the tallest of the 15 surrounding trees.

†‡ To characterise the unevenness of the distribution of trees, I used the variance of trees grouped in eight sectors around the nest (N-NE-E-SE-S-SW-W-NW), using a compass for this purpose.

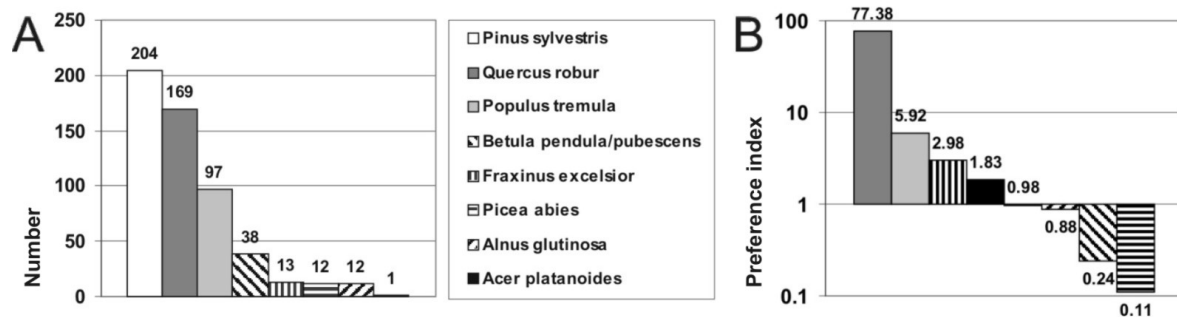


Figure 7 A: The distribution of black stork nests in various species of trees (n = 546). B: The tree selection preference index.

Characteristics of nest trees and nesting stands

Black storks can build their nests in many species of trees, but they strongly prefer the oak when it is available. In Latvia, approximately 30% of black stork nests are in oaks (Fig. 7A), but the oak is the dominant tree species in only 0.4% of stands (*Saliņš 2002*). The preference index for the oak, therefore, is 74 (i.e., oaks are chosen 74 times more often than they are present in the forest). For the next most commonly used species of tree – the Scot’s pine – the indicator is below 1 (Fig. 7B). Most nests in Latvia are built in pines, oaks and aspens (Figs. 7, 8).

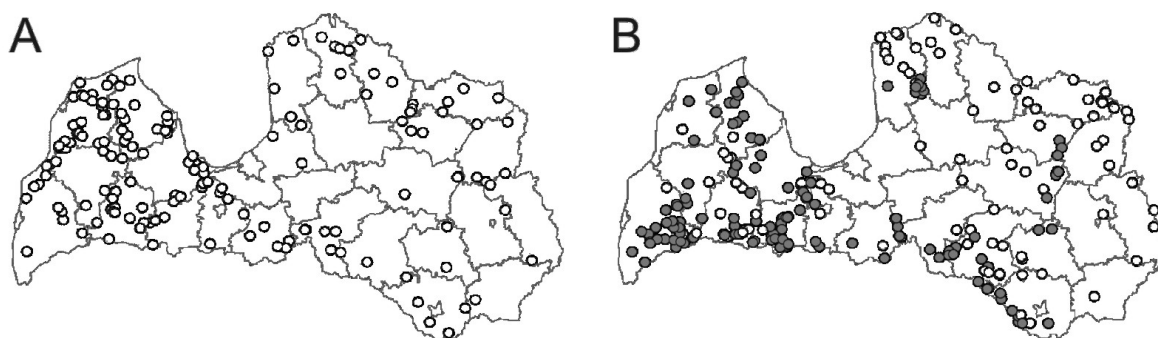


Figure 8. The geographic distribution of nests among the most frequently used species of trees. Nests in Scot’s pines (A) are distributed relatively equally, while nests in the two other species are not. Aspens (B, hollow dots) are largely replacing oaks (B, gray dots).

The importance of very old (previous generation) trees for nest building has been stressed in earlier studies (*Strazds 1998b*), and the presence or absence of such trees is considered to be a very important indicator of the suitability of the stand (*Strazds 2005*). These statements, however, with reference to the age of stands have been based on data obtained from forest taxation. These are carried out to assess the availability of timber resources for the forest industry, and they are conducted once per decade. I examined the adequacy of these data by testing 257 stands with stork nesting trees. Almost one-third of them were not listed in the taxation data at all. These could be previous generation trees or be found in small patches apart from the main stand — ones which have not been described as a separate compartment. The most frequently absent tree was the oak, and the number of missing aspens was also large (Table 10).

Table 10. The presence of nesting trees in taxation data

	Present	Absent	„Absent” ratio	Total
Scot’s pine	77	8	9.4%	85
Oak	38	43	53.1%	81
Aspen	41	16	28.1%	57
Birch	14	2	12.5%	16
Black alder	7			7
Norway spruce	5			5
Ash	4	2	33.3%	6
All species	186	71	27.6%	257

In general terms, however, the taxation data are of a very poor level of quality. If we compare the age of the tree at first nesting of aspens and pines only in terms of those nesting trees which are mentioned in taxation data (n = 64), then we find that the absolute value of the error in the age estimate is 24.6 years for the aspen and 70.5 years for the pine (Table 11 and Fig. 9).

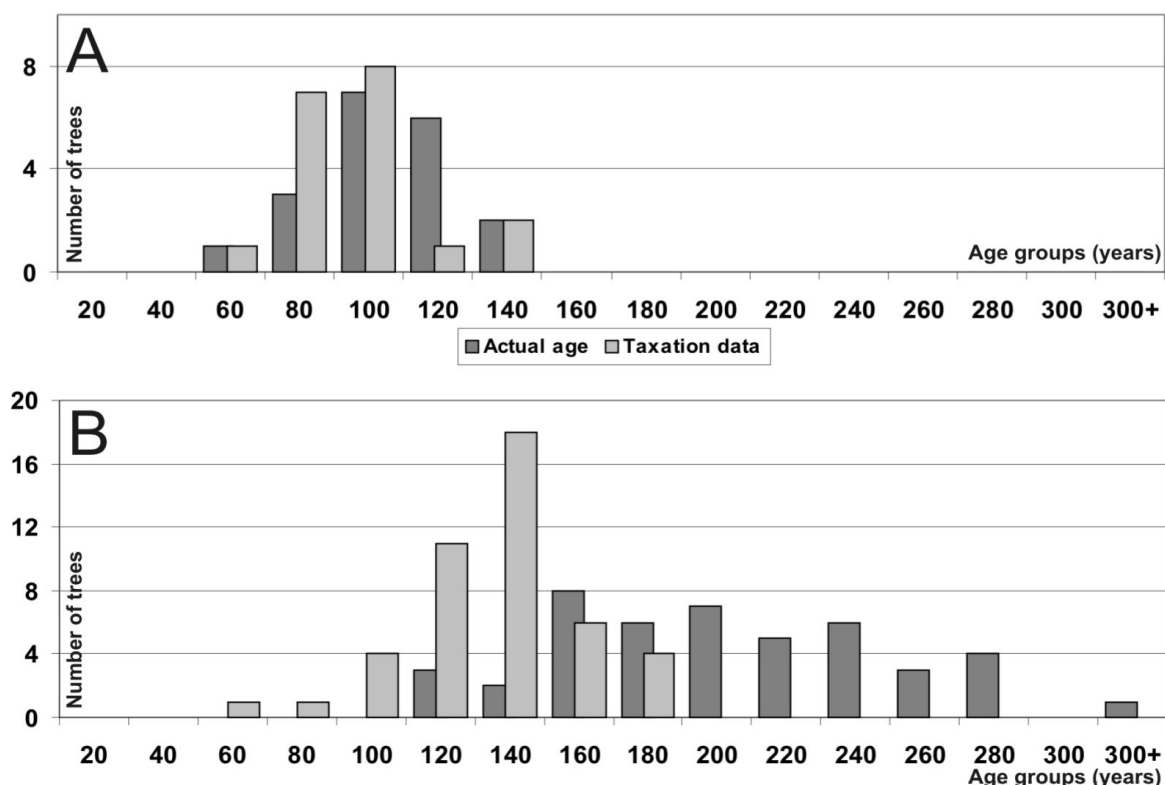


Figure 9. A comparison of the age given in taxation data and the actual age (from measurements) of aspens (A) and pines (B) at first nesting.

Table 11. The precision level in comparing age estimates for aspens and pines

Species	N	Taxation	Actual	Error	Abs. error	Error %	Adequate ¹³	Precision
Aspen	19	87.4	95.4	7.9	24.6	28.6%	2	10.5%
Pine	45	125.3	194	68.8	70.5	60.9%	7†	15.6%
Total	64						9	14.1%

† Two of these pines were in the same stand, so only 8 of 63 stands (12.7%) have been evaluated correctly.

¹³ Age estimates in forest taxation are considered acceptable if they do not exceed ± 10 years for stands between 41 and 100 years, or ± 20 years for stands older than 100 years (Štubis et al. 1990).

These data emphasise the fact that the use of taxation data for purposes of analysis must be based on very significant caution. Additionally, there is no correlation between the actual age and the taxation estimate of the aspen (T-test, $r = 0.042$, $p = 0.865$; $n = 19$). The estimated age of the pine trees was significantly lower than the actual age ($t = -8,959$, $p < 0.001$). The point here is that forestry activities are based exclusively on the taxation data, which means that it is logical to consider this information from this particular point of view (Table 12).

Table 12. The age of dominant tree species in stands according to taxation data

Species†	Average	Median	Moda	SD	Variance	Min.	Max.	N	95%
A-A	90.2	90	88	7.02	49.24	68	103	35	2.41
A-E	92	92.5		2.16	4.67	89	94	4	3.44
A-Oz	70.4	73	68	18.05	325.94	31	97	56	4.83
B-A	88.5	88	92	8.46	71.51	67	109	84	1.84
B-B	88.7	91	93	9.43	89.01	64	105	47	2.77
B-E	79.8	82		6.14	37.7	69	84	5	7.62
B-M	72	58		20.55	422.5	56	95	5	25.52
B-Os	83.2	80	84	8.18	66.97	73	98	23	3.54
B-Oz	74.8	75	96	26.14	683.14	4	121	176	3.89
B-P	80.8	81	76	9.29	86.25	59	105	73	2.17
E-A	97	102	117	19.06	363.2	56	127	41	6.02
E-B	101.3	101		3.39	11.5	96	106	9	2.61
E-E	141	140		8.45	71.33	132	158	7	7.81
E-M	154	154		1.83	3.33	152	156	4	2.91
E-Os	114.8	120		10.92	119.14	99	128	13	6.6
E-Oz	84.5	89	91	22.27	496.15	17	119	119	4.04
E-P	98.1	91	91	30.02	901.43	58	177	80	6.68
M-A	93.8	93		2.59	6.7	91	97	5	3.21
M-M	79.8	85.5	85	12.48	155.83	60	95	18	6.21
M-Oz	67.6	67		21.2	449.26	43	100	15	11.74
M-P	91.7	93		9.27	85.86	77	105	23	4.01
Os-Oz	70.8	65.5	61	18.26	333.26	48	114	54	4.98
Oz-Oz	122.8	144	146	58.21	3388.09	22	187	34	20.31
P-A	114.3	111	110	16.62	276.07	88	145	87	3.54
P-B	108.1	106.5	115	29.21	853.37	67	155	38	9.6
P-E	144.6	140		13.6	184.95	136	175	7	12.58
P-M	98.7	99		3.28	10.75	93	103	9	2.52
P-P	124.2	128	140	28.47	810.37	50	191	407	2.77
P-Oz	87.5	84.5	81	21.09	444.83	55	122	36	7.14

† The first letter indicates the dominant tree species in the stand, while the second one indicates the nest tree. A = aspen (*Populus tremula*), B = birch (*Betula sp.*), E = Norway spruce (*Picea abies*), M = black alder (*Alnus glutinosa*), OS = ash (*Fraxinus excelsior*), Oz = oak (*Quercus robur*), P = Scot's pine (*Pinus sylvestris*). Each nesting attempt is considered separately.

The discovery that the taxation data are not an adequate source for proper age estimates means that we must assess previously published information about stand ages (*Strazds 1993d, Strazds et al. 1995*) with caution. The consequence to this is that we must differentiate between proper age measurements and those that are based on taxation descriptions (Table 13).

Table 13. The nest-holding age in different species of trees

Species	Average	Median	Moda	SD	Variance	Min.	Max.	N	95%
Pine	205.7	193	177	70.31	4943.14	81	430	455	6.48
Oak	169.3	171.5		15.13	228.84	135	190	30	5.65
Oak Tax†	165.9	154	93	73.3	5373.07	65	358	311	8.18
Aspen	100.1	99	93	14.07	198.03	70	135	252	1.75
Birch	92.9	97	100	10.83	117.25	72	111	44	3.29
Ash Tax	94.9	98		24.35	592.87	50	128	27	9.63
Bl.Alder‡	119.8	111.5	95	28.14	792.08	85	159	26	11.37
Spruce	157.4	141		31.9	1017.38	119	210	17	16.4

† ‡ Because I know the exact age of only three oaks (one of which was used for 26 years), I have presented the nest-holding age for these trees separately from all other oaks. For the black alder, some of the trees have been measured, while others have been simply estimated, but the differences between these groups were not statistically significant.

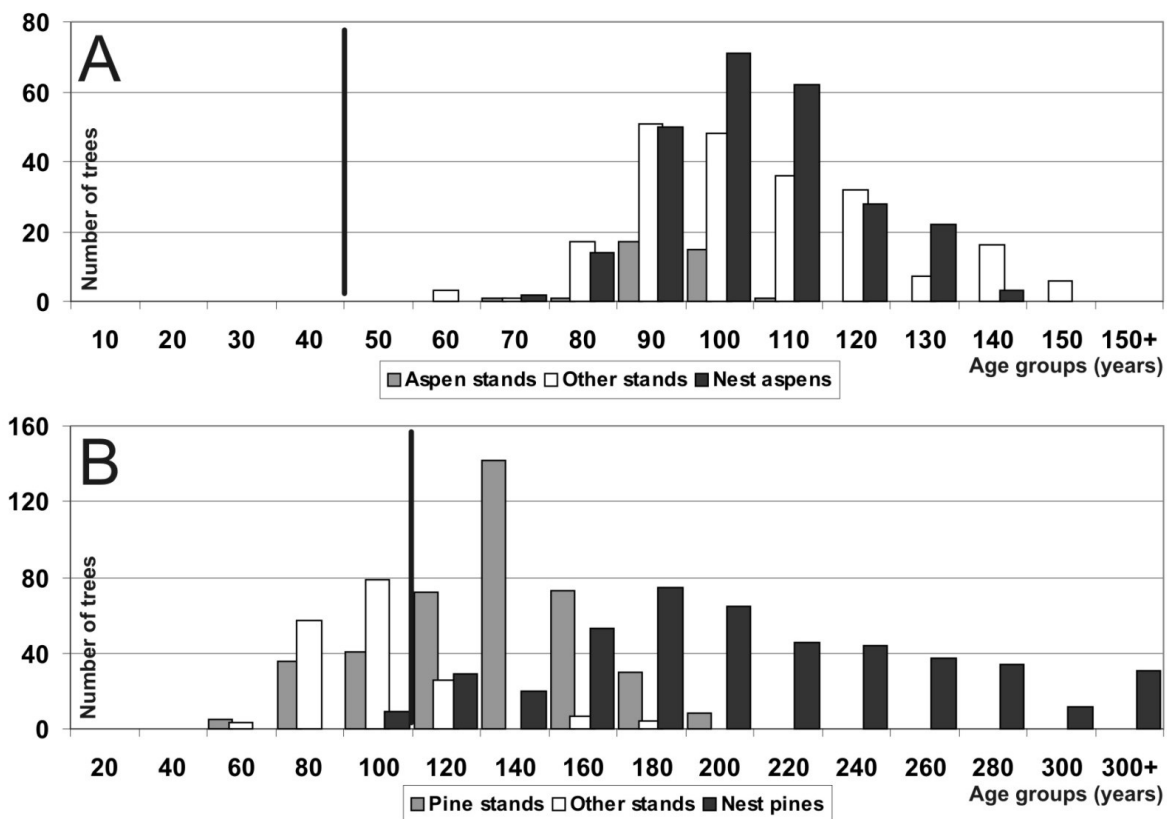


Figure 10. A comparison of the nest-holding age of nesting trees and the age of the surrounding stands (from taxation data) in corresponding years for nests in aspens (A) and pines (B). Each nesting tree has a matching value for surrounding stands in either of the stand bars. The bold line shows the logging age.

For pines and aspens with respect to which I have good data about the age of the trees, the average nest-holding age twice exceeds the respective cutting age of these species. It is also true that stands of pine in 221 of the 583 analysed cases (37.9%) were declared to be younger than their cutting age in the taxation data (Fig. 10B; note that only 2% of the nesting trees are actually younger than that). By comparison, not a single case of this has been seen in relation to the aspen

(Fig. 10A). Because I did not have sufficiently good data about the age of oaks, I did not analyse this. I have no doubt, however, that many nesting oaks are very old trees, indeed, at least judging from their thickness (Table 14).

Table 14. The thickness (diameter) of nesting trees (cm)

Species	Average	Median	Moda	SD	Variance	Min.	Max.	N	95%
Pine	56.1	53	51	16.6	274	32	119	72	3.9
Oak	93	86	102	28.6	817	50	200	65	7.1
Aspen	72.8	71	70	12.1	147.5	44	104	54	3.3
Birch	45.9	42	67	13.7	187.9	23	70	16	7.3
Ash	77.2	69.5	66	17.9	321.4	59	102	6	18.8
Spruce	44.5	41.5		21.1	447	22	73	4	33.6
Bl. alder	48.3	47		8.7	76.3	39	60	4	13.9

The location of the nest in the tree

The location of a nest in a tree represents a compromise between the stability of the nesting site on the one hand and the safety of the location on the other. The most common locations for nests include one or more side branches near the main trunk (Type a, 43%; Fig. 25 in the Appendix), on a forked side branch away from the main trunk (Type b, 37%), or in a wide fork of the main trunk (Type d, 13%). In most cases, nests are found on the lowest branches of the canopy, well shaded from above. We have also found nests, however, which have been positioned on the treetops of completely dry logs, encircled by other, taller trees. I have recorded two cases in which the nesting tree was struck by lightning during the breeding season. In both cases (a pine in one and an aspen in the other), the treetop was broken, but the nest remained in place, and the storks bred successfully both during the year of the accident and in following years (*Strazds 2005*). We also know of cases in which the nesting tree has been left all alone in a clear-cut area, and the stork has continued to nest in it. In one case, the birds remained in a completely dry aspen until the collapse of the nest, which was found at the edge of a large clear-cut area and collapsed after the adjacent forest was flooded by beavers. The stand died and was logged as a consequence (*Strazds 2005*).

In order to determine whether there are differences in the range of visibility, we performed a variance analysis (ANOVA) with the log of the visibility as the dependent variable and the species of tree as a predictor. There was a tendency of differences among the species of trees ($p = 0.09$). Post-hoc tests (the Tukey multiple comparison of means) reveal a slight difference between the pine and the oak ($p = 0.083$), so nests in pines are most noticeable from the air, while those in oaks are the most hidden ones (Table 15, Fig. 18).

Table 15. Differences in visibility range from the air in major tree species

Parameter	Average	Median	Moda	SD	Variance	Min.	Max.	N	95%
Aspen	1614.5	1050.4		2960.6	8765431.1	273.0	13627.1	19	1427.0
Oak	1162.6	674.2		1107.4	1226325.8	104.0	4195.8	33	392.7
Pine	2817.9	1204.8		5109.0	26101920.8	127.7	29719.6	35	1755.0

The lifespan of nests and nesting locations

The lifespan of a nest is a very significant characteristic from the conservation perspective (*Strazds 1993d*). However, the proper interpretation of the age of a nest is hindered by the fact that nests might be very old at the moment of their discovery, or their age might be unknown (*Strazds 2003*). What is more, the lifespan of the nest and that of the nesting location are two different issues. For instance, if a nesting tree's fork is too wide in terms of the most suitable horizontal branch, then the nest may regularly fall through this fork, particularly during the winter, when snow increases its weight substantially. Such nests may have a very short lifespan of just a year or two. However, if the location itself is good, and the bird has problems in finding a better place, it may rebuild the fallen nest in the same tree again and again. In that case, the lifespan of the nesting location is much longer. We have recorded cases in which nests at such unstable locations have been rebuilt four to six times.

