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Sand martin (*Riparia riparia*) in the Czech Republic at the turn of the millenium

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A b s t r a c t : Status and population trends of sand martins (*Riparia riparia*) were studied over a fourteen year period in the Czech Republic. In sum, 438 occupied localites were found. The population fell off 83.2 % between years 1993 and 2005, which was unexpected as the population was stable or slightly increasing for years before. Number of holes per locality triplicated from 130 in 1992 to 314 in 2005 as a result of change of quarrying methods. In all but two years more colonies were lost than were formed. Among the localities preferred were sandpits (63.6 %), gravelsandpits (5.3 %), slopes and claypits (3.7 % each). Only 3.0 % of colonies were in riverbanks. Average altitude of colonies was 313.5 m a.s.l. with maxima around 650 m a.s.l. Negative influence of water precipitation during the breeding season and positive effects of precipitation in Subsaharan regions are described.

K e y w o r d s : sand martin, bank swallow, breeding, distribution, weather influence.

Introducion

Only marginal attention has been given to the burrowing species in the Czech Republic until recently. The research focused mainly on the relations between granulometrical characteristics of soils allowing the presence of breeding colonies of sand martins *Riparia riparia* (HENEBERG 2001, 2003), bee-eaters *Merops apiaster* (HENEBERG & ŠIMEČEK 2004), and eurasian kingfishers *Alcedo atthis* (HENEBERG 2004). Knowledge about other aspects of their breeding biology, distribution, and locality selection are also fragmentary, as only a few districts were hitherto covered (see e.g. HENEBERG 1997). Among the burrowing species, the least examined seems to be the sand martin. These reasons led me to organize the systematic monitoring of this species during years 1992-2005. Its summarized results are presented in this work. Sand martins were reported to occupy 19.9 % resp. 33.6 % of squares during the Czech bird censes in years 1973-1977 and 1985-1989 (ŠŤASTNÝ et al. 1997). The aim of this paper is to clarify the sand martin status in the Czech Republic based on the direct search for breeding localities, to show basic breeding characteristics of this species, and to show current trends in its numbers and distribution. I also focused on the effect of weather conditions, mainly precipitation on the studied population on its breeding and wintering grounds.

Material and Methods

The sand martin monitoring was performed in years 1992-2005 between 15th June and 30th September. Almost all sand martin holes are dug before the beginning of this period (HENEBERG unpubl.), and after 15th June almost only experimental holes of juvenile individuals or a few holes for additional clutches are dug. The end of the period was chosen because high autumn precipitation causes the annual collapse of many embankments; this might misrepresent results of the monitoring. Colonies were counted over the whole area of the Czech Republic. I used the direct search for the potential localities in vertical slopes using the maps of the Czech Republic 1:50,000 or 1:25,000. Alternatively, I published approx. 20 calls for the monitoring of sand martin nestplaces in ornithological periodics, in the dailies, and on the web. Normally I counted the exact number of holes in each colony directly during the control; however, large colonies were counted from photographs of banks. Less than 5 % of colonies were estimated.

Using mapping cards, I collected the following items about sand martin breeding colonies: exact type of the locality, number of holes, dimensions of the breeding bank, altitude, potential threats, quarrying intensity, accessibility of holes to human beings, distance between holes and the bottom of the embankment, height of the column of holes, distance to the nearest waterstretch, etc. To measure the parameters described above, I used the methodics described e.g. in SPENCER (1962), KUHNEN (1978) or HENEBERG (1997). Abbreviations of districts are used according to HUDEC (1983).

As the "hole" I had registered each cavity dug by sand martins, and having a minimum depth of 5 cm (conf. STONER 1936, KUHNEN 1978). Shorter cavities usually disappear quickly because of erosion, and these cavities were not counted. During the monitoring, I counted all holes in breeding banks including holes dug by sand martins in previous years, but I observed that these were usually not reused for another year. Colonies, which contained only markedly old holes (grass or spider-webs in tunnel openings), or those where the observer had verified the absence of sand martins in the locality in a given year, were shown as "deserted colonies". The average hole occupancy rate was stated as 75 %. As the hole occupancy rate determination was not among the main aims of the monitoring, I estimated the number of pairs from the number of counted holes. It was not possible to state visually the exact number of occupied holes (breeding pairs), mainly because of the large scale of the monitoring, which had been conducted each year up to mid-September, when most of the birds begin the autumn migration movements. Thus I conducted experimental evaluation of the occupancy of holes using ripariascope (SVENSSON 1969). This evaluation had been realized at a few randomly selected colonies (Zaječí BV, Třebeč CB, Božice ZN). Occupancy rate of about 80 % had been determined.

Data shown are means ± SD unless stated otherwise. χ^2 test was used to compare significance of differences between colony size in colonies threatened by intensive quarrying and by natural seeding respectively, and to compare colony size in different types of localities. Otherwise, Student's paired two-tailed *t*-test was used to test parametric data; Kolmogor-Smirnov and signed-rank tests were used for the analysis of nonparametric data. Pearson correlation coefficients were calculated if appropriate, and linear regressions are shown. Data about weather in the Czech Republic were downloaded from the web page of the Czech Hydrometeorological Institute http://www.chmi.cz/meteo/ok/ (station České Budějovice).

The population indexes (fig. 1) were calculated based on all localities controlled in at least two subsequent years. "Index of interseasonal changes" shows the relative change in the number of holes in the relation to the previous year. "Index 1993" shows the population trends of Czech sand martins during the period surveyed. Amount of holes in 1993 is marked as 100 %; included are all the colonies monitored for at least two subsequent years. All discontinuously occupied localities are also included in both indexes.

For the analysis of Sahel precipitation data were used from the International Research Institute for Climate Prediction presented as Standardized Precipitation Index analyses of multiple global precipitation datasets publicly available at http://iridl.ldeo.columbia.edu/SOURCES/.IRI/.Analyses/.SPI/.SPI-GPCPv2OPI_3-Month/. Two points were selected for sampling of data, one in eastern and one in western parts of the Sahel zone – coordinates of the first were 3°75´W; 13°75´N; coordinates of the second one were 6°25´W, 13°75´N. The two sampling points were selected according to our current knowledge about Czech sand martin migration routes based on the ringing reports of the Czech ringing scheme.

Results

Population trends

Sand martin population size changed markedly in years 1992 – 2005 (Fig. 1). In sum 438 occupied localities were found during the period surveyed. Most of the localities were occupied only for a few subsequent years. The population index was calculated based on all localities controlled in at least two subsequent years. Generally, the number of sand martin holes had decreased by 83.2 % from 1993 to 2005.

The decrease of the sand martin population in the Czech Republic is clear-cut. In the test for the reasons of such a trend I found there is usually some small portion of localities, which are abandoned from unknown reasons and remain unoccupied for one or more years. I therefore tested, whether there is any trend in the numerousness of such localities. Their amount ranged between 5.5 and 20.5 % during the research period 1992-2005. The lowest amount of unoccupied localites was in years 1992 and 1999; maxima were in years 1994 and 2003. I wasn`t able to identify any long-term trend in the numerousness of such localities; there seems to be just some periodical fluctuations (Fig. 2). Thus unoccupied localities don`t serve as a buffer supporting sand martins with new potential nestplaces.

Does the sand martin population depend on the offer of new localities and might the population also decrease with the number of destroyed/defunct localities? In all the years tested, except of 1999 and 2004, the number of lost colonies outnumbered the amount of newly emerging localities occupied by sand martins (Fig. 3). Thus the number of available banks is more and more limited. Is the amount of breeding holes and breeding pairs per colony limited or does it rise to higher values with the declining number of available colonies? If we had a stable sand martin population, we would be able to observe very intense growth of the average colony size. But as reported before, the number of sand martin holes was found to be diminishing. Nevertheless, is the decrease of the number of localities really causing the population decrease observed? I tested, whether the decreasing number of localities is compensated by an increasing number of holes in each colony. Number of holes per locality increased more than twice during the surveyed period (Fig. 4). The increase observed is highly significant (correlation coef. = -0.848; linear regression y = -5.4793x + 79.293; determinance coef. $R^2 = 0.7208$; n = 1188, $p < 0.01$), but did not fully compensated the decrease of number of breeding colonies shown before.

Population characteristics

Sand martins had occupied 147 mapping squares of the Central European web of mapping squares for mapping of organisms (23.5 % of all squares in the Czech Republic) during the period surveyed. The majority of colonies had been found in Morava and Dyje valleys ("Dolnomoravský úval" and "Hornomoravský úval"), in the Labe lowland and in Southbohemian basins. Colonies of sand martins occurred in almost all parts of the Czech Republic, they were absent only in highland areas around Czech borders and in Českomoravská vrchovina mountains.