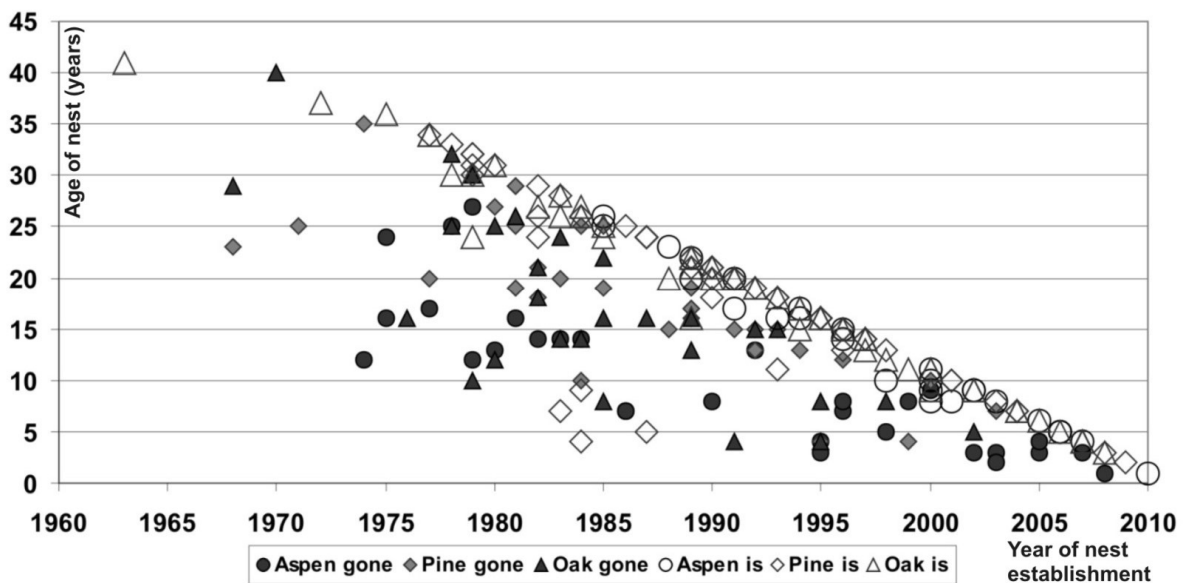


Figure 11. The lifespan of nests depending on the year of their establishment. “Gone” in this case refers to the tree species with nests that have collapsed, their lifespan is finished, and the data are final; „is” refers to nests which, at this writing, still exist and the values of which are still increasing.

We also analysed natural factors which affect the lifespan of nests — the species of tree, the thickness of the tree, the age of the tree at first nesting, the height of the nest above the ground, and the distance of the nest from the trunk. Only three of these factors affect lifespan

significantly: the species of the nesting tree ($F = 8.077$, $p = 0.001$), the thickness of the tree ($F = 12.401$, $p = 0.001$) and the distance of the nest from the trunk ($F = 9.681$, $p = 0.002$).

Among the three major species of nesting trees, the lifespan of nests in aspens is significantly shorter than is the case with pines (T-test; $t = -3.875$, $df = 61$, $p < 0.001$) or oaks (T-test; $t = -3.611$, $df = 57$, $p = 0.001$). Differences in the lifespan of nests in oaks and pines are not significant. One must stress, too, that these data are strongly affected by the longevity of the research. Many nests with the longest lifespan are still active (evidence of this is given by the average age of surviving nests which exceeds that of collapsed nests, Table 16, see also Fig. 11), and that means that we will know the actual maximum age of such nests only after many years have passed. The longest recorded use of a single nesting location, as recorded so far, is 68 years for a nest in a pine tree, but we do not know how old it was in 1938, when this nest was first discovered (*Strazds 1993d*, *Strazds 2003*, *Strazds 2005*).

The long lifespan of a nest, it must be added, does not mean that it has been occupied continuously. The longest known uninterrupted and successful nesting in a single nest lasted for 13 years. I analysed nests which were checked annually without interruption — ones in which storks began breeding at least five years in a row. The longevity of successful nesting will depend on the proportion of the disturbance-free landscape in the home range of the stork ($r = 0.290$, $p < 0.05$, $n = 60$). This means that there is reason to believe that nesting success is affected by disturbances.

Table 16. The lifespan of nesting locations in relation to different species of nesting trees

	Total†		Aspen		Pine		Oak		Birch		Black alder		Ash	Spruce	
	Gone	Exist	Gone	Exist	Gone	Exist	Gone	Exist	Gone	Exist	Gone	Exist	Exist	Gone	Exist
Avg.	15.81	16.9	10.07	12.56	19.39	18.56	17.66	18.44	16	11.5	13.5	15.67	16.83	17.75	15.0
SE	0.95	0.71	1.28	1.34	1.98	1.17	1.68	1.32	2.9	2.03	0.65	2.96	3.11	6.51	
Median	15	16	8	10	18	19.5	16	17.5	15	12.5	13.5	17	14.5	17.5	
Moda	16	20	3	9	25	24	16	20	22	14					
SD	9.84	8.67	7.03	6.94	11.35	8.46	9.02	9.53	8.21	5.73	1.29	5.13	7.63	13.02	
Min.	1	1	1	1	4	2	4	3	6	4	12	10	11	6	15
Max.	68	41	27	26	68	34	40	41	30	19	15	20	32	30	15
N	108	149	30	27	33	52	29	52	8	8	4	3	6	4	1
95%	1.88	1.4	2.62	2.75	4.02	2.35	3.43	2.65	6.86	4.79	2.05	12.75	8	20.72	

† The first two columns present descriptive statistics for all of the locations taken together, while the following columns provide the same information for each species of tree. The columns which are titled “Gone” refer to nests which have collapsed (i.e., the data are final), while the columns which are titled “Exist” refer to locations which still existed at the time of this writing, which means that their lifespan is continuing.

The longest uninterrupted lifespan of a single location, as known at this time, is 23 years. The relevant nest collapsed during the winter (it fell through the fork), and an artificial nest was constructed at the same location during the same winter. The stork continued to breed in this

place without interruption. The nest was still occupied in 2010, and it is possible that it was used before the first known inspection. The actual period of uninterrupted use, in other words, can be longer. Almost all of the nests about which a long lifespan has been identified have experienced one or more interruptions in their use because of abandonment. In terms of those locations which are older than eight years (the average lifespan of a single generation of black storks; *BirdLife International 2004*) and which have been monitored for at least 67% of the years in their total lifespan ($n = 89$), 56% of such nests have been abandoned for short periods of time once, 31% twice, 4% three times, 1% four times, and 1% five times while only 7% have not been abandoned at all (Table 17).

Table 17. Reasons for nest abandonment and the duration of the desolation

Parameter	Average	Median	Moda	SD	Variance	Min.	Max.	N	95%
Lifespan of the location	18.2	16	16	6.8	46.9	9	35	89	1.4
Uninhabited in total (years)	5.7	4	4	3.9	15.1	0	15	89	0.8
Duration of one period	4.3	3.5	3	3.1	9.3	1	13	83	0.7
Frequency of abandonment	1.4	1	1	0.8	0.7	0	5	89	0.2

The duration of periods during which nests remain uninhabited depend on the factors which cause nest abandonment, as well as, possibly, on the quality of the new nest. If the replacement nest is better than the former one, then the abandoned nest may exist unattended until it collapses. In the majority of cases, the new nest has not been found, and it has not been possible, therefore, to compare the two locations. The terminal periods of desolation are the longest ones. Terminal abandonment can be caused by a factor which degrades the landscape to a great degree — a major windstorm or a fire which destroys the surroundings of the nest. If the abandonment is caused by a predator (P) or by forestry operations (F), birds usually return to the nest after a break of one to four years (Table 18).

Table 18. The duration of desolation in relation to the causative factor

	Returned	Average	Median	Moda	SD	Variance	Min.	Max.	N	95%
F	Yes	1.7	1	1	0.9	0.9	1	4	13	0.6
F	No†	5.2	4	4	3.5	12.3	0	12	18	1.7
F	Unknown	3.4	2	1	2.7	7.1	1	10	13	1.6
P	Yes	1.8	2	1	0.9	0.8	1	4	22	0.4
P	No	3.7	2	2	3.2	10	0	9	11	2.1
P	Unknown	5.1	3	3	4.2	17.5	1	16	11	2.8

† The category “no” includes nests which are terminally abandoned, i.e., ones which have collapsed since their last abandonment. The category “unknown” includes nests which have been abandoned (relatively) recently, the result of which is that they have not collapsed, but the birds have not returned to it.

If the nest abandonment is caused by forestry-related disturbances (i.e., “yes” and “no” in Table 15.), the desolation period is significantly shorter if birds do return to the nest, as opposed to cases in which they do not return (Mann-Whitney U test, $Z = -3.312$, $p = 0.001$). For nest

abandonments that are caused by predators, this difference is not significant ($Z = -0.551$, $p = 0.121$). If we compare re-occupied nests with those of an unknown fate, then the situation is the opposite — for forestry-disturbed nests, the difference is nearly significant ($Z = -1.807$, $p = 0.071$), while for predator disturbances, it is highly significant ($Z = -3.298$, $p = 0.001$). There are no differences between terminally abandoned nests and those with an as yet unknown fate in either of these cases.

Despite this, the most important factor is that birds do return to good locations. The protection of such sites by, for example, creating permanent micro-reserves for all nests (including temporarily desolated ones) is an essential prerequisite for the maintenance of truly suitable breeding sites for the black stork in future.

We analysed all of the nests found in aspens since 1970. The lifespan of nests built in aspen trees has declined significantly during the last decades. This is significant in terms of the year when the nest was built ($r_s = 0.625$, $p < 0.01$, $n = 126$ nests), and in terms of the proportion of nests with a short lifespan, as opposed to all nests ($r_s = 0.494$, $p = 0.003$, $n = 35$ years; Fig. 12).

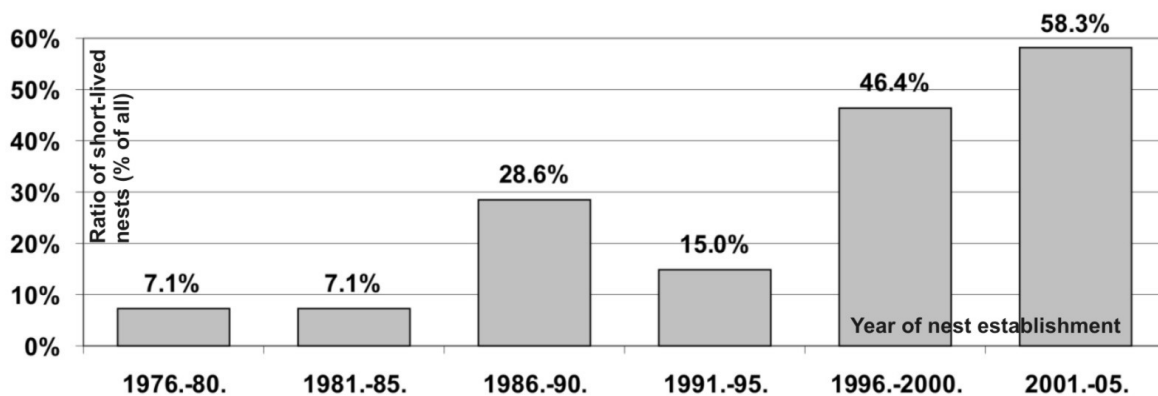


Figure 12. Changes in the proportion of short-lived (1-5 years) nests built in aspens over the course of time. The nests here are grouped in accordance to the year when they were established.

Disturbances

Land reforms were implemented during the mid-1990s, after the restoration of Latvia's independence. One consequence of this was that the intensity of forestry operations nearly tripled (Fig. 13). The ratio of unproductive nests increased significantly at the same time.

2003–2005, I found that the share of operations carried out during the spring (mid-March to mid-May) exceeded the proportion of this time period (two months represent 16.7% of the year) in terms of the volume of logging, the affected area measured in hectares, or the number of compartments (Fig. 14).

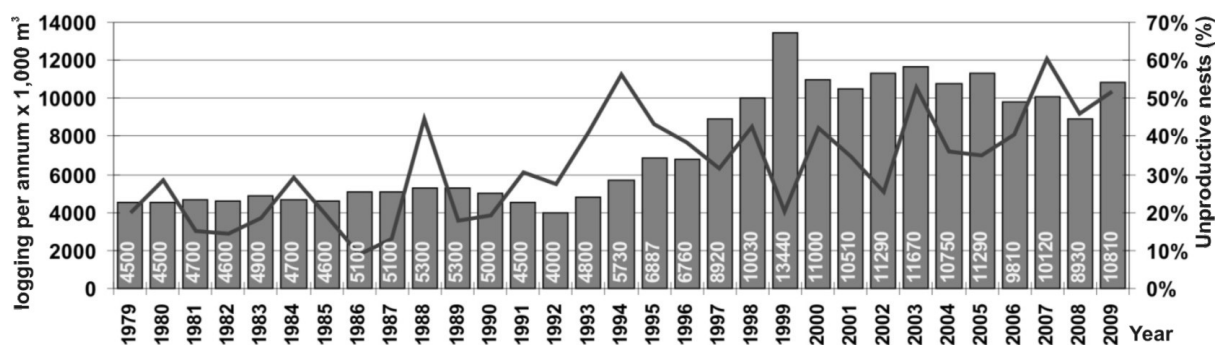


Figure 13. The possible impact of the intensity of forestry operations on the breeding success of the black stork in Latvia. The gray bars (axis Y1) show the volume of logging per annum x 1,000 m³ (Salinš 1999, State Forest Service 2000–2009). The bold line (axis Y2) represents the proportion of unproductive nests among all occupied nests. Axis X represents the years.

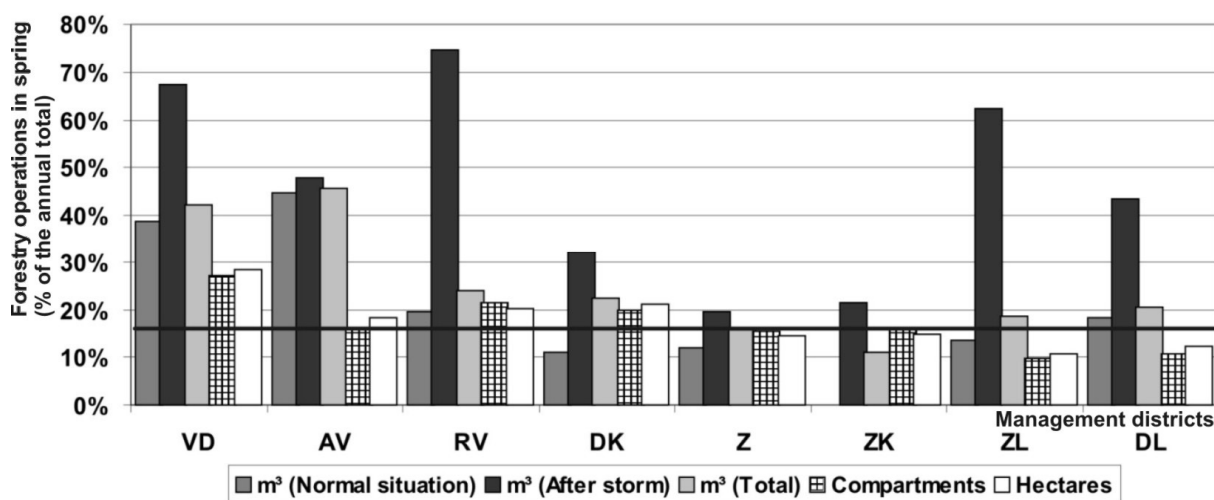


Figure 14. The intensity of forestry operations during the critical period of springtime (two months) in comparison to the annual total. The bold line shows the proportion of that period in time (from Strazds 2006a, as amended). The letters illustrate different forest management districts in state-owned forests.

This high level of activity during the springtime was easy to explain in 2005, when a massive windstorm hit large areas of Latvia on January 9, and urgent work was done to minimise economic losses. These operations, however, were almost equally intense in the spring of 2004, when forestry operations were seen as normal in all respects. Most of the forest plantings, which are not presented in the diagram, are carried out in the spring.

A comparison of disturbance level between the two analysed groups — successful nests ($n = 64$) and unsuccessful ones ($n = 30$) shows a significant difference (Mann-Whitney U Test, $Z = -2.037$, $p = 0.017$). Nesting success was significantly affected by the mean value of disturbance days in relation to distance, and the year. The model explained 72.3% of the entire breeding success variation — 95.3% of cases for successful nests and 23.3% of cases for unsuccessful ones. When changing the parameter values of the model, one of them — either the value of disturbance days or the distance — affected the result significantly in all cases. In other words,

breeding failure can be caused both by (relatively) short disturbances close to the nest, or by more massive activities at a larger distance (*Strazds 2006a*).

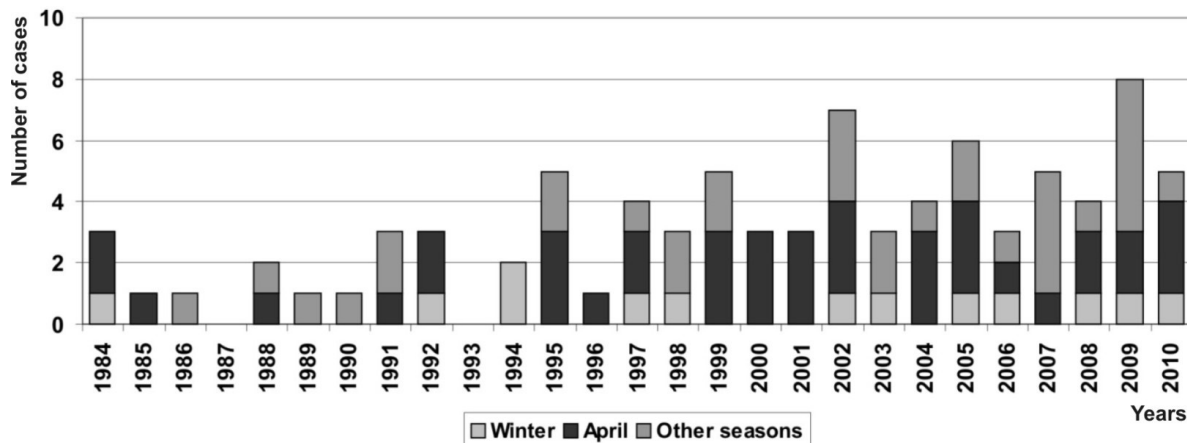


Figure 15. An increase in forestry activities registered in the close vicinity of stork nests (up to 1 km, with cuttings grouped by season).

Over the course of time, the overall intensity of forestry operations which might affect the breeding of the black stork has increased significantly ($r = 0.713$, $p < 0.001$, $n = 27$; n here represents the number of analysed years). The strongest increase relates to forestry activities during the “other seasons” (i.e., summer; $r = 0.522$, $p < 0.005$, $n = 27$) and, to a lesser extent, the spring (April; $r = 0.480$, $p < 0.01$, $n = 27$, Fig. 15). Among other activities, we must make note of road installation ($r = 0.657$, $p < 0.001$, $n = 27$).

Table 19. Nesting success and abandonment of nests as a result of disturbances

	Failure		Success		Not abandoned		Abandoned	
	N	%	N	%	N	%	N	%
Year before disturbance	17	30.9%	38	69.1%	55	100.0%	0	0.0%
Year of disturbance	48	78.7%	13	21.3%	34	55.7%	27	44.3%

The proportion between successful and unsuccessful breeding differs significantly between years with and without disturbances (likelihood ratio test, $LRT = 28.6$, $df = 1$, $p < 0.001$; Table 19). In years without disturbances, the probability of success was 0.718 (95% confidence interval: 0.570–0.829), dropping to just 0.184 (0.099–0.300) in years with disturbances. The likelihood of nest abandonment was also significantly different between years with and years without disturbances (likelihood ratio test, $LRT = 42.1$, $df = 1$, $p < 0.001$). No nests were abandoned without disturbances, while during years with disturbances, the probability of nest abandonment reached 0.442 (0.320–0.568).