Among the localities preferred were sandpits (63.6 %), gravelsandpits (5.3 %), slopes and claypits (3.7 % each), and some other loose materials listed in Tab. 1. Localities mentioned above differ largely in the number of holes per colony. The largest colonies were present in sandpits, gravelsandpits and claypits (298, 236 and 178 holes per colony), whereas short-term colonies in heaps of loose materials averaged 12 holes per colony (*t*-test $p < 0.01$, n=189 localities counted in 1999). Limited number of colonies (up to 0.7 % out of all) was placed in browncoal opencast mines, feldspar mines, kaolin pits, roofs of stonequarries, in the catchpit of the uranium mine, in the eroded dam, in faces of pond islands, in openings in a concrete bank of a pond, in peat mines, in openings in the stone wall of the bridge, in sandy parts of the bridge wall, in a silagepit, in openings in concrete panels bounding loose materials, and in heaps of many loose materials (crushed stone, crushed ceramics, gravelsand, kaolin, peat, sift-through fraction of bricks). One colony was also placed in an one meter wide trench (Jindřiš, JH), where sand martins (and especially juvenile birds) had huge problems with flying out of holes. Only 3.0 % of occupied embankments were on riversides representing formerly the only breeding possibility for these birds. Average colony size in riverbanks in 1999 was 125 holes/colony. During the research period, there were no breeding banks constructed artificially for sand martins only, and the population depends almost only on sand-excavating activities and on the excavating management of sandpits.

Average altitude of all occupied colonies found averaged 313.5 ± 118.7 m a.s.l. (n = 376, median = 269 m a.s.l., Fig. 5). There were four colonies located above 600 m a.s.l., namely catchpit of the uranium mine Krásno (SO) – 658 m a.s.l.; sandpit Číhaň (KT) – 650 m a.s.l., sandpit Supíkovice (JE) – 650 m a.s.l., and the slope near Chvalšiny (CK) – 620 m a.s.l. At 155 m a.s.l. was located the gravelsandpit near Dobříň (LT), the lowest located colony of sand martins in the Czech Republic. This sandpit was actually just near the river Labe, the water-level of which forms the lowest-situated place of the Czech Republic. Colonies in lowlands were found to contain more holes than higher-located colonies. The decrease of the number of holes in breeding colonies with the increasing altitude was characterized by the linear equation y = -0.87x + 502, where x is altitude in m a.s.l. (n = 189 localities from year 1999; determinance coef. $R^2 = 0{,}058$; $p < 0.01$).

During year 1999 I performed the overall census of all known localites, whereas in the other years was monitored only a set of randomly selected localities reaching in total > 10,000 holes for yeach year. In 1999 the number of holes reached 45,298 in 189 colonies out of 1,198 potential localities controlled. Out of the sum of 45,298 holes 44,723 (98.7 %) of holes were located in occupied colonies, and 575 holes (1.3 %) in abandoned colonies.

During year 1999 I also collected data about the intensity of quarrying activities from 145 localities. At 32.4 % of localities intensive quarrying activities were maintained, at other 26.2 % of localities was performed only small quarrying with the local importance. 41.4 % of colonies was located into banks without any excavation activities during the breeding season or were placed in banks of the natural origin. The direct quarrying of the breeding bank with holes occurred at 42.5 % breeding places (either intensive quarrying or the quarrying with local importance only). 57.3 % of nestplaces was placed in banks, which were protected from the direct quarrying of holes, but some quarrying activities might occur just around the breeding colony.

Potential threats of nestplaces are also in the direct relation with the quarrying. For this purpose I have collected data from all 197 colonies controlled in year 1999. Only nine localities (4.6 %) were in good condition throughout the whole season, whereas the others were mostly endangered by more than one factor. The investigated localities were mostly threatened by erosion (41.6 %), by slides of breeding banks or by the reduction of the height of the embankment (35.0 %), by intensive excavation (32.0 %), and by the recultivation (closing of the quarrying place) (28.4 %). 22.3 % of localities were endangered by the natural seeding of trees and shrub. Holes in 21.3 % of breeding banks were dug out by men. Intensive sand excavation is usually a problem at larger colonies (321.9: 206.0 holes; *t*-test $p < 0.01$, n=197 localities), whereas natural seeding of trees and shrub under the banks is the typical threat of small colonies (169.9: 263.8 holes; *t*-test $p < 0.05$, n=197 localities).

I found enormously high threat caused directly by man. Digging-out of holes, blocking of them, skeet-shooting, and other similar activities were present at approximately third share of localities. Thus one of the parameters recorded was the accessibility of holes to humans. Breeding holes were accessible at 53.6 % of colonies, whereas at 46.4 % of them were unaccessible.

Other factors examined in 1999 include the distance to the waterstretch, which reached 408.8 ± 798.7 m (n = 84, median = 100 m), the waterstretch was directly under the embankment in 17.9 % of cases; 13.1 % of nestplaces were in distance longer than 1 km from the nearest waterstretch. The decrease of number of holes per colony with the increasing distance to the waterstretch wasn`t found to be significant. Average distance to buildings was 764.1 ± 672.6 m (n = 110, median = 600 m). Maximal measured distance was 3,000 m, whereas 10 nestplaces were in built-up areas (nestplace in Jindřiš, JH, was placed 1 m from the sidewall of the family house). The height of the bank was between 1 and 30 m (mean = 5.65 ± 4.48 m, n = 172, median = 5 m). Larger colonies were placed in higher banks, which can be expressed using regression $y = 11.433x + 186.87$, $p < 0.05$, n=172, where x is the height in m, and y the number of holes. Only 1.2 % of breeding banks was lower than 1 m; 20.3 % was between 1 and 2 meters, 39.5 % were between 2 and 5 m, 31.4 % between 5 and 10 m and 7.6 % were higher than 10 m. Holes were placed at least 0.1 m over the foot of the embankment (Jindřiš, JH, and Radomilice, ST), maximally 29.5 m (Strakonice, ST) over the foot of the bank. The average height of the column of holes was 1.93 ± 1.37 m (n=47, median = 1.5 m), the shortest column of holes was on the locality Veská (PU) – 0.2 m, the longest one was near Strakonice (ST) – 6.5 m. Relation between number of holes and height of the column of holes express the equation y = 205.84x – 98.472, $p < 0.05$, n=47, where x is the height in m. The height of the column of holes is only barely dependent on the height of an embankment except of for the small embankments up to cca 2 m. Average length of an embankment was 95.88 ± 121.58 m (n=172, median = 50 m, min. = 4, max = about 1 km). Length of an embankment affects the colony size only if the embankment is relatively short, up to 20 m. Differences in the size of larger banks do not affect significantly the colony size.

In 1999, I collected data from all known localities in the Czech Republic. The number of sand martin holes reached 45,298. As some localities might be avoided, the total number of holes was estimated at 48-58,000 holes (36-43,500 pairs) in 1999. The expected population size in the other years may be calculated from the trendline shown in Fig. 1.

Effects of weather and other climatic factors

I found highly negative correlation between the index of interseasonal changes of the number of sand martin holes (Fig. 1) and precipitation recorded during the previous breeding season (r = -0.331; $p < 0.01$; n = 906 colonies counted in two subsequent years) – it means that if there was larger amount of rains e. g. in 2002, the number of sand martin holes in 2003 was smaller. The same was valid for the influence of precipitation in each given year (e.g. precipitation in 2003 negatively influenced size of the sand martin population in the same year; r = -0.272; $p < 0.01$; n = 906). I therefore extended the search for the influence of precipitation in each particular month of the breeding season. As expected, precipitation during April (r = 0.195; $p < 0.05$; n = 906) and May (r = 0.087; $p > 0.05$; n = 906) did not have any negative influence, whereas precipitation in June (r = -0.383; $p < 0.01$; n = 906), July (r = -0.063; $p > 0.05$; n = 906), August (r = -0.281; $p < 0.01$; n = 906) or September (r = -0.416; $p < 0.01$; n = 906) was positively correlated with smaller amount of holes found. Number of holes was monitored during June-September, so holes destroyed by rains in April and May have been re-dug, whereas holes destroyed later were not renewed.

In July 1997 the water precipitation reached 200 mm within few days in southern parts of the Czech Republic (data from CHMI, station Byňov u Nových Hradů, CB), a triple of the month`s normal level. From 27 Southbohemian and Southmoravian colonies checked, only 40.7 % were not influenced, 11.1 % of colonies were entirely destroyed and at another 14.8 % of colonies was damaged 80-90 % holes. From 5,224 holes found in June, only 66.34 % survived the precipitation described above. Collapses of whole banks were common in areas with higher content of clay in the bank material. On the contrary, in the Třeboň basin, holes were directly flooded by water soaking through the sand, which contains very low amount of clay there. The same happened in southern Moravia, where holes in sands with more than 97 % of grains < 0.9 mm. Moreover, the rains caused flooding of natural river nestplaces, which had been almost abandoned in the following year.