During years of disturbances, the season of the disturbance affected breeding success significantly (Fischer’s exact test, $p < 0.001$). None of the nests disturbed in April was successful, while after disturbances in other seasons, about 50% of pairs bred successfully. The

distance of the disturbance also has an effect on breeding success. The average probability of success at a minimal distance of 500 m is around 0.5. The success decreases sharply if the distance is shorter than 100 m (Fig. 16).

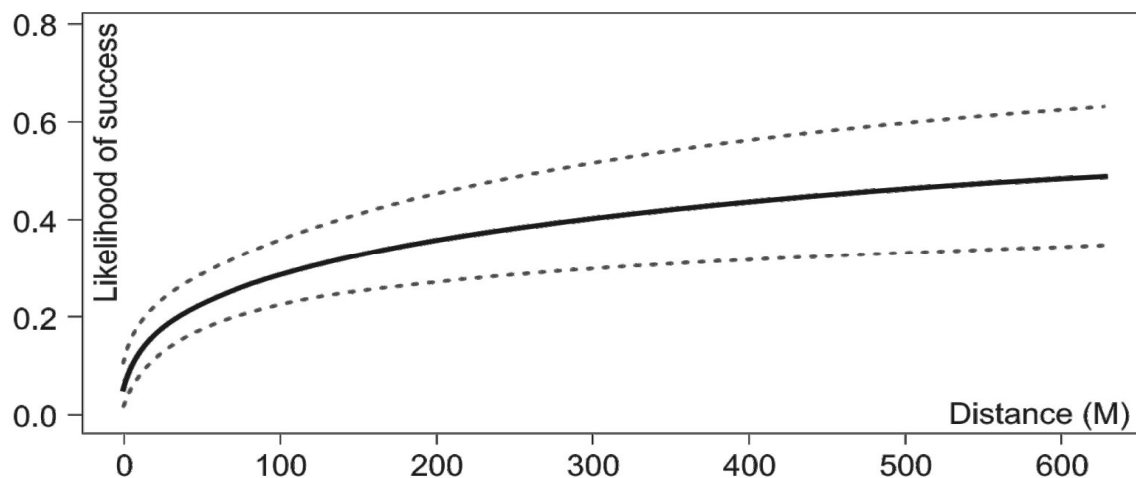


Figure 16. The impact of the minimal distance (axis X) on the likelihood of breeding success (axis Y). The bold line is the predicted value, while the broken line indicates a 95% confidence interval of the prediction.

Table 20. The impact of forestry activities on the breeding of the black stork

Disturbance	Total	KC	KC%‡	Breeding*		Not abandoned, non-breed.	Nest aband.	Unknown	Desolated after disturbance†
				Success	Failure				
By type of disturbance									
Road building	17			3	2	6	5	1	1.8
Transportation	8			1	1	5	1	0	
Forest planting	6			0	1	1	4	0	6
Clear-cuts (KC)	27	27	100%	6	1	5	10	5	3.3
Other cuttings	28			6	3	8	11	0	2.9
By season									
Winter (XII-III)	13	10	76.9%	8		1	1	3	4
April	40	12	30.0%	0	3	10	27	0	3.3
Other seasons	33	5	15.2%	8	5	13	4	3	3
By the closest distance									
Up to 10 m	26	10	38.5%	2	2	9	11	2	4
11-50 m	23	7	30.4%	3	3	6	8	3	4.1
51-250 m	20	9	45.0%	7	0	5	8		3.3
251-500 m	11	1	9.1%	4	3		3	1	
Further	4			0		3	1		

‡ Proportion of clear cuts among all operations in a given group of category.

* Success means fledged juveniles, failure — any other outcome. The next column („Not abandoned, non-breed.”) differs from this by eggs not being laid in the nest.

† The duration of the desolation period in years after the disturbance. This also covers cases with an as yet unknown total desolation period (i.e., nests which have not yet collapsed and also have not been re-occupied).

Spring disturbances also trigger most nest abandonments (likelihood ratio test, LRT = 34.7, df = 2, $p < 0.001$). The minimal distance also played an important role (likelihood ratio test, linear trend: LRT = 6.8, df = 1, $p = 0.009$; quadratic trend: LRT = 7.9, df = 1, $p = 0.005$). There was no significant influence in terms of the type of the disturbance.

Nests abandoned after spring disturbances were desolated, on average, for 3.3 years. Furthermore, 25% of the nests that were not abandoned were unproductive in the year of disturbance (Table 20). To summarise, the impact of forestry has not increased the number of abandoned nests, but it has significantly increased the share of unproductive ones.

Analysis of the impact of clear cutting (variable X1kmF010 = logged area in a 1 km circle around the nests over the course of 10 years, 1990–1999, see Table 4) produced negative results. The overall influence of X1kmF010 on the six breeding success variables was not significant (approxF = 0.67, df1 = 30, df2 = 710, $p = 0.91$). Among the separate tests related to the various breeding success variables, none was significant. All p-values were higher than 0.35.

Impact of predators

The pressure of predators on the breeding performance of the black stork has increased significantly over the course of time (for mammalian predation: $r = 0.595$, $p < 0.001$, $n = 30$; for birds of prey: $r = 0.376$, $p < 0.05$, $n = 30$; Fig. 17). The role of birds and mammals must be kept separate, however. We are aware of three cases in which predation by birds is known with certainty. In the first case, an unknown bird of prey (possibly an eagle owl) ate an incubating female next to the nest (1995). In the second case, half grown juveniles were taken from the nest and eaten by a goshawk (1996, identified by the fact that its breast plumes were found among the feathers of juvenile storks at the plucking site next to the ravaged nest). The third case involved almost fledged juvenile storks which were probably attacked by a juvenile sea eagle which had only recently fledged from a nearby nest (2007, Fig. 17).

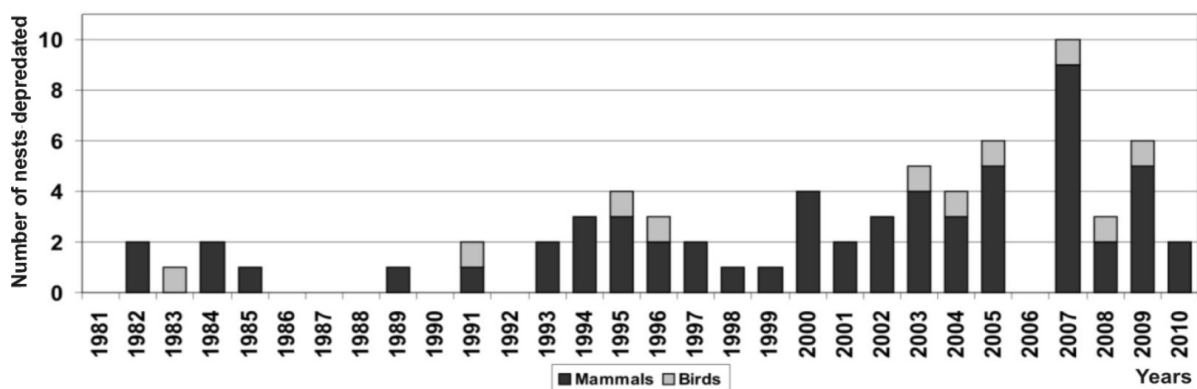


Figure 17. Changes in the frequency of predation in 257 black stork nest locations during 1981–2010.

In all other cases of bird predation, as presented in the diagram above, we are dealing with suspicions (or, in a few cases, actual observations) of a conflict between a black stork and a white-tailed eagle at the nest or in its vicinity. The consequence of such events has been abandonment of the nest or the disappearance of the juveniles. In all cases in which we have evidence about the role of white-tailed eagle (5), the relevant stork nests were in pine trees (Fig. 18, Table 21). All of the stork nests which were affected by the sea eagle were easier (from a larger range) to discover from the air (Two sample t-test; $t = -2.4993$, $df = 33$, $p = 0.018$).

Table 21. The impact of the sea eagle in accordance with the visibility of black stork nests from the air

Parameter	Average	Median	Moda	SD	Variance	Min.	Max.	N	95%
Affected	9491	3060.5		13503.7	182348564.2	2123.6	29719.6	4†	21487.3
Not affected	1956.8	1012.9		2154.9	4643687.9	127.7	7312.3	31	790.4

† For one of the five affected nests, I have no microhabitat measurements. The fifth tree, however, was very similar to the other four – it was in a fairly open place at the edge of a forest path, and the nest itself was built on a fork of the main trunk, close to the treetops.

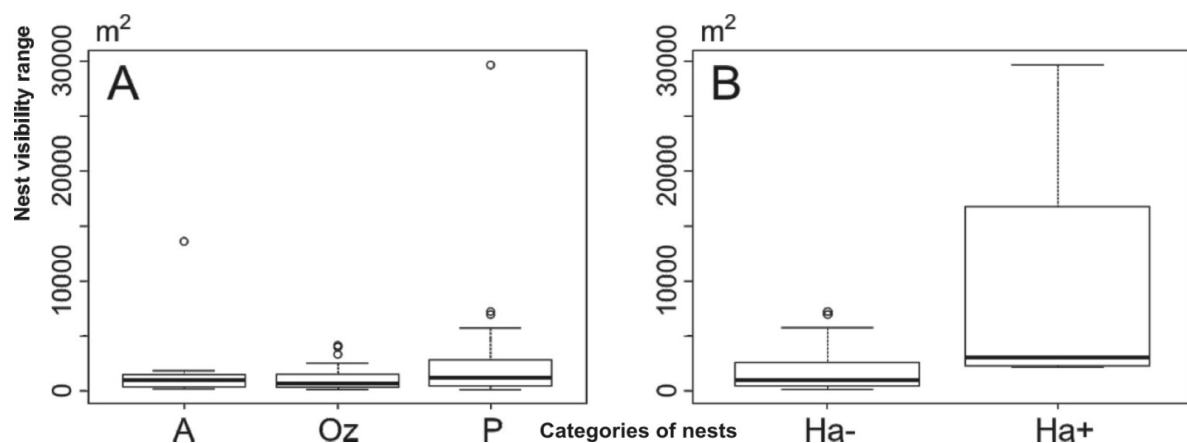


Figure 18. The role of nest visibility in the probability of white-tailed eagle predation. Bold line = median; box = 50% of data; whiskers = “normal” data; dots = outliers. A: Differences among species of trees (A = aspen; Oz = oak; P = pine). B: Nests which have not (Ha-) and have (Ha+) been visited by the sea eagle.

There is a link between the likelihood of marten predation on the one hand and the lifespan of the location on the other hand. The longer the location exists, the more likely is predation in it. Martens obviously inspect all of the nests regularly once they have found them. This is seen in the fact that the period between the first and the second predation is significantly shorter than the amount of time that is needed to find the nest in the first place (Mann-Whitney U test, $Z = -2.258$, $p = 0.024$). The latter period, however, has declined significantly over the course of time ($r_s = 0.550$, $P < 0.01$, $n = 55$; Fig. 19, Table 22). So far we have not found any case in which the same nest has been attacked by martens more than two times.

Table 22. The difference in years between the first and the second case of marten predation

Predation	Average	Median	Moda	SD	Variance	Min.	Max.	N	95%
First	12.5	13	3	7.3	53.1	1	29	55	2
Second	4.6	4		3.4	11.3	1	10	5	4.2

Martens do not attack nests by chance in terms of nest location (Table 23). Nests which are built at the top of broken trunks (Type E) or on a side branch away from the trunk (Type B, Fig. 25 in the Appendix) were attacked far less often than those which were close to the trunk (Pearson's Chi-squared Test; $\chi^2 = 8.9496$, $df = 2$, $p = 0.01139$).

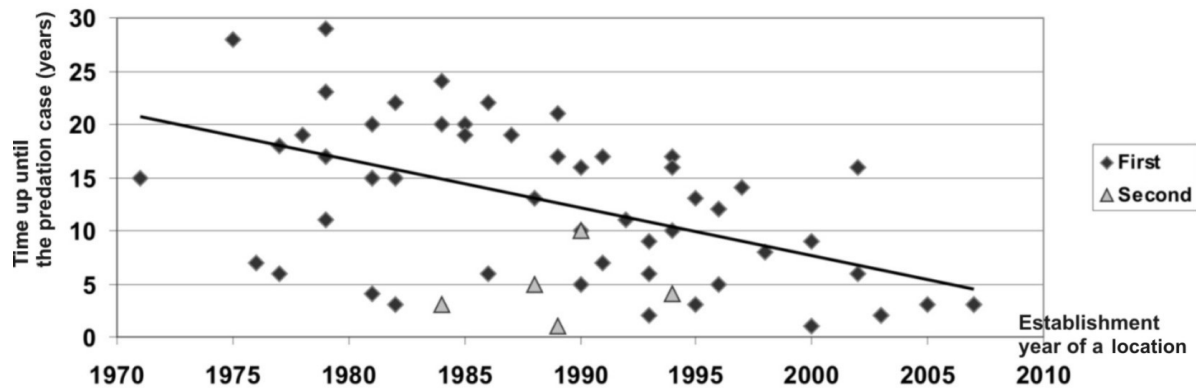


Figure 19. Changes in the period of time between the establishment of a location and the first case of predation, as well as between the first and second case of predation. Axis X = year of the territory's establishment; axis Y = the period of time up until the first case of predation. The bold line shows the trend (1).

Table 23. The frequency of marten predations in relation to the location of the nest in the tree

Location type†	E	ACD	B
Nests at this location	13	98	65
Depredated by martens	0	30	7

† E = on a broken tree-top, ACD = various locations near the trunk, B = on a side branch away from the trunk. For detail, see Fig. 25 in the Appendix.

Reasons for nest abandonment and movement distances

The main reasons for nest abandonment include collapsing nests, predation and disturbances (Strazds 2005). In most of the analysed cases (38%, Table 24), the reason for nest abandonment was unknown. The collapse of a nest triggered the building of a new nest in almost one-third of cases (89, or 26.7%). In 34 cases, the former nest site was still there (i.e., the former nest fell down without crushing the supporting branch). In another 55 cases, the former nest site did not exist anymore. The main reason for collapsing nests is their weight. A very old nest may have a size of 170 x 155 x 115 cm, and the estimated weight of such a nest can exceed one tonne. The average size of stork nests is 115 x 111 x 49 cm ($n = 139$; Strazds 2003). Other reasons for collapsing nests include windstorms. In two cases, nests fell because of beaver activities (causing a neighbouring tree to fall, which, in turn, broke the branch which supported the nest).

Table 24. Reasons of nest abandonment

Category	% of all	Group	N	% of category
Unknown	38.4%		128	
Definitive†	26.7%	Exists	34	38.2%
		Doesn't exist	55	61.8%
Possible	34.8%	Shading‡	45	38.8%
		Single adult	9	7.8%
		Disturbance	6	5.2%
		Mammalian predation	46	39.7%
		Bird predation	10	8.6%
Total	100.0%		333	

† The reason for the nest abandonment is the collapse of the former nest. “Exists” refers to previous nesting sites which are still there (i.e., the rebuilding of the nest in the same place is possible). “Doesn't exist” refers to nesting sites which are gone forever (the branch or tree is gone).

‡ Shading = cases in which nest abandonment could have been triggered by the death of the nesting tree or the surrounding stand, thus resulting in significant changes in nest shading; Single adult = cases in which the desertion may have been the result of a lack of a partner in the previous season; Disturbance = cases in which abandonment was caused by forestry.

If the former nesting site is still there, storks will tend to build their new nest in the same place or, alternatively, as close to it as possible. Data published in the past have shown that the average distance between a nesting site that was gone and the new nest that was built was 80 m (*Strazds 1993d*), while a later study reduced the distance to 72.7 m (SD = 226.9 m, n = 42). In those cases in which the former nesting site remained in place, the new nest was always built at the same place, so the translocation distance was 0 (*Strazds 2005*). In this evaluation I used fewer nests, because nests with indefinite information about breeding success in most of the relevant years were omitted. Current data indicate the following translocation distances: If the former nesting site is still in place, the movement is, on average, 0.2 metres (0–3 m). If the site was gone, the average distance was 249.1 m (0–2,450 m). The distance was zero in the two cases in which the birds did restore their nest in a place which, in fact, was no longer really suitable. In one case, the branch broke off at the trunk, and the nest was built on its remains. In another, the tree broke under the level of the former nest, and the nest was rebuilt on top of the remaining log (Table 25).

Table 25. Translocation distances after nest abandonment triggered by various causes

Parameter	Group	Average	Median	Moda	SD	Variance	Min.	Max.	N	95%
Nest site exists	1	0.2	0	0	0.7	0.5	0	3	25	0.3
Nest site gone	2	249.1	5	2	546.6	298778.9	0	2450	27	216.2
Forestry disturbance	3	1072.5	1015		273.3	74691.7	810	1450	4	434.9
Marten predation	4	1340.6	1370	1370	885.7	784477.8	80	2920	9	680.8

The differences among the translocation distances are not significant (Table 26) only for translocations triggered by different disturbances such as forestry operations (various cuttings, road building, etc.; Group 3 in Table 25) and predation (Group 4 in Table 25). Both of these processes, however, were the most significant in terms of triggering translocations (Table 24).

Table 26. The level of significance between differences in translation distances (Mann-Whitney U test)

Group	1	2	3
2	Z = -5.694, p < 0.001		
3	Z = -4.212, p < 0.001	Z = -2,716, p = 0.007	
4	Z = -5.143, p < 0.001	Z = -3,274, p = 0.001	Z = -0.927, p = 0.354

If birds had to move because of the collapse of their nesting site, then in most cases they did find a new location within the same stand. In one case, however, the birds moved much further than the next (seemingly) suitable stand (Table 27). We could not identify any significant changes in translocation distances or frequencies over the course of time.

Table 27. Translocation distances in relation to the size of old forests in the initial nesting stand

Nest Nr. and name ¹⁴	Year	Nest tree		Nest stand		Transloc. distance	Old forest†		Distance to	
		Spec.	Age	Spec.	Age		Area	I	II	III
864301 Vorožas purvs	1986	A	112	B	105	75	67.73	+		
722702 Ozolsalas purvs	1989	E	124	E	95	2450	517.38		1643	73
032903 Ventnieki	1991	P	193	P	175	284	96.09	+		
212321 Garā līnija	1992	P	171	P	122	600	11.57		94	94
505201 Zariņi	1992	A	116	P	130	150	76.37	+		
752612 Smelteri	1993	A	120	A	137	150	8.7	+		
032902 Ventnieki	1995	P		E	179	319	96.09	+		
182422 Āķu mežs	2002	Oz		Oz	67	330	116.15		*	
202601 Tušķu mežs	2003	P		P	174	190	11.04	+		
894003 Nokalne	2006	A	130	M	94	27	32.88	+		
212324 Līčupe	2009	A	83	A	105	320	34.59	+		
723102 Deguma pļava	2009	A	110	B	93	200	101.66	+		
093903 Zūru m-ba	2010	A	108	B	88	1600	3.46		1124	5

* The new nest was built outside of the old forest in a solitary oak tree that was within a young stand.

† An old forest for our purposes is a separate patch of stands older than 80 years, as determined by GIS analysis (Fig. 6). The column “Area” shows the size of the initial patch. In Column I, “+” means movement within that patch. Column II shows the distance to the patch where the bird has moved. Column III shows distance to the closest “suitable” forest (the next closest patch).

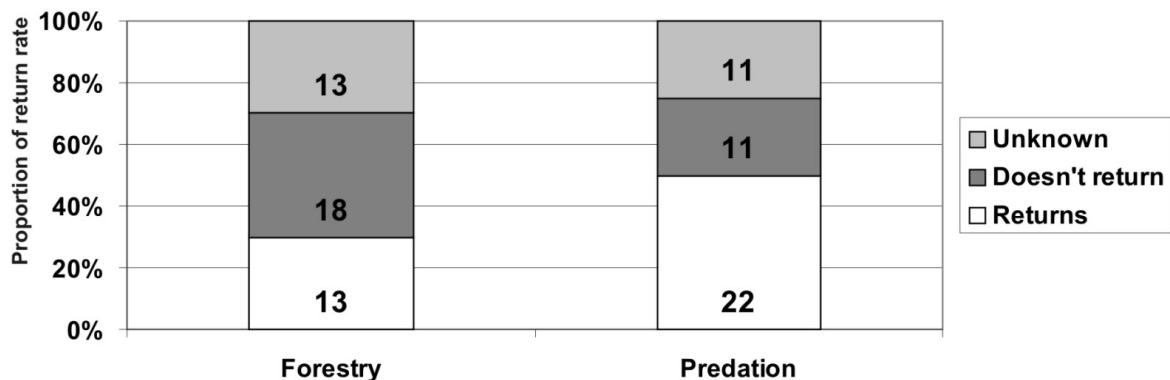


Figure 20. Differences in nest abandonment caused by forestry and mammalian predation. Nests attacked by birds of prey have not been analysed, because I have insufficient data.