I also tested for the influence of precipitation in the Sahel zone on the numerousness of sand martins. Winter precipitation (January to March) on the eastern Sahel sampling point was found to be unrelated to the fluctuations of the number of sand martin holes (r

= -0.097; $p > 0.05$; n = 906); whereas winter precipitation on the western Sahel sampling point was found to be strongly positively correlated with the fluctuations of the number of sand martin holes (r = 0.499; $p < 0.01$; n = 906). Even more important seems to be precipitation between August and October before the autumn arrival of sand martins, which showed the positive correlation r = 0.629 and r = 0.544 (for both $p < 0.01$; n = 906) respectively. The total Sahel precipitation were found to be positively associated with the sand martin numerousness too (r = 0.730 and r = 0.617; both $p < 0.01$; n = 906), which shows that we should not measure precipitation only, but also other variables like the vegetation cover and abundance of insect on the given migration stop. Interestingly, numerousness of the sand martin holes wasn`t found to be negatively associated with desert locust plagues (*t*-test $p > 0.05$; n = 15 years) present frequently in Sahel and causing extensive defoliation and thus temporary fadeaway of an insect.

Discussion

The most important part of this paper is the outline of the way a member state of the European Union is disregarding its obligations. The European Union may encourage economic development but it has laws to ensure that the environment isn't harmed as set out here during economic activities. During the research period 1992-2005, significant increase of the sand martin colony size was found. Current colony size around 300 holes per colony causes an extreme vulnerability to any disturbances including effects of weather and damages caused by man. I assume that the most important factor inducing this trend is the rapid change of sand excavation methods. Since the end of communism in the Czech Republic, there were opened many large sandpits with extensive and intensive sand excavation activites. On the contrary, small sandpits (common in previous times) were usually returned to their prior owners, who usually did not continue in quarrying activities. Such sandpits cannot be used as sand martin nestplaces any more, and the birds had just a limited offer of possible localities eligible for breeding. The non-mined localities are quickly overgrown with vegetation, the bank usually collapses after few years and the soil is becoming to be more compact. These parameters generally lead to the abandonment of such breeding banks by any burrowing species (HENEBERG & ŠIMEČEK 2004, YUAN et al. 2006a, b). The number of new localities outnumbered the number of lost banks with former sand martin colonies just in two years out of thirteen examined (Fig. 3).

There is a question, whether the increase in colony size is limited only to postcommunistic countries and only to last years or whether it is a general problem common also in previous years. Because of lack of any relevant data from the area of the Czech Republic, I pooled available data mostly from western-european sand martin nestplaces since 1930 (Tab. 2). The increase of colony size is obvious. In the collected dataset weren`t even recorded any colonies over 250 holes up to 1950 and any colonies over 500 holes up to 1975. GLUTZ VON BLOTZHEIM & BAUER (1985) recorded colony with 2360 holes as the largest in the Central Europe; SZÉP (1991) had observed colony of 4228 holes in Tiszatelek in year 1989. During the monitoring described above, I found the largest colonies mostly in southeastern parts of the Czech Republic – Hrušovany u Brna, BO, 4300 holes (2000), Pouzdřany, BV, 3425 holes (1995), Zaječí, BV, 3087 holes (1996). O.ŠLAPANSKÝ (in litt.) recorded colony occupied by 5-7,000 pairs of sand martins near

Ivančice, BO. Colonies larger than 1000 holes were commonly found in all three main population centers of the sand martin in the Czech Republic and formed 7 % of all colonies found. JÓZEFIK (1962) stated that colonies up to 50 holes are short-living, colonies with 100-200 holes should have lifetime from two to three years, and colonies over 200 holes are permanent but rare (up to 10.1 %), according to him. His theory could partially explain large size of colonies in the Czech Republic, because the turn-over of colonies was just 26.2 % – each year formed approximately 9.3 % new colonies and ceased 16.9 % out of the total number of occupied localities. In the same way are the observations of JONES (1986), who stated that the colonies present in sandpits are larger than those in natural localities. Here I observed the similar differences between sandpit and riverbank colonies (297 vs 125 holes per colony). As the sandpits are usually more long-lasting than the vertical river banks, it fits the theory of JÓZEFIK (1962) presented above. According to the KUHNEN`s (1983) theory should the colony size depend on the density of breeding pairs per km^2. I do not exclude it for areas with the smaller offer of banks, where the colony size is really smaller. But his data are entirely unusable in the conditions of the Czech Republic – he calculated colony size about 20 pairs/colony for the density 0.3 pairs/km^2 and 40 pairs/colony for the density 1.2 pairs/km^2. Because the average sand martin density in the Czech Republic in 1999 was between 0.4 and 0.5 pairs/km^2, thus the colony size should be slightly above 20 pairs/colony according to Kuhnen, which is entirely in disagreement with the data found (226 holes/colony in 1999 = 10x more). Interestingly, BRYANT & JONES (1995) hypothesized that the larger colonies may attract large individuals, while small colonies may be filled by smaller birds. Than we would have larger sand martins throughout the Czech Republic as the average colony size is severaltimes higher than in Western Europe. But this provocative hypothesis is still waiting to be tested.

Colonies were found in altitude range between 155 and 658 m a.s.l. The distribution of sand martin colonies was bimodal (Fig. 5.) as the areas with sandy soils are located mostly in Morava and Dyje valleys and in the Labe lowland (peak with max around 200 m a.s.l.). In discordance with previously published results, sand martins created numerous colonies in altitudes over 400 m a.s.l., which were located mostly in southbohemian basins at 360-480 m a.s.l. (second peak). Sand martin altitudinal distribution disagrees with data published previously by HUDEC (1983), who stated the upper level of sand martin distribution in the Czech Republic up to 400 m a.s.l.; only in the Třeboň basin up to 450 m a.s.l. These data were doubted already a few years before in HENEBERG (1997), where was published nesting of sand martins at 620 m a.s.l. near Chvalšiny (CK). Described was also quite a number of nestplaces placed above 400 m n.m. (SLAVÍK 1982, FOLK & KOŽENÁ 1987, PLACHÝ 1987, GÁBA & TUŠA 1991). These were published mostly as "rare" observations, which was caused probably by the misguided information in the Hudec`s compendium. Currently I found 33.5 % of localities placed above 400 m a.s.l., which confirms results from the West-European countries published by SIEBER (1982), GLUTZ VON BLOTZHEIM & BAUER (1985), and FERNÁNDEZ & DURANGO (2000). The altitudinal expansion is probably related to the May 10 °C isotherm as in lower latitudes the sand martin were reported to breed even up to 4,500 m a.s.l. (HARRISON 1982). Nevertheless, this is the first evidence that the Czech sand martin population frequently occupies higher altitudes than thought before.

Another controversial value is the distance of an embankment to the nearest water. Most of the nestplaces had been located apart from water; average distance was 408,8 ± 798,7 m (n = 84, median = 100 m); water sheet under the embankment was present only at 17.9 % of nestplaces. These data disagree with findings of KUHNEN (1975), who found 50 % of colonies with the water sheet just below the banks. It is probably caused by the higher share of natural nestplaces; for the same reason HUMPHREY & GARRISON (1987) found maximal distance from the water 21.8 m because all the colonies they recorded were in banks generated by erosion, not by the quarrying activities as it is more common in the Czech Republic. Main localities occupied by sand martins in the Czech Republic are still sandpits mined by small mechanisation, whereas KUHNEN (1975) reported sand excavation below the water table as the main activity responsible for creation of new sand martin colonies in Germany. Currently, the same trend began in the Czech Republic too, and I expect that it is just a matter of time when the situation will be similar to those described by Kuhnen. Nevertheless, 83.5 % of colonies were located up to 500 m from the nearest water sheet, but some of them had been located as far as 5 km from the nearest water sheet. DIEHL (1985) found all the 72 colonies controlled in the distance up to 500 m from the nearest water sheet. But it seems that breeding of sand martins is less dependent on the presence of water than presumed before. This hypothesis is supported also by DUNN & WHITTINGHAM (2005), who found that tree swallow (*Tachycineta bicolor*) females often roosted farther away than the nearest available roost site, they used different roosts on different nights, and during the day they foraged up to 10 km from their nest site. Also MEAD (1979) recorded feeding adult sand martins up to 8-10 km from the colony.

I found 58.6 % of nestplaces in directly mined localities, whereas 41.4 % of colonies were located to localities with the finished mechanized logging or on localities with natural origin. Sieber (1982) found this ratio to be 75 % : 25 %, whereas DORNBERGER & RANFTL (1983) published it as 69.8 % : 30.2 %. The importance of localities of human origin for the sand martin nesting is still increasing in the Czech Republic as well as in many countries abroad (see e.g. DE AZUA et al. 2007). Lower amount of mined localities found in this work is only temporary and is caused mainly by abandonment of many restituted localities.

More than fifty percent of colonies were accessible to humans. It caused an enormous threat by human disturbance. It would be good to focus more on this topic in areas with higher densities of human settlements as e.g. BENGTSSON (1995) didn`t recorded any such disturbance in his work, whereas I recorded direct influence of humans like blocking of entrances, digging out of holes, etc., at one third of localities. In contrary VAN DER SPEK (2006) found that human disturbance was responsible for bee-eater nest failures.