¹⁴ Here and in the appendix all names are given only in latvian to avoid mistakes and misunderstandings originating from translation of multiple-word site names (e.g. Seržu bog or Seržu heath for „Seržu tīrelis”).

The probability of return depends on the cause of abandonment. We only compared those nests which have “final” data — either terminally abandoned nests or ones to which birds have returned. After cases of marten predation, birds return to former nests more often than is the case after forestry disturbances (Pearson’s Chi-squared Test; $\chi^2 = 3.9453$, $df = 1$, $p = 0.047$; Fig. 20).

Another part of our analysis had to do with the likelihood of birds breeding in the first year after their relocation to a new location. Both in cases in which storks occupied an existing nest (an abandoned stork nest or the nest of a raptor such as a goshawk or buzzard) and in which they built a new nest themselves, more than one-half of the birds did not breed (Table 28).

Table 28. The breeding frequency of black storks during the first year after translocation

	Non-breeding	Breeding	Total	Non-breeding in %
New nest is built	34	26	60	56.7%
Existing nest is used	17	14	31	54.8%
Total	51	40	91	56.0%

Eggshell weight

During the years when DDT was used intensively (after 1947), the average weight of eggshells dropped significantly ($p < 0.05$) in comparison to the period before 1946 (Fig. 21). Since 1980, the average weight of eggshells and its dispersion have been increasing (*Grünblate 2010*).

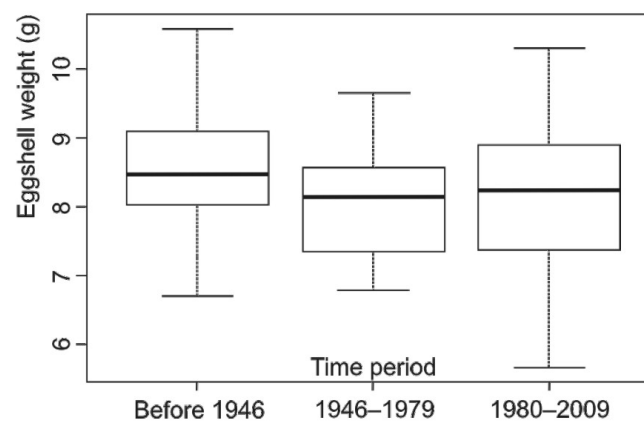


Figure 21. Changes in the weight and dispersion of eggshells (g) during different periods of DDT use (from *Grünblate 2010*)

Changes in eggshell thickness

We did not find a significant reduction in eggshell thickness when comparing recently addled eggs with the eggshells of eggs that were collected before DDT use began in 1946. The overall reduction was only 5.5%. We did, however, find a significant increase in variations in terms of the thickness of the eggshells — exceeding 40% in some cases (*Grünblate 2010*), as compared to

< 10% before 1946 (Fig. 22). Eggshells from broken eggs found under nests in recent years (0.37 ± 0.07 mm,¹⁵ n = 16) were significantly thinner than normal eggs prior to 1946 (0.50 ± 0.04 mm, n = 172, reduction 25.5%; p < 0.05). This suggests the effects of contamination, although it was impossible to test broken eggs for DDT (because of the lack of egg content).

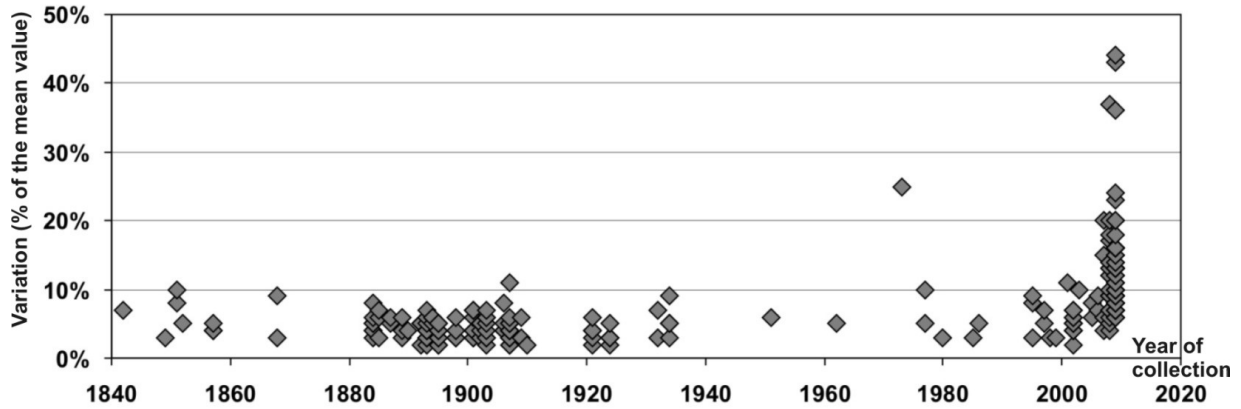


Figure 22. Variations in eggshell thickness (% of the mean value), measured at 9 points.

Presence of DDT

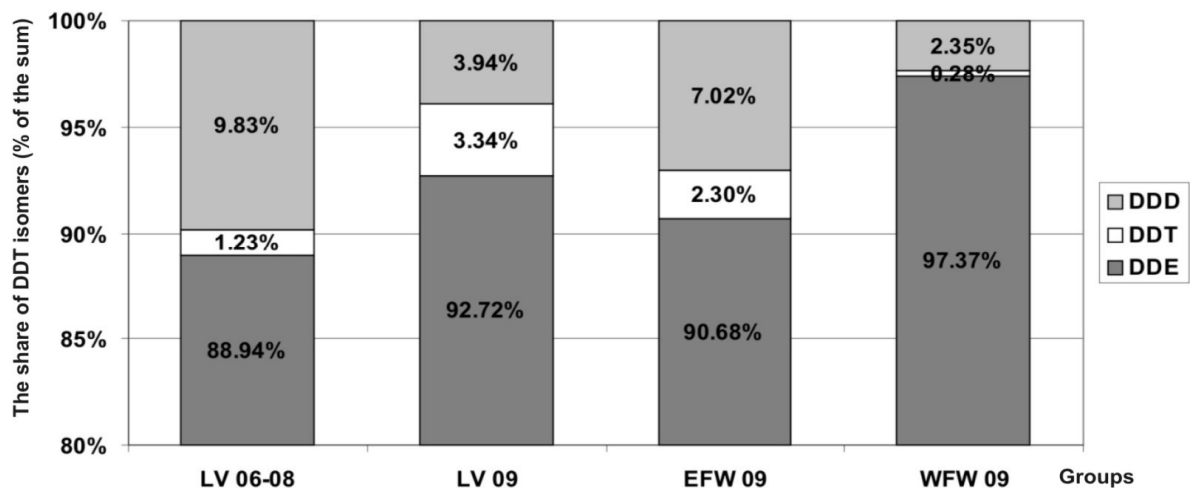


Figure 23. The share of DDT isomers in various black stork eggs (from *Grünblate 2010*). LV = Latvia (eastern flyway); EFW = other countries along the eastern flyway; WFW = western flyway. The figures after the abbreviation refer to the year of egg collection (e.g., 09 = 2009).

All 49 of the failed black stork eggs contained residues of DDT or its metabolites. The level of DDT in the analysed eggs varied from $0.582 \mu\text{g/g}$ to $219.84 \mu\text{g/g}$ of lipid weight. The share of DDT in “total DDT” (including the metabolites DDE and DDD) exceeded 1% in eggs collected from eastern flyway birds, which indicated fresh contamination. Black stork eggs collected in Latvia in 2009 show a higher proportion of p,p’DDT than those collected in 2008 and earlier,

¹⁵ Average value \pm SD; amended data from *Grünblate 2010*.

which implies increasing exposure (*Grinblate 2010*, Fig. 23, Table 37–39 in the Appendix). The high level of DDT in all of the eggs suggests extensive contamination. The data would be even more dramatic if a greater number of nests in which contaminated storks bred could have been studied in subsequent years. The problem is, however, that such nests were often abandoned after a high rate of egg loss and/or a very low level of breeding success in previous seasons (Table 29).

Table 29. The condition of 12 nests during seasons after DDT was found

Nest condition	First year after DDT	Second year after DDT
No eggs lost (all hatching successfully)	3	3
All eggs lost before the 2nd control	3	3‡
No eggs found	1	1
Nest abandoned	2	4
Contains adled eggs †	3	1

† Of the 12 nests from which a “DDT curriculum” could potentially be obtained during the following years, only three (the last column) provided material in the 2nd season, and only one did so in the 3rd season. Eggs could also have been collected from the three successful nests (the first column), but given the low breeding success of the species in general, we did not wish to reduce breeding success artificially.

‡ In 2010, we found one egg in one of these nests under a nest with contents, so it will be analysed.

Changes in the breeding season

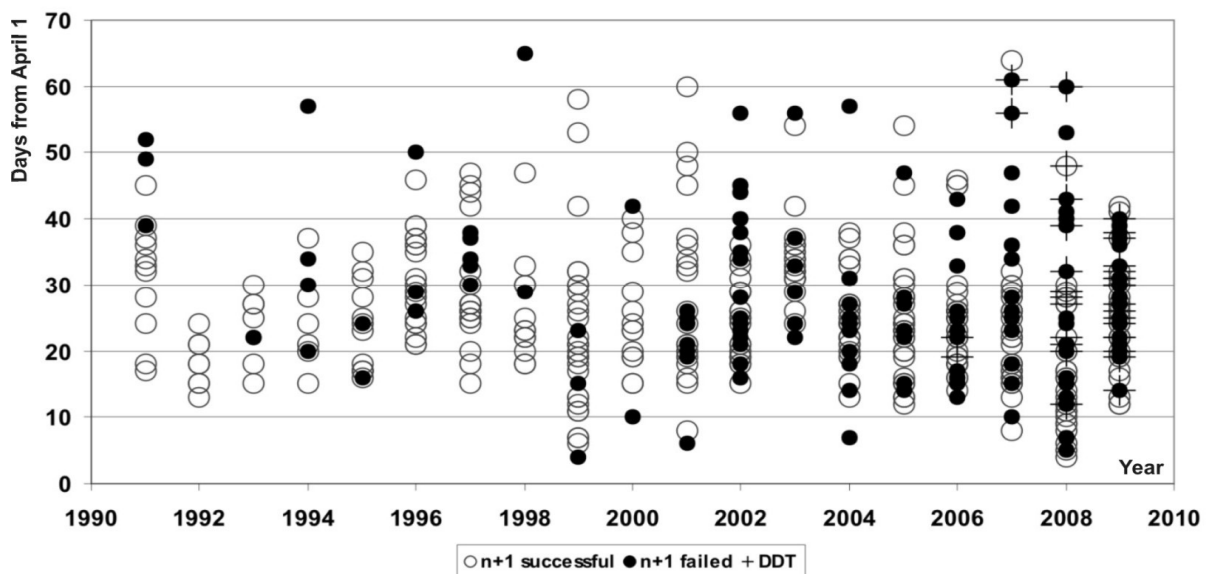


Figure 24. Changes in breeding seasons and the role of DDT contamination therein. Each dot represents the date of the first laid egg in a different nest. Nests in which there was successful breeding in the next season, too, are shown with hollow dots, while nests in which breeding failed during the nest season are shown in black.

The presence of DDT causes delays in the laying of eggs. The first DDT-contaminated eggs ($n = 25$) were laid, on average, 10 days later than was the case which pairs which were nesting successfully during the next breeding season ($n = 89$; which might have been less affected by DDT) during the same time period between 2006 and 2009 ($\chi^2 = 12.8368$, $df = 1$, $p < 0.001$;

Kruskal-Wallis rank sum test), although there was a slight but significant general advance in the nesting season between 1979 and 2009 ($R = -0.139$; $p = 0.002$; Fig. 24).

Changes in breeding success

I have noted a significant reduction in the recovery rate of ring-marked juveniles during their first autumn journey (Table 30). In 1996, 23% of ringed juveniles were recorded in Israel, as opposed to 0 and 3.8% in 2008 ($\chi^2 = 17.3024$, $df = 1$, $p < 0.001$; Pearson's Chi-squared test) and 2009 ($\chi^2 = 9.8474$, $df = 1$, $p = 0.0017$), respectively. The hatch-specific survival frequency of juveniles has changed. In 1996, 56% of the re-sighted birds were the oldest in their brood, while in recent years, none of the first-hatched juveniles was seen again.

Table 30. Changes in breeding success and juvenile survival

Year	Nests	Number of chicks in nest during ringing visit						Average	Ringed	Sighted	Sighted in Israel from N-size brood					Recorded Nth			Pre-R **	Post-R	Attacked
		5	4	3	2	1	0				5	4	3	2	1	1.	2.	3.			
1996	26		8	10	8			3	78	18		10	7	1		10	3	5	6	2	
2008	31	2	4	11	11	2	1	3	83										13	7	5
2009	38		3	12	14	4	5	2	80	3		1	2			2	1	45	4		

** Pre-R: Pre-ringing mortality consists of lost eggs (if known) found failed eggs, and dead juveniles found in or under the nest. In 2009, we also found further abnormalities such as two fully developed but unhatched embryos in a single egg (counted as “1” lost egg). PostR is the post-ringing mortality rate, which consists of the juveniles found dead or under the nest (identified from rings; cause of mortality unknown) over the course of the next year. Attacked refers to those eaten in their nests by predators.

Observations in 1996 suggested that the majority of juveniles ($n = 18$) reached Israel in about 74 days covering the distance $> 2,700$ km that is approximately one-half of the full migration route in one direction (based on readings of color rings; *Willem van den Bossche, pers. comm.*). The mean departure date for these birds was August 3, and the mean arrival date in Israel was October 16 (September 19 to November 18). The latest hatching date of a juvenile bird re-sighted in Israel is June 13, which was 43 days after April 1.

Discussion

Food

The main source of food for the black stork is small and medium-sized fish from shallow waters (*Cramp & Simmons 1979*). The bird also eats large insects, frogs, salamanders and, to a lesser extent, small mammals, snakes, lizards, crustaceans, and passerine nestlings (Table 31 in the Appendix; *Кративный 1957*; *Bauer & Glutz 1966*; *Bezzel 1985*; *Janssen et al. 2004*). Either frogs (mostly *Rana temporaria* or, less often, *R. arvalis*) or small fish are the main food source for the black stork in Latvia, depending on weather conditions. The most frequently found items of food for the stork have been the roach (*Rutilus rutilus*), the bleak (*Alburnus alburnus*), the perch (*Perca fluviatilis*), the pike (*Esox lucius*), and the belica (*Leucaspius delineatus*). There are also benthic fish such as the burbot (*Lota lota*), the spiny loach (*Cobitis taenia*), and the pond loach (*Misgurnus fossilis*) (*Strazds 2005*). Since 2005, we have found large numbers (more than 100 in some samples) of the nine-spine stickleback (*Pungitius pungitius*) and juvenile western brook lampreys (*Lampetra planeri*). Most of the fish that are eaten by storks are common in all inland water basins in Latvia (*Plikšs & Aleksejevs 1998*), although there is a lack of precise information about their densities, particularly in small streams or ditches. Neither is there any information about the number or density of frogs in Latvia.

The quality of habitats

The availability of trees which are appropriate for stork nests is clearly a fundamental property of a nesting stand. Several studies have argued that oak trees are of great importance in this regard (e.g., *Cieslak 1998*; *Löhmus & Sellis 2003*; *Treinyš et al. 2008*). Our data also suggest a strong preference for the oak (Fig. 7B). Reasons for this, however, can be various. The lifespan of the tree and the strength of its branches are certainly important (Table 16). Second, the oak provides the best protection against two major predators — the white-tailed eagle and the pine marten. Nests in oak trees are least visible from the air (Table 15, Fig. 18). The frequent presence of long and horizontally forked branches offers the safe placement of the nest away from the trunk of the tree. The free space above the nest might be of importance, too. Because storks copulate in the nest (*Janssen et al. 2004*), they need at least 1.5 metres of free space above it (Table 9). A lack of space, in turn, can be the main reason why storks avoid spruces for nest building. A review of the use of nesting trees from a broader perspective suggests that tree species as such are of very little importance (*Janssen et al. 2004*). Three factors contribute significantly to the selection of a nesting site — the ability to build the nest, accessibility and free space above the nest, and safety against predators. The last of these aspects is obviously the main

reason why storks tend to build nests on side branches (Table 23, also *Horváth et al. 2004*). Such nests, however, collapse more often. The importance of this factor strongly depends on the age of the nesting tree and the strength of its branches. This could be the main reason why particularly old nests are found on old pine or oak trees, while nests in comparatively young (80 to 90 years old) trees collapse quickly. The branches of such trees are not strong enough to support a nest for several years (*Strazds 2005*).

In order to rate the importance of the age of trees properly, I used the “nest-holding age” — the age of the relevant tree at the time of each nesting occasion. This approach gives different weight to short-lived and long-lived nesting trees, and it also allows to set priorities in a much better way. A tree in which a stork can and does breed for 20 years in a row is far more important from the perspective of site conservation than is a tree in which a stork breeds for only one year. This is particularly true in cases in which all nesting sites cannot be protected, and so priorities must be defined.

Habitat studies in Estonia point to the limited distribution of suitable nesting habitats. Although formally suitable trees were found in 3.5% of forests, taking into account the location and structure of stands, only 0.3% appeared to be suitable in Estonia (*Lõhmus & Sellis 2003*). There is no reason to question the conclusions of the study, although the method that was used to determine the suitability of the various trees can be questioned. Even the most experienced expert cannot determine whether a tree is or is not suitable for a stork nest. Assessment of trees from the ground (as experts do) and from the air (as birds do) is not comparable. Even a very old and gigantic tree might be useless because it lacks a single proper fork, because the forks are too wide and thus unsuitable, etc. It is regularly true that a nesting tree has only a single good location in it, and if it disappears, the bird is forced to move elsewhere. If the location for the nest remains in place, the nest is restored in it almost without any exceptions (Table 25).

I believe that a much better indication as to the next suitable tree is the bird’s own choice in terms of nest relocation, particularly in cases if the change is not driven by external factors (Table 25). Birds have major problems in finding suitable nesting trees. Sometimes birds are forced to move very far away, and there are also cases in which nests are restored in places which are not suitable for that purpose anymore. Movement distances are not correlated with the age of the stand or with the stand of the “old-growth” patch of the forests where a nest was formerly located. A stand that appears to be suitable in formal terms can prove to be completely useless because the bird cannot find a single good tree therein.

Another indication of this problem is a significant reduction in the lifespan of nests that are built in aspen trees (Fig. 12). The most likely reason for this is a shortage of trees which are of a proper age. Older trees are approaching their natural collapse. If such an aspen is chosen for a nest, the remaining lifespan of the tree is naturally shorter. A proper evaluation of this issue is severely influenced by the quality of data which relate to forest stands. Most aspens in which storks are nesting are found in stands that are dominated by other species of trees (usually spruces or pines; Fig. 10, Table 12). In these cases, particularly with regard to stands of spruce, the nesting tree is often the only one or just one of a few suitable trees in the stand. If that tree collapses, the bird has no alternative but to move very far away. In the very few cases in which nests are located in pure stands of aspen trees, the bird builds its new nest in the next suitable aspen tree that is nearby.

The literature mentions “reserve nests,” but only the distances between the nests are cited — e.g., 150–1,000 m in Belarus (*Ivanovsky 1998*) or 350–3,200 m in Poland (*Zawadska et al. 1990*) — not the reasons for the change. In areas where the stork population has lower breeding density and a higher rate of disturbance, birds move their nesting sites regularly. The distance of movement is largely affected by the availability of the next suitable nesting site. In Schleswig-Holstein one pair travelled a distance of 17.5 km in 1998/1999 and another 26.4 km (11.1 km from the original nesting site) in 1999/2000. After the construction of an artificial nest nearby, the next shift was only 300 metres — to the new nest. Another case which was documented in Lower Saxony shows that birds moved more than 10 km away from a nest which, during the winter, was occupied by the pine marten (*Janssen et al. 2004*). Because every shift means an unproductive season for more than one-half of moving pairs (Table 28), a large number of nest changes will affect overall breeding success. One possible reason for a failure to breed in a new place is that the storks are testing the site, domesticating their new home range, and assessing whether the new nesting site is sufficiently stable, but there is no empirical proof of this.