For the estimation of the average hole occupancy rate, I conducted the experimental evaluation of the occupancy of holes using ripariascope. Occupancy rate of about 80 % had been determined. It is similar to the occupancy rate published by HECKENROTH (1969) - 86 %, BRIAR & STEVENSON (1976) - 80 %, LEYS (1990) - 85 %, LEYS (1991) – 82 %. Data collected were in direct disagreement with Kuhnen`s theory (KUHNEN 1978). Kuhnen stated that occupied holes are only those having its length over 40 cm. During the monitoring, many such occupied holes had been found; some localities even had average tunnel lenth at the same value – e.g. holes in the colony by Nová Ves nad Lužnicí (JH) were on average just 45.8 cm deep (HENEBERG 1997). Kuhnen`s equation had been used for the calculation of occupancy mainly by German-writing authors in eighties (SIEBER 1982, DORNBERGER & RANFTL 1983 etc.), but its usage would be wrong in our case. I also did not used the second method described by KUHNEN (1978), which is based on observations of the frequency of birds by each hole. The main problem of this method consists in the irregularity of frequency of sand martin occurrence in holes; this is valid especially for midday hours, when the sand martins often stay away from the holes for hours (HENEBERG unpubl.). Based on results from randomly selected localities I finally selected value 75 % as the average level of the hole occupancy. Lower values were usual in breeding banks with the less penetrable sand and gravelsand, where sand martins created usually smaller colonies. Whereas in embankments with the fine sand with higher penetrability was the occupancy rate higher – sand martins did not dig so many unfinished holes because of the absence of structures impairing their digging activities.

I assess that the total number of sand martin breeding holes in the Czech Republic reached 48 to 58,000 (36 to 43,500 pairs) in 1999. Number is slightly higher than the number of directly found holes, because of the insufficient coverage of border regions of northeast Moravia and northern Bohemia. During the monitoring, I identified substantial and constant decrease of the Czech sand martin population together with some time-limited fluctuations. The decrease reported was variable. Some of the population fluctuations could be explained by the extreme precipitation in summer months (1997 and 2002), whereas some others can be explained by the cold weather during the breeding season (2004). Reasons for the fluctuations observed will be discussed later, but the downtrend is obvious.

Influence of local precipitation

Aerial feeders (Hirundinidae and Apodidae) are particularly good models for the studies of the influence of local precipitation since their food (aerial plankton) strictly depends on the temperature and other weather parameters like rain, atmospheric pressure and wind (KOSKIMIES 1950, BROWN & BROWN 1999). There have been reports of short-term effects of cold and rainy weather on pre- and postmigratory fattening (PILASTRO & MAGNANI 1997), on prebreeding roosting behaviour (SACKL & PUTZ 1998), and on the clutch size and mortality (BRYANT 1975, LOSKE & LEDERER 1987, BROWN & BROWN 1997) of swallows and martins; on the contrary hot summer weather during the chick rearing period, but not during the laying and incubation period, was reported to negatively influence the number of fledged young crag martins (*Ptyonoprogne rupestris*). Negative relationship between survival of sand martins and the previous summer`s rainfall in the study area was currently detected by the long-term study of COWLEY & SIRIWARDENA (2005). High May and June temperatures were reported to be associated with the increase of sand martin population increase in Britain (COWLEY 1979). Influence of summer temperatures on the sand martin population in Maglarp, Sweden, had been recorded by PERSSON (1987).

In accordance with data described above, I found highly negative correlation between the precipitation level and sand martin population level. Moreover, during the sand martin monitoring, I had recorded two extremely rainy breeding periods affecting the reproduction success. I did not focused directly onto the effects of hatching or mortality of adults, but tried to identify degree of damage of banks after heavy rains and/or flooding. In

1997, 33.66 % of holes in southern parts of the Czech Republic were destroyed directly by heavy rains as found by two subsequent censes in June and July 1997. When comparing long-term population trend of the Czech sand martin population, I identified local precipitation as an important factor influencing the sand martin population dynamics. Important is the geographical range of precipitation as the immigration-emigration of adults from unaffected areas may substantially support the diminished populations (see SZÉP 1995b).