Observations of birds which are fighting over a nesting site also suggest a lack of suitable nesting trees. In one case, we found the evidence to show that the breeding pair in the nest was replaced after such a conflict (*Strazds 2009*). It is likely that the new breeding pair threw out the former pair’s eggs and then re-nested. The most probable explanation is faith in a good nesting site (this particular site has been used for more than 30 years).

Preliminary measurements of annual increments show that the oak is one of two species of trees which achieve a size that is suitable for stork nesting most quickly. The youngest oak tree in which there is a nest is just 65 years old (Table 13). The age of the surrounding stand which

encompasses oaks where storks can breed, is ~30 years (the youngest stands are aged 17, 22 and 31 years; Table 12). In theory, therefore, oak trees left in clear-cuts could be the first retention trees at which storks re-nest around the year 2020. Although the oak is present throughout Latvia (*Priedītis 2005; Laiviņš et al. 2008*), and its range stretches all the way to Finland, the fact is that the oak is seldom used for nesting sites in Estonia (*Lõhmus & Sellis 2003*). In Latvia, in turn, the oak is not used as a nesting tree in about one-half of the country's territory, probably because the trees are not of a suitable size (Fig. 8B). The aspen which "replaces" the oak when it is absent becomes suitable for nest building at a similar age, but only if it grows in a stand that is two times older. Nests in aspens have been found in stands of spruce (that are 56 years old), in stands of birches (67), and in stands of aspen trees (68). Lots of aspens are left as retention trees, but most of them eventually die. Among the trees that were tested, 21% of all aspens, were dead just a few years after cutting (*Valsts meža dienests 2009*). The majority of retention aspens will not be alive when the next stand encompasses them. The few surviving aspens will be able to serve as a nesting tree only for a short period of time. In ranges where oaks are absent, the future existence of a stork breeding habitat can only be maintained by maintaining stands of aspens so that all age classes are represented to a substantial degree. If the government lowers the cutting age for aspens from 41 to 31 years, as has been reported,¹⁶ then that will cause significant deterioration in the quality of future habitats, and that may be detrimental to the black stork in much of its current range in Latvia.

The impact of forestry

Forestry has been mentioned as a significant factor in affecting black stork populations (e.g. *Strazds 1995*). The literature mostly discusses such aspects as logging in old-growth forests, a lack of suitable nesting trees, the fragmentation of forests, etc. (e.g., *Tucker and Evans 1997*). Most studies which look at the impact of forestry on large forest birds (e.g., *Rosenvald & Lõhmus 2003; Lõhmus 2005*) have discussed forestry operations from the perspective of the size and distribution of clear-cut areas, the remaining structure of forest stands, etc. I have not found any studies which speak to the impact of forestry as a process or consider its role in space and time. The most likely reason for this is a lack of reliable data about operations that are carried out in certain territories. Much the work, moreover, is considered to be a commercial secret by forestry companies which are loath to offer information to experts.

¹⁶ See <http://www.mezi.lv/index.php?newsid=1827%pg=1&al&m=1>. The story, which is in Latvian, speaks to a claim by an organisation of forest owners to the effect that cutting restrictions for aspens are to be repealed completely.

I faced a similar problem, even though the information that I received was as comprehensive as possible. Not all data were 100% certain vis-a-vis the season to which they were officially attributed. This was true concerning both clear-cuts and thinning operations (*Strazds 2006a*). We must also take into account the fact that the impact of any operation will extend beyond its edge as the respective distances are measured. The average visibility in forest stands is at least 50 m, and the noise that is produced by forestry machines can be heard at a radius of several kilometres. The noise as such probably does not affect storks directly, but the casual presence of humans in the vicinity of a nest can be a problem. Another consequence of such disturbances may be predation which would not have occurred otherwise (e.g., an egg-eating bird such as a raven ravages a nest which has temporarily been deserted by the adults).

The impact of forestry operations on the breeding performance of the black stork is much larger than the ~23% that was determined in the 2003-05 study. The method used for that study did not make it possible to evaluate the impact of forestry on the likelihood of nest abandonment. A later and separate study of this issue shows that this is the most likely outcome after forestry-related disturbances (Tables 19 and 20, Fig. 20). Analysis of the impact of the type of disturbance shows that it does not have a significant effect on the result (i.e., an unproductive season or nest abandonment). Because most clear-cutting is done outside the sensitive period (Tables 2 and 17), we can understand why attempts to use them as a proxy for forestry disturbance have failed (e.g., *Rosenvald and Lõhmus 2003*; our data, Page 47). A very important consequence is the fact that spring disturbances have a highly significant negative effect (Tables 19 and 20). In some cases, birds have not abandoned their nests despite springtime cutting near their location (*U. Sellis, pers. comm.*). The analysed data, however, suggest that these are exceptions which may be caused by various factors that are very difficult to assess. One factor is the age of the relevant bird, which relates to the bird's knowledge about its feeding range. For long-living territorial birds, this is an important predictor of success (*Martin 2010*). The analysed data show that ***spring disturbances cause unsuccessful breeding for ~70% of disturbed pairs*** (birds which omit breeding, as well as shifting birds which do not breed during the first year after their relocation; Table 28). Given the increased intensity of forestry operations, there is no doubt that ***forestry plays a major role in the increased ratio of unproductive pairs***. It must be stressed here that this analysis does not cover cases in which nesting trees are cut or nests are otherwise destroyed. Such cases have been identified not just in the 1990s, but also recently (*Driķe 2002*; *Strazds 2006b*; *Dzērve 2008*).

Recent forestry activities have been handled in a way which significantly narrows the range of possible breeding habitats — ***during the last 20 years, one-third or, in extreme cases, more***

than one-half of formally suitable forests have been logged (Table 7). The recently proposed concentration of cutting areas in each forest tract (e.g., *Anon. 2008*) — could cause even more severe problems. There are, however, also claims about reduced disturbances with this approach (*Jaunbelzere 2009*). The total number of disturbances, however, will probably increase, and substantially. Cut areas will have to be replanted and then maintained. Because cut areas are usually interspersed with uncut areas (Fig. 6B) in the form of slips which usually do not exceed 50–100 metres, the simultaneous disturbance will mean that almost all of the remaining forests will become completely useless. If there is massive disturbance in the entire home range, the affected pairs whose nests are unknown and, therefore, unprotected will probably move to the nearest suitable location. The relocation may cover tens or even hundreds of kilometres¹⁷, possibly outside of Latvia.

There is no clear understanding of the factors which actually cause sensitivity among the birds against disturbances in the vicinity of their nests and, thus, affect breeding success. Here is one possible mechanism in terms of how a disturbance in a feeding territory may affect the breeding performance of storks therein: Black storks mostly feed in rivers, brooks and ditches. In wet forests, they also feed under canopies on the ground or in clear-cut areas. It is known that the stork prefers to feed close to its nest, although feeding flights that cover a distance of 10–40 km from the nest are not uncommon (*Cramp 1966; Laguet 2001; Mahieu 2001; Nellis et al. 2008*). Nesting locations in Latvia are very long-lived (*Strazds 2005*). Nests are thought to be occupied by the same pair (*Cramp & Simmons 1979*). It is obviously the case that birds are well familiar with their feeding range, being aware of permanent sources of possible disturbances (e.g., occupied households). Telemetric studies in the Czech Republic have show that birds even use human settlements (in mountainous areas), essentially during those hours in which people are not active (*Ľ. Peške, pers. comm.*). In the mountains, however, the presence of forests and feeding grounds depends first and foremost on the terrain. It is also true that mountainous forests always offer a significant share of undisturbed (i.e., inaccessible) locations — something that is almost completely absent in Latvia with its flat terrain.

There are currently a great many drainage ditches in our forests, and most small forest streams have been straightened (Table 7). Forestry infrastructure objects such as forest roads or compartment lines are quite often arranged along them. This means that a large proportion of all

¹⁷ The distance between the birthplace and the known nesting site of the only two ringed juveniles in Latvia which had been recorded was 221 km (to 217° from the birthplace, in Lithuania, gender unknown) and 63 km (to 323° from the birthplace, in Latvia, female). The distances and directions were calculated by the Latvian Ringing Centre.

feeding sites is subject to the potential of disturbance. Drainage ditches form a substantial part of foraging grounds for many nesting territories (*Strazds 1993c*, Table 35 in the Appendix), but disturbances at feeding sites almost always trigger changes in feeding sites (the author's own observations). If disturbances are frequent and available food is not plentiful, that may substantially increase the amount of time which storks need to feed themselves.

Black storks start incubating after the first or second egg is laid. Both adults incubate, although the time spent in this by the female is slightly higher than is the case with the male. During incubation, adults replace one another (*Cano et al. 2001*), so one of them should be present at the nest. If there is a food shortage, however, an incubating bird that is getting hungry may leave the nest before the other bird has returned — as has been the documented case with the golden eagle (*Jenny 1992*). If weather conditions are unfavourable, moreover, the unattended clutch may cool, and that may kill the embryos. Alternatively, an unattended nest can be an easy target for egg-eating birds. Whichever the case, the nest is unsuccessful (*Strazds 2005*).

Forestry activities are by no means the only source of disturbance. The nesting performance can also be affected negatively by people who simply want to visit the nest or the nesting tree. The role of this factor is certainly much more extensive than may seem to be the case, because such visits are often discovered because of the reports filed by foreign birdwatchers (*Strazds 2005*). There have been cases in which nests are visited by entire classes from a school (*O. Keišs, pers. comm.*).

The tolerance of birds against disturbances can be dependent upon the extent of foraging habitat and its quality in the birds' home range. A proper evaluation of this factor, however, is possible only if the entire size and condition of the habitat are reconnoitred in the field. Available maps quite often present incorrect information about ditches and natural streams. Quite often, natural streams along which only a few segments have been straightened are presented on maps as ditches. This may create a false image of no permanent habitat in the vicinity of a nest at all (Table 7 and Table 35, Appendix), even though there may be plentiful habitats in real life.

There are two other important factors here. It is known that it is not just the length of a waterway, but also its condition which is very important (*Strazds 2005*). The condition of forest drainage ditches is largely affected by the presence or lack thereof of beavers (*Strazds 1993a*). An increase in the beaver population in Latvia in forest drainage ditches in the 1970s may have been one of the major driving forces in safeguarding the increase of the black stork population at that time (*Strazds 1993c*). The second factor which may restrict the use of drainage ditches is overgrowth. Without management, the sides of a ditch may become so dense that the stork

simply cannot access the water. This information can only be obtained from a field inventory of all ditches. Because there are lots of ditches around many nests (Table 7), this is practically not possible.

Another factor which is significant for the stork but is not reflected on maps is the change in feeding grounds which is caused by the construction of “small” hydroelectric power plants. They make feeding less effective, reduce the available stock of prey items, and reduce the extent of the feeding habitat. In 2003, such power plants were built on the Dienvidsusēja River and the Kaugurgrāvis River, and the result was that eight (of nine) pairs which were using these rivers for foraging purposes were unsuccessful in breeding that year (*Strazds 2005*).

The role of predators

The main predators in relation to black stork nests in Eastern Europe are the pine marten and to a lesser extent, the European lynx (e.g., *Horváth et al. 2004; Bumar & Gorban 2004; Czuchnowski & Profus 2004*). I have tried to assess the probability of predation by using different microhabitat variables, but all of our attempts have failed. That is probably because the data which I used for analysis were average indices of a parameter, as opposed to measurements taken specifically for this purpose. If, for instance, the very long branch on which the nest is built sticks into neighbouring spruces, then the distance from the trunk is misleading. There are such cases in Latvia. Still, nests which are positioned away from the trunk are less prone to predation (Table 23, also *Horváth et al. 2004*). One of the possible explanations of the stated case is a shorter lifespan, so that martens do not manage to find the nest, as opposed to the inability to reach it.

The amount of time that martens need to discover a newly established nesting site has shrunk constantly. This is due to the rapid shrinkage in the amount of old-growth forests (Table 7), structural differences between current forests and natural ones (*Lõhmus & Kraut 2010*), as well as a larger number of martens (*J. Ozoliņš, pers. comm.*). Martens are territorial, and they prefer tall forests with a large proportion of spruces (e.g., *Brainerd & Rollstad 2002; Larivière & Jennings 2009*). This is a perfect description of most of the nesting territories of the black stork (Table 9). Martens commonly explore large nests as a place to sleep, particularly in the winter. This means that once they have discovered a nest, they may visit it regularly. We are aware of seven cases in which storks did not abandon their nests after predation. Only two pairs were successful the following year. Two other nests were occupied, but the storks did not lay any eggs. There were two clutches which failed to hatch (cause unknown, predation not being excluded), and in one case the juveniles were once again eaten by a pine marten. In undisturbed forests, the marten

may even be the primary factor in reducing the breeding success of the stork. In the Białowieża Forest, for instance, the black storks reared 1.7 juveniles per occupied nest between 1985 and 1987, largely because of the pine marten (as against 2.5 in successful nests; *Pugacewicz 1995*).

It is quite likely that the *change of nesting location* which takes place after predation may be an *evolutionary trade-off between the costs of translocation* (the time to find a new location and to build a nest, as well as the absence of breeding during the first season; Tables 25 and 28), *and the likelihood of repeated predation* during the following years. The most likely reason as to why we do not know about nests which have been attacked more than twice is that we lack information about the annual occupancy and breeding success of storks in the most long-lived nesting locations.

The frequency of predation by pine martens is probably associated with the availability of its primary source of food — rodents (*Larivière & Jennings 2009*). It is known that in the spring of 2007, when martens attacked more stork nests than ever before, the reason was that there was a strong reduction in rodent populations (*Bergmanis 2008*). Additional evidence relates to the obviously cyclical character of marten activities. Predation cases involving the European lynx are rare and, therefore, insignificant.

The role of the white-tailed eagle in this became significant only in the mid-1990s (*Źuże 2010*), and the impact has been on the rise as its population has increased. The first direct evidence of predation was that the remnants of black storks were found in eagle nests in 2001 and 2003 (*Bergmanis & Strazds 2001; Strazds & Źuże 2006*). The first known attack against a black stork nest occurred in 2007. We are aware of two more cases in which the likely conflict between the white-tailed eagle and the black stork caused the abandonment of the stork nest. The relationship between the two species has also been reported in Hungary. The ring of a juvenile stork has been found under the fledged nest of a white-tailed eagle. What is not clear, however, is whether the eagle attacked the stork's nest or caught an already fledged juvenile elsewhere (*Horváth et al. 2004*).

The black stork and the white-tailed eagle share the same feeding habitat. Their breeding habitats can also be very much the same (*Hagemeijer & Blair 1997*). The white-tailed eagle is a generalist predator whose principal prey is fish and medium-sized birds (*Ferguson-Lees & Christie 2001*). If alternative food is plentiful for the white-tailed eagle, then both species can co-exist in large densities, as has been recorded at the Gemenc National Park in Hungary (*Bank et al. 2004; Tucakov et al. 2006*). If easy prey is lacking, the eagle may try to catch anything that is available, including a black stork. The stork, in turn, may decide to move to a safer territory if it

manages to escape. It is probable that such long-lasting relationships have influenced the breeding habits of the relevant species. The tendency to build nests which are as well hidden as possible from the air could be one of explanations as to why storks are so very eager to use oaks as nesting trees. There are several reasons, as to why storks may build nests in easily visible locations: (1) Most stork nests were built long before the restoration of the white-tailed eagle population, so the birds which built those nests had little or no experience with this particular predator. (2) The availability of suitable nesting trees is certainly another limiting factor in terms of increasing the risk of aerial predation in certain situations. One of the affected nests was built in the tallest tree in the area, so it is very likely that the eagle visited the tree because it was an obvious place to perch. The discovery of the stork nest could have been a side-effect of that decision. (3) The most visible nest (Fig. 18B) is actually built on an artificial platform. After the collapse of the original nest in the same tree, it was built in the most suitable location, but it was unusually high for a stork, and it was close to the canopy tops of nearby trees. Although we lack firm evidence of this, it is likely that white-tailed eagles are pushing black storks out of the area of fishponds and other optimal feeding grounds (like coastal lakes) because available food resources are not guaranteed and change over the course of time (*Baumanis et al. 1999*). The continuous increase in the white-tailed eagle population should allow one to expect that new stork territories will be established in locations where the possibility of similar conflicts is least likely. The impact of other birds of prey is insignificant because of the low frequency of such cases.

Contamination with DDT

The impact of DDT on birds, particularly apex predators and fish-eaters, has been known for a long time (e.g., *Bitman et al. 1968*; *Hickey & Anderson 1968*; *Bailey & Bunyan 1972*). This fact has been used as an important argument in favour of a ban on the agricultural use of the chemical (*Stockholm Convention 2008*). Despite this, the black stork has never been mentioned among the species that are affected by DDT (e.g., *Prinzinger & Prinzinger 1979*). The main reason for this is obviously the fact that most studies concerning the impact of DDT (e.g., *Prestt & Ratcliffe 1972*; *Anderson & Hickey 1972*) have been carried out outside its range.

The evidence that the black stork was affected by DDT between the 1950s and the 1970s relates to a reduction in the weight and thickness of eggshells (Fig. 21, *Grinblate 2010*). It may be that other studies have indicated the same (e.g. *Cramp 1966*). In Poland in 1963, for instance, only 31% of nests produced fledged young, as compared to a 92% success rate in 1959. There were reports of birds engaging in conflicts over nests, as well (*Cramp 1966*). The author did not link his observations to the presence of DDT, and he mentions the different success rates only as

an example of „very marked variation in nesting success in different years”. It is indeed possible that he was unaware of this, because major publications about this issue appeared only a few years later (e.g. *Bitman et al. 1968*; *Hickey & Anderson 1968*). Other publications from this period also mention high mortality rates, e.g., 32% of laid eggs did not produce young in the Bialowieza forest in Belarus in 1956 (*Крaпивный 1957*). Krapivniy attributes this low success to delayed breeding. Later (although the exact years are not known), eggs with reduced eggshell thickness were reported in Poland, too (thickness of 0.25–0.35 mm, or an average of 0.29 mm). For “normal” eggs, the thickness is considerably larger — 0.40 mm (n = 12; p < 00.5; *Zawadzka et al. 1990*). One must stress that this measure is notably smaller than was the case involving eggs from the pre-DDT period (*Gr̄nblate 2010*). This scene is similar to that which has been seen in Latvia during recent years.

In the mid-1960s, the spread of black storks to the mountains was noted in Poland (*Cramp 1966*) and elsewhere in Central Europe (e.g., *Boettcher-Streim 1992*). It is possible that this increase was related to the fact that fast-flowing streams on mountains have been much less contaminated by pesticides than has been the case with slow-flowing lowland waters. The breeding success of the black stork in this habitat has been supported by the independently ongoing release of trout for fishing purposes (*Janssen et al. 2004*).

The impact of DDT covers far more than just Latvia. The first thoughts about this problem were expressed by Hungarian colleagues in 2006 (*Tamás & Kalocsa 2008*). In 2008, we devoted special attention to eggshells that were found under nests, as well as to the number of addled eggs in the nests. The next year, we carried out a study in partnership with researchers from other countries (Tables 37–39 in the Appendix; *Gr̄nblate 2010*). Symptoms very similar to those found in Latvia (increasingly late clutches and a drop in breeding success) have also been reported in Lithuania (*R. Treinys, pers. comm.*), but Lithuanian colleagues did not take part in the study because they could not obtain permits for the collection of addled eggs.

An important finding in all of this was the discovery of variations in the thickness of eggshells (*Gr̄nblate 2010*). The level of DDT in the analysed eggs varied from 0.582 µg/g to 219.84 µg/g of lipid weight, which is far above the European Union’s accepted threshold of 0.05 µg/g (*CRLs 2008*) — above that threshold by a factor or > 4,000. Current DDT concentrations are lower than was the case in the late 1960s (e.g., *Ratcliffe 1970*; *Anderson & Hickey 1972*), when DDT had been used intensively for 15 to 20 years (>40,000 tonnes per annum; *Stockholm Convention 2008*). Then the reduction in eggshell thickness was expressed as a significant negative deviation from the average value. Recently addled eggs show reductions of only 5.5%. The increase in the

variation of eggshell thickness probably illustrates just how the eggshells are thinning — starting with just a few points. These points can cause breeding failure, but they do not have a significant effect on the average eggshell thickness as such. We found only three eggs in museum collections that were collected during the early period of DDT use. The egg collected in 1973 was the only one apart from recently collected ones where the variation exceeded 10% (Fig. 22). This may also offer evidence of the impact of DDT on the black stork population during the early use of the pesticide.

All of the identified avian impacts of DDT (Prinzinger & Prinzinger 1979) are present in black storks in Latvia. This includes reductions in eggshell thickness (*Grünblate 2010*), delayed laying of eggs (Fig. 24), a reduction in clutch sizes (Fig. 4), abnormal development of embryos, and an increased mortality rate among juveniles and fledglings (Table 30). It is possible that as far as the black stork is concerned, the impact of DDT is manifested most quickly through the delayed laying of eggs. In the northern part of the range, the breeding season is almost one month shorter than is the case elsewhere (e.g., *Janssen et al. 2004*). This means that “northern” storks have approximately 140 days of time. The incubation of an egg takes at least 30 days (32–28), while juveniles fledge at the age of some 64 days. The adults arrive about one week before the first egg is laid. A normal clutch consists of three to five eggs, which are laid at an interval of one or two days. Incubation begins after the first or the second egg (*Janssen et al. 2004*). The actual season lasts longer than 100 days, so any delay exceeding 40 days can be seen as critical. All but one of the juveniles from Latvia which were re-sighted during their first migration in Israel were hatched no later than 43 days after April 1. This matches the theoretical estimates quite well.

The presence of DDT causes delays in the laying of the first egg for at least 10 days (Fig. 24). This may have been the reason for the disappearance of black storks from the northern part of their range during the period of intensive DDT use. The last known breeding of the black stork in Sweden was in 1953 (*Risberg 1990*), and the same was true for the Jutland Peninsula of Denmark (*Janssen et al. 2004*). In other words, this happened five to seven years after the intensive start of DDT usage first began. In the northern part of Estonia, the numbers dropped from 15 in the 1950s to just 2–3 in 1968 (*Õun 1994*). “Significant reductions in numbers” were also reported in Latvia during the 1960s (*Вилкс 1968, Балтвилкс 1972*). The data of Kārlis Vilks were gathered in the north-eastern part of the country. The authors did not link the decrease to contamination, but this may have been a forbidden subject in the Soviet Union at that time. It is also true that the strongest decline in population numbers in recent times has been seen in the northernmost part of the species’ range in Estonia (*Sellis 2000; Sellis 2004*) and Latvia.

The source of the DDT is open to speculation. Latvia and its neighbouring countries are unlikely sources for a number of reasons: (1) DDT residues tested in water bodies and fish are at a minimal level — well below WHO-defined thresholds (*Klavinsš et al. 1998; Roots 2001; Roots & Zitko 2001*). (2) In those cases where two eggs were taken from one and the same nest, the level of DDT always differed (e.g., the second egg was less contaminated than the first one). (3) The liver of dead juveniles which were examined did not show any presence of p,p’DDT, which shows that the birds did not absorb the chemical along with their food (*Grīnblate 2010*). (4) The white-tailed eagle, which is the non-migratory apex predator, has been monitored for residues of contaminants in the Baltic Sea region, but no fresh contamination has been found (*Helander et al. 2002*). It is thus likely that the black stork becomes contaminated at stop-over locations during migration and/or wintering.

Ethiopia, which has recently been cited for the illegal use of DDT (*Weber 2009*), is a major wintering area for black storks from Eastern Europe (*Bobek et al. 1997; unpublished data from the Eagle Club of Estonia*,¹⁸ *U. Sellis, pers. comm*). Black storks which use the western flyway have exhibited DDT in their eggs, suggesting other geographical sources in Africa or en route. Concentrations in their eggs were much lower, and there have been no signs of contamination so far in these populations. This suggests that black storks ingest more DDT on the easterly route. Contamination may not have yet reached the pre-1975 DDT level, but breeding success has already been reduced markedly. As far as we know, this is the first suggestion in the European-African migration system that the breeding success of a species is being affected by pesticide contamination imported from winter grounds, even though this issue has been raised with respect to at least one other species (*Jagannath et al. 2008*). Because the black stork is not known to be particularly prone to contamination by chlorinated hydrocarbons, there is a considerable risk that other African migrant species may be affected, as well.

Conservation measures and management

The earliest recommendations related to the size of protected zones around the nesting sites of the black stork in Latvia were elaborated in the 1970s. In May 1971, the Institute of Biology was preparing new recommendations about environmental conservation, and it listed a series of protected animals in two categories. The black stork and 13 other species were listed as “natural monuments” — the highest category (*Spuris et al. 1971*). The recommendations said that in order to protect this species, “extreme measures, including a total ban (on exploitation) can be

¹⁸ see <http://www.kotkas.ee/ENG/strack.html>

implemented”. In regard to the black stork, Jānis Baltvilks and Jānis Vīksne¹⁹ wrote that “over the last several decades, the number of black storks has diminished significantly, because these birds are very sensitive toward disturbances in the vicinity of their nests, as well as toward changes in the nearby surroundings of the nest.” Baltvilks and Vīksne recommended a ban on “all activities closer than 300 metres to the nests (including forest cutting, drainage, and use of turf resources).”

Along with data that were gathered for the Red Book beginning in 1977, micro-reserves were designated in relation to almost all of the breeding sites that had been discovered. In a few cases, the State Forest Service objected to this designation, using arguments such as “This stand has been prepared for clear-felling, so it cannot be protected.” At the same time, however, the first detailed recommendations on the creation of micro-reserves were drafted only in 1983 (*Lipsbergs 1983*). Lipsbergs defined a micro-reserve as “a territory with strict protections — ideally a circle which encompasses the nest tree from all sides, one where any activities and other disturbances are banned.” Micro-reserves, he wrote, should “usually be created” for a 10-year period, and they absolutely must “encompass all compartments of old-growth stands.” He also recommended that strictly protected zones be created for black stork nests with a radius of 100-150 metres, although he admitted that the size and shape of individual zones “would vary according to local circumstances.” Also for the first time, rules were defined as to permitted management activities: “Where necessary between September 1 and March 1, only intermediate thinning and/or sanitary cuttings shall be allowed on the basis of individual permits issued by the Department of Nature Conservation of the Ministry of Forestry.” The same period was applied to cuttings planned for compartments “directly adjacent to micro-reserves” (*Lipsbergs 1983*). Obviously this was a compromise between the desired regime and that which was accepted by the contracting authority — the Ministry of Forestry and Forest Management. Neither the defined areas of protection nor the longevity of the micro-reserves were based on any arguments, however.

The first evaluation of the adequacy of recommended micro-reserve sizes was conducted in 1993, when this author was evaluating the role of such services (*Strazds 1993d*). The author’s conclusions led to an increase in the target radius of a reserve to 250 metres. This was implemented in practice beginning in 1996, when the designation of micro-reserves in Latvia was re-started after a six-year interruption. (*Strazds 2005*). When work was performed on new conservation legislation in 1999, additional analysis was performed with respect to the trans-

¹⁹ These ornithologists authored the section of the recommendations which related to birds, and they may also have been the originators of the concept of a “micro-reserve.”

location distances of birds. The evidence showed that a micro-reserve with a 250 m radius (20 ha on average), if designated in relation to all suitable nesting stands, would encompass 84–89% of all natural translocations (*Strazds 2003*).

In turn, the discovery that the nest trees of the black stork (pines) were two times older than the ordinary cutting age of that species led the Latvian Ornithological Society (LOB) to organise an advocacy campaign that was supported by BirdLife International. Latvia's Parliament was asked to safeguard the maintenance of elements that are essential for the protection of biodiversity during more intense forest use, as well as to ensure adequate conditions in new forestry-related legislation. The LOB was successful in its lobbying, and Paragraph 36 of the law was expanded with this sentence: "Particularly important elements of the forest structure shall be maintained during all cuttings."²⁰ The established practice referred to the maintenance of five to 10 wind-safe trees in clear-cut areas. This had been a part of operational regulations related to cuttings since 1997,²¹ but now the requirements were enshrined by law. The recommendations of the LOB in this regard also served as the basis for new Cabinet of Ministers regulations to define the principles and criteria of the maintenance of retention trees.²²

A forestry impact study that was conducted between 2003 and 2005 identified quite a few cases in which forestry operations in the immediate vicinity of micro-reserves disturbed breeding. That was because existing restrictions related to micro-reserve buffer zones did not allow for the creation of proper zones of that type all around a micro-reserve. Given that the minimum disturbance distance for successful nests in 90% of cases was beyond the threshold of 500 metres, that distance was recommended as the minimal radius within which no activities may be carried out during the breeding season (*Strazds 2005*). This study confirms (Table 17, Fig. 16, and text on Page 46) that 500 metres is the minimal acceptable distance within which no activities are to be allowed if the breeding success of the stork is to be safeguarded.

The formerly recommended longevity of micro-reserves — 10 years — is too short a period of time, because the average lifespan of nesting locations is greater than 15 years (Table 16). In

²⁰ The law was published in *Vēstnesis*, No. 98/99, 16 March 2000, with amendments of 13 March 2003 reported in *Latvijas Vēstnesis*, No. 47, 26 March 2003 and *Ziņotājs*, No. 8, 2003, and amendments of 27 January 2005 reported in *Latvijas Vēstnesis*, No. 20, 4 February 2005.

²¹ This refers to regulations regarded to final cuttings, enshrined in Instruction No. 38 of the State Forest Service, Ministry of Agriculture, 24 April 1997.

²² Cabinet of Ministers Regulation No. 45, 30 January 2001, „Regulations on the Designation, Protection and Management of Micro-reserves,” as amended on 31 May 2005. See *Latvijas Vēstnesis*, No. 2406, 2 February 2001. See also Cabinet Regulation No. 189, 8 May 2001, “Environmental Protection Regulations in Forest Management,” as amended on 12 May 2001, 1 March 2002, 12 February 2005, and 21 May 2005, *Latvijas Vēstnesis*, No. 73(246), 11 May 2001.

many cases, immediate cutting of a former nesting stand after the abolishment of the relevant micro-reserve has been the principal causative factor in terms of restricting the birds' return to former nesting sites. Almost all locations in which storks were found to be nesting 30 and more years ago and which have remained undisturbed are still active today. The only argument-based solution for the maintenance of the nesting sites of the black stork, therefore, must be the establishment of permanent reserves, with discussions about the abolishment of reserves being possible only in those cases when large areas have been completely deforested.

Causal relationships

Annual productivity is one of the significant factors in determining a demographically stable population (e.g., *Newton 1989*), but when it comes to long-lived species, demography-driven changes are manifested with a certain time lag. Accordingly, we can conclude that poor annual breeding success is the main factor in causing population decline in the long run (e.g. *Lõhmus et al. 2005*). Both predatory activities and disturbances caused by forestry can trigger changes in nesting sites (Table 25), but the probability of return in these cases does differ (Fig. 20). Our data suggest that nests which have been affected by forestry remain unattended for a much longer time (Table 18). The most likely explanation of this is that the impact of forestry apart from the disturbance itself has affected the nearby vicinity of the nest so that the altered environment has become unattractive. Apart from the direct impact of disturbance, translocation also occurs, and in most cases this means at least one unproductive season (Table 28). Furthermore, new nesting sites are usually not protected. This makes them more prone to disturbances related to forestry or other human activities, and that once again triggers the abandonment of such sites. There are cases among studied nests which confirm such scenarios (*Strazds 2006*).

Predator activity might have been very high in some years (Fig. 17), but there have also been years in which predators have not affected any nests at all. Predators operate on the basis of the “all or nothing” principle. Furthermore, if the breeding performance of black storks is affected only by predators, the characteristics of this process change in two opposite directions. Under severe pressure from predators, overall breeding success may diminish, and yet the season for successful breeding season becomes shorter (*Pugacewicz 1995*) as a result of no disturbance-related interruptions. Although predator-related pressure on the black stork population in Latvia has increased significantly, the direct impact of martens on the breeding performance of storks (Tables 33 and 34 in the Appendix) is not higher than is the case in the undisturbed forests of Bialowieza (*Pugacewicz 1995*). The negative impact of predation cases has more to do with changes in habitat quality, which is subordinated to the impact of forestry.

Forestry, in turn, has a twofold effect. Apart from direct disturbances, forestry also leads to a reduction in the number of suitable nesting stands and, particularly, specific trees (*Lõhmus & Kraut 2010*). The intensity of forestry operations during the spring season has increased significantly (Figs. 14, 15), and this has remained at a high level during the last several years. This particularly affects unprotected nests, but it also has an effect on protected ones because the protected zones of micro-reserves are too small.. This is doubtless the most significant factor in causing low productivity and, in the long run, a reduction in the size of the stork population.

Neither of the aforementioned factors could cause a delay in the laying of eggs, a reduction in the size of the clutch or, particularly, any reduction in the rate of juvenile survival after fledging. All of these factors have been observed in Latvia, and they could be associated exclusively with the impact of DDT. This provides a firm foundation for the conclusion that the role of chemical contamination has become more important during the last several years. It is absolutely certain that it is occurring together with other factors. For instance, a delay in the laying of eggs extends the period during which birds are sensitive toward forestry-related disturbances. This, in turn, can increase the overall negative impact of forestry, as well.

Finally, it has been concluded that adverse weather conditions can affect breeding success, at least at the local level because of the reduced availability of food (*Strazds et al. 1989*). These factors were not analysed intentionally, mostly because the impact of this factor cannot be manipulated. Furthermore, the large dispersion of the breeding season means that proper analysis would be possible only if the individual meteorological measurements of the surrounding area of each nest were taken every year, as opposed to the average indices for the country or a larger region. Such data are not available.

Conclusions

- 1) The presence of trees from previous generations — particularly pines and oaks — in the stand is an essential element of the nesting habitat of the black stork. This means that when choosing retention trees, priority must be given to trees that are likely to reach the next successive stand where they can serve as nesting trees for the black stork.
- 2) In forests without suitable oak trees, black storks prefer aspens as nesting sites. The lifespan of nesting sites in aspens is much shorter than it is in pines or oaks, because aspens have a shorter lifespan and also have weaker branches. Existing forestry policies have significantly reduced the availability of appropriate aspens, which means that in regions without suitable oaks, it is very important to maintain adequate stands of aspens from all age groups.
- 3) The black stork has learned to co-exist with its main predators — the pine marten and the white-tailed eagle. The most likely expression of this fact is a tendency to build nests in oaks (where the birds are less visible from the air) and on side branches (where they are less accessible for pine martens). The change of a nesting site after cases of predation could be a reaction against repeated predation.
- 4) The predation rate of the marten is of a cyclical nature, most probably related to the availability of small rodents which are the main food for the animal. Although the marten's impact on the breeding performance of the black stork has increased significantly, it does not exceed the impact of predators in undisturbed forests.
- 5) Forestry-related disturbances, particularly in the spring, can be held responsible for omitted breeding seasons or breeding failures in approximately 70% of the relevant cases. The large proportion of unproductive breeding cases is the most important factor in terms of overall productivity, and in the long run, this will inevitably lead to a further reduction in the population.
- 6) During the last several years, the impact of chemical contamination on the breeding success of the black stork has increased. It has caused delays in the laying of eggs, reductions in the size of clutches, and reduced survival of juveniles after fledging.

Recommendations for conservation

Implemented recommendations

Retention trees

The necessity to preserve biodiversity conservation elements that are of importance for the structure of forests is addressed in Section 36 of the Latvian Forest Act. The relevant Cabinet of Ministers regulations specify this as a requirement that “during final or intermediate cutting, at least the five oldest and largest viable trees be left uncut in any hectare of cutting, primarily selecting trees with large and thick branches, hollow trees, trees with burn marks, and oaks, lime trees, pines, ashes, elms, flatter elms and maples.”²³ Although the requirement to leave the oldest and most vital trees in place is often ignored in practice (*Valsts meža dienests 2009*), the overall role of retention trees is a very significant investment in the future quality of the forest, and this has already provided direct advantages to some species (*Ķuze 2010*). At the same time, however, it would be very desirable if in the selection of trees that are to be left uncut, people give greater consideration to the composition and quality of the trees. Trees which can perform a significant role in the next-generation forest must be given priority (*Lõhmus & Kraut 2010*).

The size of micro-reserves

Based on our analysis of translocation distances related to natural collapses of nests, we proposed the creation of micro-reserves for black storks with a 250 m radius around the nest or an average of 20 hectares. If designated properly, these territories should encompass 84-89% of all natural translocations (*Strazds 2003*). Regulations that are based on these recommendations²⁴ require that micro-reserves around black stork nests be of an area of 10–30 ha.

Required changes in forest management

(with changes from *Strazds 2006a*)

The optimal solution in benefitting not just the black stork, but also the majority of other forest-dwelling birds or mammals, would be a complete ban on forest management activities during the critical period of the black stork’s breeding season — mid-March to mid-June.

²³ Cabinet of Ministers Regulation No. 189, 8 May 2001, “Environmental Protection Regulations in Forest Management,” as amended 12 May 2001, 1 March 2002, 12 February 2005 and 21 May 2005. See Latvijas Vēstnesis, No. 73(2460), 11 May 2001.

²⁴ Cabinet of Ministers Regulation No. 45, 30 January 2001, “Regulations on the Designation, Protection and Management of Micro-reserves,” as amended 13 May 2005. See Latvijas Vēstnesis, No. 19(2406), 2 February 2001.

If this is impossible for other reasons unrelated to the conservation of biodiversity (social aspects, important forest replanting activities in specific seasons, etc.), then it is nevertheless of essential importance to halt all forestry activities in Latvia at least during the month of April if we want to maintain the population of the black stork. Work that can be done during other seasons must absolutely be minimised during the spring, and the overall proportion of forestry activities in April and May should not exceed 8 to 10% of the total annual amount.

In the 2003–2005 study, I found that lots of early thinning activity occurs in the vicinity of black stork nests, and the number of such operations has only increased since that time. It is of key importance to amend regulations related to springtime forest management to ban them from April 1 (or March 15 for work that begins in March). The ban must be applied to all plantations and naturally regenerated stands up to age of 20 years.

Required changes in legislation

The buffer zone around micro-reserves which have been established for black stork nests must be expanded to no less than a radius of 500 metres around the nest, including all segments of any property which even partially abuts this radius. Only seasonal restrictions can be applied to this buffer zone. Any management activities there must be carried out between September 1 and March 1.

The status of micro-reserves must be made permanent. Planning in this regard must take into account not just stands where the black stork can breed at this time, but also those stands which will become suitable for this purpose over the next 20 years. Such stands must be included in micro-reserves. This applies to aspen stands that are older than 50, any stands which contain aspens of that age, stands of pines, ashes and oaks that are older than 70, and any stands with trees that are suitable for nest building. Stands without suitable trees for nesting or in which it is likely that no such trees will emerge during the next 20 to 30 years are not to be included in the territory of a micro-reserve.

The existing restriction which says that micro-reserves can be established only in regard to “inhabited” nests must be repealed. What this means is that the designation of micro-reserves outside of the breeding season is not possible. Short-term abandonment is characteristic of all long-lived stork nests, and the main cause for this is the presence of forestry activities or predators.

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Appendix

Table 31. The prey items of the black stork in Latvia and surrounding territories

Species / group	Location†	Years	Share in total number	Mean weight (g)	N	Source
Fish						
<i>Misgurnus fossilis</i>	Byalowieza, BY	1955–56	31.4%	6.6	981	Крапивный 1957
	Kampinos NP, P	1985–87	10.5%		58	Zawadzka et al. 1990
<i>Rutilus rutilus</i>	Latvia	1990–2005		12.8	27	Strazds 2005
	Kampinos NP, P	1985–87	12.8%		56	Zawadzka et al. 1990
<i>Alburnus alburnus</i>	Latvia	1990–2005		16.3	23	Strazds 2005
<i>Gobio gobio</i>	Byalowieza, BY	1955–56		4.9	167	Крапивный 1957
<i>Carassius carassius</i>	Byalowieza, BY	1955–56		20.4	35	Крапивный 1957
<i>Esox lucius</i>	Byalowieza, BY	1955–56	18.7%	16	243	Крапивный 1957
	Latvia	1990–2005		73	17	Strazds 2005
	Kampinos NP, P	1985–87	34.7%	84		Zawadzka et al. 1990
<i>Perca fluviatilis</i>	Latvia	1990–2005		10.8	21	Strazds 2005
<i>Leucaspis delineatus</i>	Latvia	1990–2005		11.9	15	Strazds 2005
<i>Lota lota</i>	Latvia	1990–2005		90	2	Strazds 2005
<i>Cobitis taenia</i>	Latvia	1990–2005		6	1	Strazds 2005
<i>Tinca tinca</i>	Latvia	1990–2005		40	1	Strazds 2005
<i>Anguilla anguilla</i>	Kampinos NP, P	1985–87	5.4%		1	Zawadzka et al. 1990
<i>Leuciscus idus</i>	Kampinos NP, P	1985–87	1.8%		10	Zawadzka et al. 1990
Amphibians						
<i>Rana ridibunda</i>	Byalowieza, BY	1955–56	20.3%	31	136	Крапивный 1957
<i>Rana temporaria</i>	Byalowieza, BY	1955–56		9.4	218	Крапивный 1957
	Latvia	1990–2005		15.1	180	Strazds 2005
<i>Rana arvalis</i>	Byalowieza, BY	1955–56		5.9	226	Крапивный 1957
<i>R. arvalis/temporaria</i>	Kampinos NP, P	1985–87	22.4%		217	Zawadzka et al. 1990
<i>Rana „esculenta”</i>	Kampinos NP, P	1985–87	2.4%		12	Zawadzka et al. 1990
<i>Triturus cristatus</i>	Kampinos NP, P	1985–87	0.05%		2	Zawadzka et al. 1990
<i>Triturus vulgaris</i>	Kampinos NP, P	1985–87	0.05%		1	Zawadzka et al. 1990
Invertebrates						
Invertebrates	Byalowieza, BY	1955–56	4.6%		1236	Крапивный 1957
Invertebrates	Kampinos NP, P	1985–87	0.4%		56	Zawadzka et al. 1990
Reptiles						
<i>Lacerta vivipara</i>	Byalowieza, BY	1955–56			1	Крапивный 1957
Birds						
<i>Emberiza citrinella</i>	Kampinos NP, P	1985–87	0.3%		1	Zawadzka et al. 1990
<i>Saxicola rubetra</i>	Byalowieza, BY	1955–56			5-n	Крапивный 1957
<i>Alauda arvensis</i>	Byalowieza, BY	1955–56			5-n	Крапивный 1957

† Byalowieza, BY = Byalowieza Forest in Belarus, Kampinos NP, P = Kampinos National Park, Poland

Table 32. The number of measured and ring-marked juveniles and a precision of estimated ages

Year	Ring-marked juveniles	Number of nests where juveniles are ringed	Number of nests where the laying date of the 1st egg is estimated	Precision of estimate (days)	Variation of estimate (days)
1991	21	7	14	4.3	2–10
1992	20	6	8	2.9	2–5
1993	15	6	8	3.1	2–5
1994	24	8	10	2.7	2–4
1995	28	13	14	3.4	1–10
1996	78	26	24	2.1	1–3
1997	23	9	23	4.0	2–10
1998	23	12	14	3.1	2–5
1999	36	12	30	3.8	2–10
2000	8	4	15	3.8	2–6
2001	39	16	27	4.3	2–16†
2002	82	30	38	3.6	2–10
2003	37	14	23	3.6	2–10
2004	52	19	32	4.0	2–10
2005	73	25	44	3.7	2–10
2006	55	21	41	3.6	2–5
2007	66	26	41	3.5	2–10
2008	83	30	50	2.8	1–5
2009	80	33	47	2.2	1–10
Total	843	317	503		1–16

† The precision of ± 10 is attributed to unmeasured juveniles which were close to fledging. Fledged juveniles were not subject to estimations except for one extremely late breeding case (± 16) in 2001, when juveniles with poor flight skills were still in the nest on September 11 (*I. Medne, pers. comm.*).

Table 33. The results of annual nest inspections

Year	Checked		Other species nesting	Collapsed		Just abandoned		Occupied nests	Success	
	nests	territories		between seasons	in season	N	%		unknown	known
1	2	3	4	5	6	7	8	9	10	11
Total	4981	4577	1.56	3.22	1.38	359	7.3%	2930	1296	1634
1979	62	62	0	0	0	1	1.6%	59	39	20
1980	63	63	0	0	0	1	1.6%	60	32	28
1981	64	62	0	0	1	1	1.6%	60	40	20
1982	79	76	0	2	0	2	2.6%	64	50	14
1983	102	96	0	2	1	3	3.1%	78	51	27
1984	140	133	2	2	1	7	5.3%	111	80	31
1985	175	163	1	1	1	8	4.9%	127	85	42
1986	195	182	1	1	1	7	3.8%	149	115	34
1987	160	151	1	2	1	7	4.6%	122	84	38
1988	163	153	0	2	4	7	4.6%	114	78	36
1989	185	170	0	3	0	8	4.7%	120	81	39
1990	82	76	1	1	0	5	6.6%	55	34	21
1991	293	265	2	6	1	10	3.8%	155	106	49

Table 33. The results of annual nest inspections (continued)

1	2	3	4	5	6	7	8	9	10	11
1992	132	125	2	3	0	6	4.8%	95	66	29
1993	146	130	1	11	4	8	6.2%	81	47	34
1994	149	131	4	1	2	12	9.2%	80	32	48
1995	181	152	4	2	1	15	9.9%	86	28	58
1996	191	177	2	0	1	11	6.2%	98	33	65
1997	132	121	0	4	1	16	13.2%	78	24	54
1998	105	102	0	3	3	9	8.8%	64	17	47
1999	116	110	0	4	1	5	4.5%	81	17	64
2000	130	115	4	1	3	12	10.4%	74	29	45
2001	132	121	2	2	1	6	5.0%	79	27	52
2002	157	145	2	2	4	14	9.7%	92	29	63
2003	196	176	2	4	1	17	9.7%	93	19	74
2004	184	170	3	6	0	20	11.8%	94	19	75
2005	225	196	2	15	1	19	9.7%	94	8	86
2006	236	211	7	2	2	19	9.0%	95	6	89
2007	249	227	2	8	4	18	7.9%	106	10	96
2008	213	194	1	3	2	34	17.5%	106	6	100
2009	179	168	2	3	1	29	17.3%	84	3	81
2010	165	154	2	7	1	22	14.3%	76	1	75

Table 34. The main characteristics of breeding success in nests with known success

Year	Total	Non-breeding		Predated		Unproductive in total		Successful		Pull./Occupied nest		Pull./Successful nest	
		N	%	N	%	N	%	N	%	Avg.	SD	Avg.	SD
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Total	1634	339	18.1%	69	4.2%	601	32.7%	1033	63.2%	1.81	1.35	2.66	0.85
1979	20	1	5.0%	1	5.0%	4	20.0%	16	80.0%	2.45	1.50	3.06	0.93
1980	28	5	17.9%	2	7.1%	8	28.6%	20	71.4%	1.71	1.30	2.40	0.96
1981	20	1	5.0%	1	5.0%	3	15.0%	17	85.0%	2.80	1.51	3.29	0.99
1982	14	1	7.1%	1	7.1%	2	14.3%	12	85.7%	2.57	1.55	3.00	1.21
1983	27	2	7.4%	0	0.0%	5	18.5%	22	81.5%	2.41	1.45	2.95	1.01
1984	31	2	6.5%	2	6.5%	9	29.0%	22	71.0%	2.03	1.47	2.86	0.83
1985	42	6	14.3%	1	2.4%	8	19.0%	34	81.0%	2.26	1.40	2.79	0.95
1986	34	2	5.9%	0	0.0%	3	8.8%	31	91.2%	2.44	1.08	2.68	0.80
1987	38	3	7.9%	0	0.0%	5	13.2%	33	86.8%	2.58	1.23	2.97	0.85
1988	36	6	16.7%	2	5.6%	16	44.4%	20	55.6%	1.39	1.42	2.50	0.89
1989	39	5	12.8%	1	2.6%	7	17.9%	32	82.1%	2.46	1.45	3.00	0.95
1990	21	2	9.5%	1	4.8%	4	19.0%	17	81.0%	2.05	1.16	2.53	0.62
1991	49	11	22.4%	1	2.0%	15	30.6%	34	69.4%	2.02	1.52	2.91	0.83
1992	29	7	24.1%	0	0.0%	8	27.6%	21	72.4%	2.03	1.55	2.81	1.03
1993	34	7	20.6%	2	5.9%	14	41.2%	20	58.8%	1.32	1.27	2.25	0.79
1994	48	13	27.1%	7	14.6%	27	56.3%	21	43.8%	1.02	1.28	2.33	0.80
1995	58	14	24.1%	5	8.6%	25	43.1%	33	56.9%	1.28	1.29	2.24	0.87
1996	65	18	27.7%	3	4.6%	25	38.5%	40	61.5%	1.65	1.49	2.68	0.90
1997	54	9	16.7%	2	3.7%	17	31.5%	37	68.5%	1.59	1.22	2.32	0.67
1998	47	13	27.7%	0	0.0%	20	42.6%	27	57.4%	1.28	1.25	2.22	0.82

Table 34. The main characteristics of breeding success in nests with known success (continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
1999	64	7	10.9%	2	3.1%	13	20.3%	51	79.7%	2.41	1.48	3.02	0.93
2000	45	11	24.4%	3	6.7%	19	42.2%	26	57.8%	1.27	1.21	2.19	0.69
2001	52	9	17.3%	2	3.8%	18	34.6%	34	65.4%	1.67	1.50	2.56	1.08
2002	63	7	11.1%	1	1.6%	16	25.4%	47	74.6%	1.97	1.44	2.64	0.95
2003	74	20	27.0%	4	5.4%	39	52.7%	35	47.3%	1.12	1.31	2.37	0.77
2004	75	16	21.3%	2	2.7%	27	36.0%	48	64.0%	1.63	1.36	2.54	0.74
2005	86	13	15.1%	6	7.0%	30	34.9%	56	65.1%	1.91	1.55	2.93	0.81
2006	89	29	32.6%	0	0.0%	36	40.4%	53	59.6%	1.61	1.45	2.70	0.75
2007	96	30	31.3%	10	10.4%	58	60.4%	38	39.6%	1.05	1.45	2.66	1.02
2008	100	20	20.0%	5	5.0%	46	46.0%	54	54.0%	1.58	1.64	2.93	1.07
2009	81	27	33.3%	2	2.5%	42	51.9%	39	48.1%	1.12	1.35	2.33	0.85
2010†	75	22	29.3%	1	1.3%	32	42.7%	43	57.3%	1.40		2.44	

† Indices from 2010 were incomplete at the time of the publication of this dissertation, so standard deviations of breeding success indices were not calculated.

Table 35. The characteristics of nests included in the forestry impact study (from *Strazds 2006a*)

Nest Nr. and name	Homesteads within 3 km zone	Homesteads within 1 km zone	Total feeding habitat within 3 km zone (ha)	Permanent feeding habitat within 3 km zone (ha)	Temporary feeding habitat within 3 km zone (ha)	Forest cover within 3 km zone %	Percentage of permanent feeding habitat %	Year when the territory was found	Known age (years)
1	2	3	4	5	6	7	8	9	10
011803 Jēcupe	3	1	4.5	1.4	3.1	99.0%	30.5%	1992	14
031602 Šuķene	37	0	3.0	1.8	1.2	76.8%	60.7%	1983	23
032905 Gagarina dambis	2	0	5.5	0.6	5.0	94.6%	10.2%	1989	17
041904 Spārmuiža	50	2	5.8	0.5	5.4	58.9%	7.8%	1995	11
043202 Labrags	5	0	5.7	3.2	2.5	97.9%	55.9%	1998	8
072401 Robertkalns	58	1	3.2	2.5	0.7	25.1%	77.8%	1994	12
072801 Dumburpurvs	22	0	6.5	4.4	2.0	25.5%	68.5%	2004	2
081902 Dāmas mežs	46	2	2.1	1.0	1.1	43.0%	49.8%	1994	12
083602 Naiži	0	0	4.2	0.2	3.9	87.5%	5.9%	1978	28
083901 Bolderi	3	0	3.8	0.2	3.6	81.5%	4.5%	1986	20
093705 Dižlaucinieki	4	0	0.8	0.2	0.7	98.1%	19.5%	2002	4
093802 Priekšpiltene	1	0	2.3	0.6	1.6	94.2%	28.2%	2002	4
094402 Maisteru pūrs	29	1	4.7	1.7	2.9	76.3%	36.9%	1995	11
094601 Liepkangars	1	0	1.3	0.3	1.1	95.6%	19.7%	1981	25
112501 Sūnkalns	43	2	3.3	1.5	1.8	62.6%	44.5%	1995	11
113606 Zlēku dzirnavas	14	0	2.0	0.2	1.8	86.4%	9.7%	1984	22
134002 Vasenieku purvs	0	0	4.2	2.6	1.5	76.7%	63.6%	1995	11
152801 Dzeņu mežs	12	0	3.4	1.3	2.2	45.9%	36.6%	1979	27
153404 Lielais tīrelis	37	0	5.6	0.2	5.3	65.3%	4.3%	1981	25

Table 35. The characteristics of nests included in the forestry impact study (continued)

1	2	3	4	5	6	7	8	9	10
154202 Pārkaktes strauts	5	0	6.6	3.9	2.7	93.2%	59.3%	1996	10
154801 Rākstu strauts	24	0	4.0	2.5	1.5	96.4%	63.0%	1997	9
163406 Renda	37	2	6.3	3.5	2.8	69.0%	55.6%	2002	4
172102 Grīvaišu mežs	47	0	6.0	2.7	3.3	44.8%	44.8%	1996	10
173401 Jaunezera mežs	14	0	2.0	0.9	1.1	76.0%	44.7%	2000	6
174407 Kaļķupes ozols	11	0	3.1	1.9	1.2	67.2%	61.8%	2000	6
182101 Līkupe	10	0	6.2	4.2	2.0	68.2%	67.2%	1996	10
182423 Āķu mežs	34	0	2.3	0.2	2.1	52.6%	7.3%	2002	4
182901 Brancu mežs	38	2	3.2	1.3	1.8	39.2%	41.7%	2005	1
183202 Dziru mežs	37	0	3.5	0.3	3.1	30.9%	9.6%	1978	28
184201 Tiltiņi	65	3	4.3	2.3	2.0	22.7%	53.4%	1983	23
184605 Pilsupe	12	1	7.3	2.8	4.5	89.4%	38.0%	2005	1
192105 Sodnieku ozols	24	0	5.3	3.7	1.7	56.2%	68.8%	1999	7
192106 Dekšenieki	11	0	3.8	2.4	1.3	60.4%	64.4%	2002	4
192902 Bičkas	41	0	2.9	1.1	1.9	45.8%	36.7%	1999	7
202203 Rumbu mežs	1	0	3.5	2.0	1.5	86.9%	57.5%	2002	4
202302 Laugaļu leja	2	0	3.3	1.8	1.5	81.7%	54.7%	1996	10
202303 Stiepenes purviņš	6	0	3.2	0.6	2.6	62.5%	19.2%	2004	2
202602 Tušķu mežs	17	0	3.0	0.4	2.6	66.4%	13.7%	2004	2
202801 Saulīšu purvs	39	1	4.2	1.2	3.0	48.0%	28.5%	1972	34
203502 Šķersciems	39	0	1.8	0.0	1.8	67.4%	0.0%	1993	13
212503 Smukupīte	19	0	4.6	2.1	2.6	39.9%	44.6%	2000	6
213206 Zemītes skola	36	0	2.3	0.1	2.3	59.7%	2.3%	1982	24
222802 Viesatas egle	20	2	3.8	2.1	1.7	61.1%	54.7%	1995	11
223901 Dravas priede	50	0	4.6	1.7	2.9	33.0%	36.3%	1979	27
234101 Liepiņu dambis	2	0	7.0	0.0	7.0	94.5%	0.0%	1999	7
252102 Zape	20	0	3.1	0.1	3.0	52.0%	2.9%	2004	2
252301 Dārzieki	22	3	1.9	0.6	1.3	52.7%	30.6%	2000	6
261901 Stērķu mežs	33	1	3.0	0.0	3.0	32.8%	0.8%	1980	26
262108 Kārklumuižas mežs	40	0	5.1	0.4	4.7	53.6%	7.0%	1996	10
262201 Penkule	49	4	3.7	2.0	1.8	42.2%	52.8%	1984	22
272006 Iršu dārzs	32	0	3.4	0.9	2.5	36.1%	26.1%	1989	17
272401 Pakaisu mežs	25	0	2.6	0.8	1.8	48.4%	31.4%	1994	12
273304 Lustūžkalns	40	5	3.8	3.1	0.7	86.0%	80.7%	2000	6
283203 Smārde	35	1	2.9	1.3	1.6	47.9%	45.3%	1984	22
292951 Apšupe	38	1	3.8	0.1	3.6	56.7%	3.5%	1986	20
293011 Bozes	35	3	6.3	3.1	3.2	42.2%	49.0%	2002	4
293203 Fazāni	7	2	2.3	1.4	0.9	75.2%	62.0%	1995	11
302901 Lielmežs	1	0	7.3	1.8	5.6	99.3%	23.9%	1990	16
303005 Sumragi	7	0	4.3	2.7	1.6	84.0%	62.6%	1995	11
303008 Kaļķis	12	0	2.7	1.2	1.5	72.0%	44.8%	1996	10
303009 Sumragu pussala	0	0	2.7	1.4	1.3	61.9%	52.2%	2001	5
312002 Zāmelis	49	1	3.6	2.0	1.6	41.4%	54.9%	1994	12
322501 Tumes stacija	60	2	5.5	2.1	3.4	67.7%	38.4%	1994	12
362601 Serenu purvs	40	1	3.9	0.0	3.9	89.9%	1.0%	1991	15
372001 Pilsrundāle	90	4	4.8	3.4	1.4	19.3%	70.3%	1999	7

Table 35. The characteristics of nests included in the forestry impact study (continued)

1	2	3	4	5	6	7	8	9	10
372503 Silmaču mežs	37	1	5.3	1.7	3.6	57.3%	32.0%	1993	13
442201 Dundagas	64	4	2.5	0.0	2.5	38.2%	0.0%	1996	10
491803 Straumēnu mežs	42	0	2.2	0.0	2.2	37.1%	0.0%	1983	23
495401 Mērnīeku dumbrājs	23	0	5.2	0.0	5.2	94.3%	0.0%	2002	4
504001 Ķivuļurgas	49	0	4.9	1.4	3.5	67.7%	28.2%	1997	9
505202 Zariņi	64	5	3.2	0.0	3.2	76.0%	0.0%	1975	31
505203 Zariņi	61	6	3.2	0.0	3.2	76.0%	0.0%	1975	31
512102 Sūrģenes	33	4	5.4	3.0	2.4	64.4%	55.6%	1996	10
512301 Buku purvs	67	2	2.3	0.2	2.1	40.3%	10.4%	1999	7
512405 Rutku ozols	34	3	3.6	1.7	1.9	64.3%	47.3%	2001	5
532205 Seržu tīrelis	0	0	2.9	1.9	1.0	99.6%	66.5%	2002	4
532304 Svētupes	22	0	3.0	1.8	1.2	89.3%	60.8%	1999	7
533301 Pilsakti	17	0	5.1	0.2	4.9	83.6%	4.3%	1986	20
551801 Vilku purvs	29	1	4.9	2.8	2.1	80.7%	57.0%	1998	8
553630 Zušu avots	53	5	3.3	0.4	2.9	48.1%	13.0%	1986	20
561901 Zalves ozols	30	0	6.2	2.8	3.4	92.0%	45.1%	1978	28
562203 Jūgu purvs	0	0	1.3	0.2	1.1	82.2%	12.6%	2002	4
564502 Cēsu kalns	47	4	1.6	0.5	1.1	66.9%	29.5%	1993	13
571907 Zalvītes purvs	10	0	5.1	2.8	2.2	94.9%	55.6%	2002	4
585302 Dukšu purvs	45	3	2.6	0.0	2.6	39.7%	0.0%	2002	4
585601 Ipiķu skola	30	0	4.1	1.2	2.9	42.1%	29.2%	2005	1
591801 Plostiņi	18	0	4.9	1.8	3.1	62.1%	37.6%	1993	13
591901 Kuilis	8	1	5.1	2.2	3.0	92.8%	42.2%	2002	4
601901 Gāršas	17	0	3.5	0.1	3.4	86.6%	3.7%	1978	28
622701 Briežāres	14	0	6.8	2.5	4.3	94.3%	36.4%	1994	12
623303 Apsītes	11	1	1.5	0.1	1.4	87.0%	6.3%	2002	4
631702 Krustceles	2	0	3.4	0.0	3.4	79.7%	0.6%	1991	15
641701 Dimantu mežs	34	0	2.3	0.1	2.2	60.9%	4.3%	1978	28
645201 Acupīte	17	0	7.5	1.5	6.0	76.8%	19.4%	2001	5
651202 Baltmuižas purvs	14	0	2.3	0.9	1.4	54.6%	39.6%	2005	1
651503 Domnieki	14	1	2.3	0.1	2.2	58.0%	2.3%	2001	5
661901 Vārzgunes ez.	11	0	4.5	1.3	3.2	83.9%	29.2%	1996	10
672503 Sīmāts	81	4	4.1	1.7	2.5	58.2%	40.3%	2002	4
690803 Raudines mežs	53	3	3.6	2.8	0.8	37.6%	78.7%	1986	20
691451 Majaks	15	1	1.4	0.0	1.4	77.1%	0.0%	2002	4
692702 Triekēli	32	1	7.2	2.7	4.5	81.4%	37.7%	1982	24
700602, 03 Ilgas mežs	85	8	3.3	2.0	1.4	43.6%	59.4%	2004	2
700711 Rauda	53	5	1.6	0.6	1.0	87.1%	36.1%	1992	14
711004 Poguļankas ceļš	27	1	4.0	2.0	2.0	72.7%	50.1%	1978	28
711702 Krievu purvs	2	0	8.5	0.0	8.5	59.9%	0.5%	2005	1
720604 Latveļu ez.	90	8	2.8	2.0	0.8	78.1%	71.6%	2004	2
733101 Pietnieks	5	0	7.0	2.1	4.9	89.1%	29.5%	1995	11
733102 Deguma pļava	14	0	5.8	1.9	3.9	64.5%	33.0%	2005	1
742101 Kurčīnu ozols	25	0	6.0	1.2	4.8	21.1%	20.5%	1991	15
750601 Kumbuļu mežs	60	0	2.6	0.1	2.5	56.9%	4.3%	1977	29
752803 Saukas purvs	41	1	5.9	0.1	5.8	31.4%	1.0%	1987	19
760402 Riču ez.	49	5	2.4	0.7	1.7	30.3%	28.5%	2004	2

Table 35. The characteristics of nests included in the forestry impact study (continued)

1	2	3	4	5	6	7	8	9	10
761502 Šusta ez.	70	1	3.3	1.0	2.4	38.8%	28.8%	2001	5
770501 Zabolotņiku ez.	39	0	1.8	0.9	1.0	81.2%	47.2%	1977	29
773003 Rūšsala	14	0	6.2	0.0	6.2	64.6%	0.0%	1988	18
804401 Avotu mežs	70	0	4.2	1.7	2.5	51.5%	41.0%	2002	4
823801 Sāmaņu purvs	15	0	4.2	1.2	3.1	73.3%	27.5%	1992	14
832801 Malnosola	28	1	5.5	2.9	2.6	36.8%	52.9%	2001	5
832901 Vakšīnīki	71	9	5.9	3.1	2.8	53.7%	52.4%	1985	21
833901 Svilte	1	0	3.4	0.2	3.1	79.9%	7.1%	1980	26
843501 Ploskīne	18	1	3.4	0.2	3.2	76.0%	6.1%	2001	5
873802 Gruzdovas purvs	24	0	3.3	1.0	2.4	82.4%	28.7%	1996	10
874102 Katlešu meži	11	0	2.3	1.0	1.3	85.2%	44.5%	2000	6
894003 Nokalne	55	0	3.8	2.4	1.4	70.1%	63.5%	2004	2
903801 Robežnieki	53	3	4.7	3.9	0.8	31.1%	83.1%	1997	9

Table 36. Parameters used for the evaluation of forestry-related disturbances (2003–2005)

Parameter	Given range	Used value
Start of operation after signing the operation contract or getting cutting allowance	From „a few days” to „almost a year”; most frequently „one–two weeks”	Ten days
Use of harvesters	For clear-cuts for large enterprises 80–100%, for non-clear-cuts up to 50%	Used if involved relevant or forest district manager confirmed use of harvester in a given place ²⁵
Productivity of a harvester (m ³ /hour)	12.5–14	13.25
Working time of a harvester	10–24	17.2
Volume processed in one day by a chain saw operator in clear-cut (m ³)	6–12	9
Volume processed in one day by a chain saw operator in a non clear-cut (m ³)	4–15, depending on conditions and foest type; for storm-related „sanitary cuttings” about ~ 20% less	8
Transportation of sortiments to a road-side landing with agriculture tractor	30–50 m ³ / day, or 3.5 m ³ / hour on average	3.5
Transportation of sortiments to a road-side landing with special forest tractor	150–200 m ³ / day, or 6.3–15 m ³ / hour on average	12
Area which can be thinned in one day by one person	0.2–1 ha, most often 0.3–0.5 ha	0.48
Area which can be planted in one day by one person	0.27–1 ha (depending on type of seedlings used)	0.44

²⁵ This means that I might have missed the use of some harvesters, because not all managers were surveyed. Instead, I engaged in direct consultations only with the largest operators. I have not, however, “estimated” the use of harvesters in locations where they were not used.

The concentration of DDT and its metabolites in the fat of addled or unhatched eggs in Latvia ($\mu\text{g/g}$) and the thickness of their shells (mm) (from *Grinblate 2010*).

Table 37. Addled eggs collected in Latvia (2006-2008)

Sample No.	Year	Eggshell thickness (mm)			DDT ($\mu\text{g/g}$) in lipid weight basis			
		Avg.	Max.	Min.	DDE	DDT	DDD	Σ DDT
MS08-460-3	2008	0.484	0.505	0.460	110.000 [†]	4.560	39.253	153.813
MS06-419-2	2006	0.556	0.578	0.528	192.400	0.000	27.440	219.84
MS06-511-1	2006	0.487	0.509	0.473	14.400	0.000	0.000	14.400
MS07-706-1	2007	0.431	0.465	0.400	13.100	1.125	2.400	16.625
MS07-752-4	2007	0.566	0.578	0.557	44.356	3.644	5.200	53.200
MS08-512-1	2008	0.431	0.454	0.416	71.520	0.240	0.720	72.48
MS08-529-2	2008	0.441	0.488	0.415	7.227	0.000	0.000	7.227
MS08-533-3	2008	0.440	0.460	0.417	42.582	0.000	0.000	42.582
MS08-548-3	2008	0.376	0.409	0.356 [‡]	9.120	0.000	0.000	9.120
MS08-556-1	2008	0.504	0.515	0.494	3.459	0.000	0.376	3.835
MS08-607-2	2008	0.484	0.501	0.465	21.829	0.000	0.000	21.829
MS08-616-2	2008	0.447	0.456	0.432	26.462	0.000	0.246	26.708
MS08-622-3	2008	0.433	0.494	0.409	39.933	0.000	0.000	39.933
MS08-622-4	2008	0.638	0.682	0.607	32.291	0.000	0.000	32.291
MS08-603-1	2008	0.386	0.406	0.378	61.267	0.000	0.600	61.867
							Total:	775.75
		% eggshell thickness			88.94	% DDT		100

Avg. = average; DDE, DDT, DDD = metabolites of DDT; Σ DDT = DDT sum of all metabolites; % = percent of the total DDT sum; † = for DDT presence, the largest recorded values are shaded; ‡ = for eggshell thickness, the smallest recorded values are shaded.

Table 38. Addled eggs collected in 2009 from the eastern flyway, both in and outside of Latvia

Addled eggs collected in Latvia in 2009								
Sample No.	Year	Eggshell thickness (mm)			DDT ($\mu\text{g/g}$) in lipid weight basis			
		Avg.	Max.	Min.	DDE	DDT	DDD	Σ DDT
1	2	3	4	5	6	7	8	9
09.37.LV	2009	0.423	0.437	0.408	2.535	0.004	0.027	2.566
09.30.LV	2009	0.452	0.488	0.414	22.381	0.000	2.975	25.356
09.28.LV	2009	0.388	0.408	0.377	20.609	0.002	0.091	20.702
09.27.LV	2009	0.432	0.573	0.388	27.709	0.018	0.431	28.157
09.35.LV	2009	0.466	0.498	0.435	91.974	0.032	4.646	96.653
09.39.LV	2009	0.443	0.475	0.416	3.043	0.004	0.013	3.060
09.51.LV	2009	0.407	0.432	0.38	41.708	12.402	5.226	59.337
09.33.LV	2009	0.476	0.52	0.449	94.899	0.080	0.416	95.396
09.32.LV	2009	0.391	0.424	0.372	3.270	0.062	0.184	3.516
09.31.LV	2009	0.351	0.374	0.327	4.551	0.012	0.047	4.609
09.41.LV	2009	0.447	0.466	0.420	1.858	0.027	0.080	1.965
09.34.LV	2009	0.409	0.442	0.389	14.471	0.006	0.040	14.517

Table 38. Added eggs collected in 2009 from the eastern flyway, both in and outside of Latvia (continued)

1	2	3	4	5	6	7	8	9
09.38.LV	2009	0.469	0.488	0.448	17.183	0.309	0.741	18.233
09.42.LV	2009	0.509	0.542	0.460	5.537	0.023	0.315	5.875
09.40.LV	2009	0.439	0.486	0.381	8.122	0.000	0.048	8.169
							Total:	388.111
					%	92.72	3.34	100
Added eggs collected in 2009 outside of Latvia from the eastern flyway								
Sample No.	Year	Eggshell thickness (mm)			DDT (µg/g) in lipid weight basis			
		Avg.	Max.	Min.	DDE	DDT	DDD	ΣDDT
09.01_EE	2009	0.467	0.501	0.443	30.925	0.000	0.229	31.154
09.24_D	2009	0.426	0.444	0.415	2.049	0.006	0.040	2.095
09.26_PL	2009	0.407	0.422	0.375	6.960	0.000	1.049	8.008
09.18_D	2009	0.473	0.486	0.459	0.941	0.012	0.042	0.995
09.19_D	2009	0.487	0.505	0.468	1.010	0.014	0.031	1.056
09.10_CZ	2009	0.409	0.421	0.392	19.416	1.782	5.629	26.827
09.02_CZ	2009	0.442	0.483	0.416	18.584	0.000	0.266	18.850
09.08_CZ	2009	0.468	0.494	0.446	9.439	0.659	0.170	10.268
09.25_PL	2009	0.435	0.475	0.404	1.971	0.004	0.034	2.009
09.17_D	2009	0.459	0.495	0.431	6.293	0.000	0.061	6.354
							Total:	107.616
					%	90.68	2.30	100

Table 39. Added eggs collected in 2009 outside of Latvia from the western flyway or an unknown flyway

Added eggs collected in 2009 outside of Latvia from the western flyway								
Sample No.	Year	Eggshell thickness (mm)			DDT (µg/g) in lipid weight basis			
		Avg.	Max.	Min.	DDE	DDT	DDD	ΣDDT
09.04_B	2009	0.446	0.498	0.395	5.845	0.008	0.068	5.921
09.05_B	2009	0.461	0.476	0.440	0.558	0.000	0.024	0.582
09.07_CZ	2009	0.44	0.453	0.418	4.161	0.025	0.119	4.305
09.20_D	2009	0.477	0.492	0.458	3.135	0.01	0.031	3.176
09.21_D	2009	0.487	0.507	0.472	4.744	0.000	0.301	5.044
09.22_D	2009	0.505	0.524	0.489	8.955	0.010	0.032	8.998
09.23_D	2009	0.484	0.507	0.466	2.021	0.031	0.137	2.189
							Total:	30.215
					%	97.37	0.28	100
Added eggs collected in 2009 outside of Latvia from an unknown flyway								
Sample No.	Year	Eggshell thickness (mm)			DDT (µg/g) in lipid weight basis			
		Avg.	Max.	Min.	DDE	DDT	DDD	ΣDDT
09.12_CZ	2009	0.499	0.529	0.480	8.914	0.000	0.244	9.159
09.16_CZ	2009	0.485	0.503	0.458	17.554	0.016	0.178	17.748
							Total:	26.907
					%	98.37	0.06	100

Ligzdas # **032501** **LIGZDAS PĀRBAUDES KARTĪTE**
 Sastādījis Pēteris Zakls un Māris Strazds, M. Strazda noformējums; 1995.04.04.

Adrese **Grobiņas 27-8 [88]** Suga **Cinig** Kartītes # **LP 219/95**

Pārbaudīja **M. S. & M. W.** Datums **950630**

Visi paskaidrojumi kursīvā; m = mērīts / n = novērtēts; atzīmē kur nepieciešams

Ligzda novietota: kokā uz klints citur: _____ Klints augstums (H) m n

Koka augstums jāzīmē tabulā lapas otrā pusē; piemērā klints augstums H ir vienāds a, b, c un d gadījumiem

Ligzdas novietojums klintī: a b c d e + f g h ; citur: _____

Ligzdas koka novietojums: i j k l m n citur: _____

Klints platums: m n

b, c un d atšķiras ar to, vai ligzda ir aizsegta ar mežu (d), uz klints augošiem krūmiem (c), vai nav aizsegta (b)

j, k un l atšķiras ar ligzdas koka novietojumu nogāzes apakšējā (j), vidējā (k) vai augšējā (l) trešdaļā

Nogāzes slīpums (α): 0 m n Virziena novērtēšanai lietot tikai debespušu standartiedalījumu:
 Z Z A A D D R R R R

Nogāzes virziens (β): 0 m n Z Z A A D D R R R R

Ligzdas virziens no stumbra (χ): 123 m n Z Z A A D D R R R R

Ligzdas pamata augstums virs zemes / ūdens (λ): 6,5 m m n

Nākamā klints zara / pārkāres augstums virs ligzdas (γ): 24 m m n

Ligzda pārsegta ar koka vainagu / klinti ; jā / nē

Pielidošanas ceļš: dabisks klajums (izgāzies koks) mākslīgs klajums (ceļš, stīga u. tml.) upe, / strauts / grava / cits: **Kiepiņu opols apaugušais upe**

Ligzdas novietojums kokā: a b c d e f

Ligzdas stabilitāte: g h i j k l

Cits variants: _____

Ligzdas attālums no stumbra (w): 0 m m n

Ligzdas izmēri: x: 150 cm y: 100 cm z: cm m n

Vainagu saslēgšanās: 51.39% m n → _____

63° - 102° + 146° - 220° + 268° - 330° + 63° **ALD 03 ENT D**

Vainagu saslēgšanās raksturo to, kāda daļa no ligzdas koka vainaga perimetra saskaras ar blakus koku vainagiem. Zīmējumā parādītajā piemērā vainagi saslēdzas par 50% (melna līnija). Precīzi izmērīt šo rādītāju iespējams, nosakot azimutu saskares līnijas robežpunktiem (ϵ , zīmējumā 360°, 90°, 180°, 270°). Mērījumu pieraksts var izskatīties šāds: 360° + 90° - 180° + 270° - 360°. Sektori, kur vainagi nesaslēdzas, atzīmēti ar mīnus (-), sektori, kuri saslēdzas - ar plus (+).

Piezīmes

Figure 25. The front side of the protocol for describing nest microhabitats. At the top is a description of the position of the nest tree in the terrain. The second section focuses on the accessibility of the nest and the space above it. The third section refers to the size of the nest and its location in the tree. The fourth section deals with canopy closure.

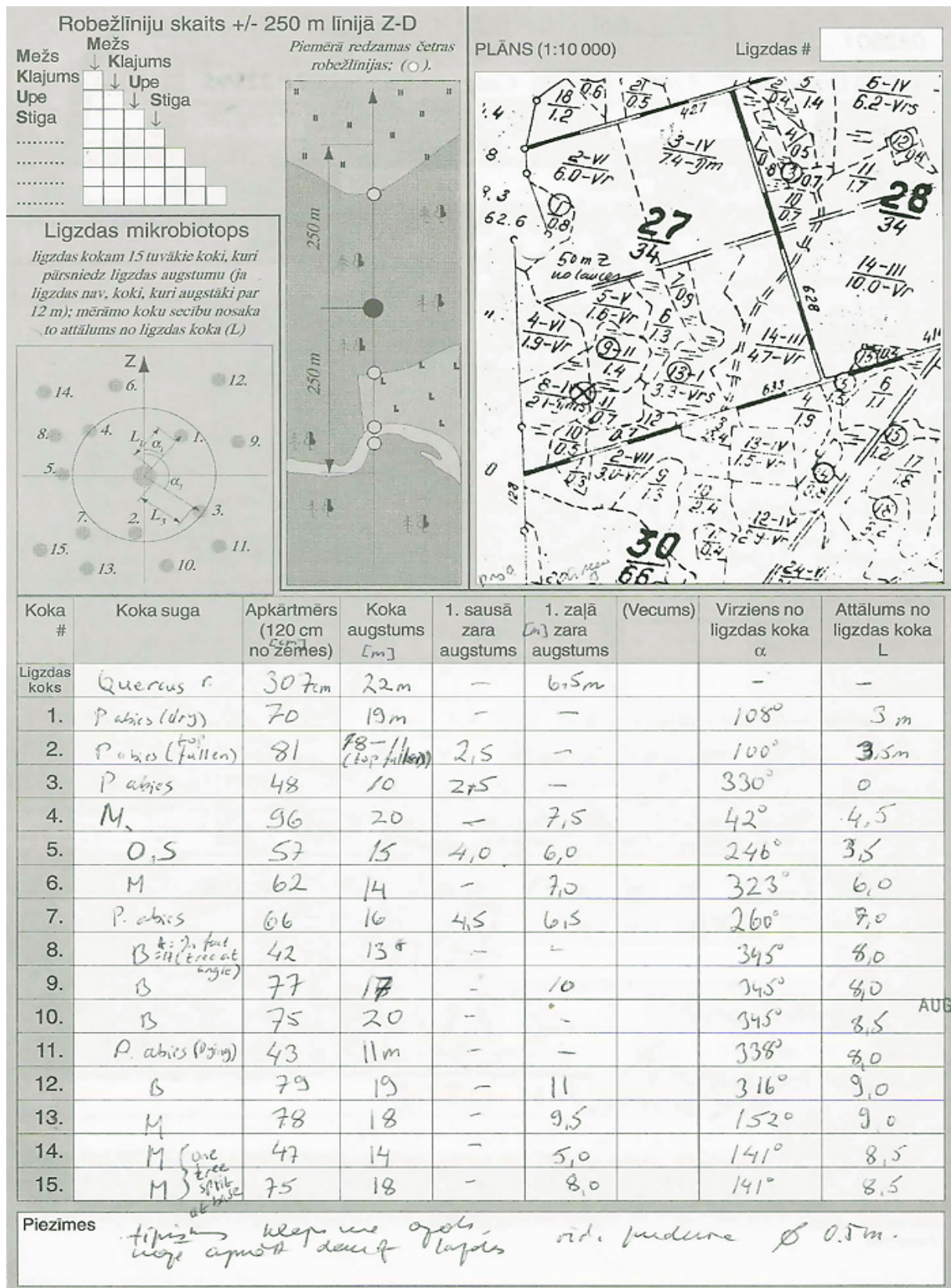


Figure 26. The reverse of the protocol for describing nest microhabitats. The first line shows the measurement of the nest tree, followed by the 15 nearest trees which exceed the height of the nest. The columns read: Tree species, circumference at height of 120 cm, tree height, height of the first dry branch, height of the first live branch, compass direction from the nest tree, distance from the nest tree.