Conditions on wintering grounds

Previously, fluctuations of swallow populations had been found to be associated with the precipitation level in Sahel (MORGAN 1979, JONES 1987, SZÉP 1995a, ROBINSON et al. 2003, COWLEY & SIRIWARDENA 2005) or South Africa (MØLLER 1989). Controversial is the influence of the North Atlantic Oscillation weather system. HUBÁLEK (2003, 2004) claims that there is no such influence on swallows in the Czech Republic, whereas MØLLER (2002) found it to be closely related to the reproduction success and immunity level of the swallow population in Denmark. Generally, the higher precipitation at the winter quarters were found to be associated with the lower mortality rate measured after the return of birds back to nest sites. Precipitation level is closely related to the plant primary production and subsequently to the insect density. Thus environmental conditions can affect survival rates, and also provoking spatial synchronisation of annual survival rates. E.g. variation in the primary production in the eastern contributed up to 88 % to the temporal variation in survival of Polish and German white stork (*Ciconia ciconia*) migratory populations. Annual survival was reduced when primary production in the Sahel was low (SHAUB et al. 2005). Similarly, the breeding dates of barn swallows in consecutive breeding seasons were advanced and clutch sizes were larger and breeding success increased after winters with higher primary production in their wintering quarters (SAINO et al. 2004).

During this study, I found that the sand martin population fluctuations had highly positively correlated with winter (January to March) precipitation in Sahel areas around 6°25´W and 13°75´N (cor 0.499), and even more with the Sahel precipitation during the late summer and early autumn (August to October). This precipitation cannot directly influence sand martin survival, but can induce growth of new vegetation supporting increasing populations of an insect used as a nourishment of sand martins, which is also in agreement with data published by SCHAUB et al. (2005).

Primary production of Sahelian region is largely influenced by desert locust plagues (*Schistocerca gregaria*). Locust plagues can cause disappearance of the vegetation cover followed by decreased amount of insect used as feed for migrating sand martins. There are also some other side-effects like application of insecticides and avicides to control periodical plagues of locusts, grasshopers and birds. Effects differ, but some of pesticides used were reported to kill or debilitate nontarget vertebrates (KEITH & BRUGGERS 1998). Last locust plague was recorded in 1986-1988; later upsurges in 1992-1994, 1996-1998 (SYMMONS & CRESSMAN 2001), and 2005 (http://www.fao.org/ag/AGP/AGPP/EMPRES/ Default.htm). There have been six major plagues of desert locust in the 1900s, one of which lasted almost 3 years. The area in which plagues occur covers about 29 million km^2 and can extend across 57 countries. Currently, I did not find any significant relationship between locust upsurges and Czech sand martin population trends. It was probably caused by the fact that the recent upsurges occured mainly in Eastern Africa; they developed in the Red Sea Basin and spread to the nearby countries only. As East-African countries are not among the main winterquarters for European sand martins (see e.g. MEAD & HARRISON 1979), it would be highly interesting to see effects of these plagues if they will occur in countries like Chad or Libya used as winterquarters or migration routes of Czech sand martin populations.

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I thank to 71 ornithologists, who helped me with the collection of data about sand martin colonies in the Czech Republic. Together I wish to thank to 42 quarrying companies and landlords who willingly provided me data from some worse available localities. Last but not least I wish to thank to presidents of regional mining office boards for the data about deposits of non ore stock in the Czech Republic, and to J.Řehounek for the cooperation on the propagation of the sand martin census.

Zusammenfassung

Über 14 Jahre wurde der Zustand und die Bestandsentwicklung der Uferschwalbenpopulation (*Riparia riparia*) in der Tschechischen Republik erfasst. Insgesamt wurden 438 Gebiete besiedelt. Im Zeitraum zwischen 1993 und 2005 nahm die Population um 83,2 % ab, was überraschend war, da der Bestand in den Jahren zuvor stabil war bzw. nur leicht abnahm. Die Anzahl der besetzten Höhlen pro Kolonie verdreifachte sich von 130 im Jahr 1992 auf 314 2005, was auf die veränderte Bewirtschaftung der Abbaugebiete zurückzuführen ist. In all den Jahren der Untersuchung wurden mehr Kolonien aufgelassen als neu begründet. Am häufigsten wurden Sandgruben besiedelt (63,6 %), gefolgt von Kiesgruben (5,3 %), Abhängen und Lehmgruben (jeweils 3,7 %). Nur 3 % der Kolonien befanden sich in Abbrüchen an Flussufern. Die durchschnittliche Meereshöhe betrug 313,5 m, die höchste Kolonie lag auf 650 m. Die negativen Auswirkungen der Niederschläge während der Brutsaison und die positiven Auswirkungen des Niederschlages in trockenen Subsaharan Gebieten werden beschrieben.

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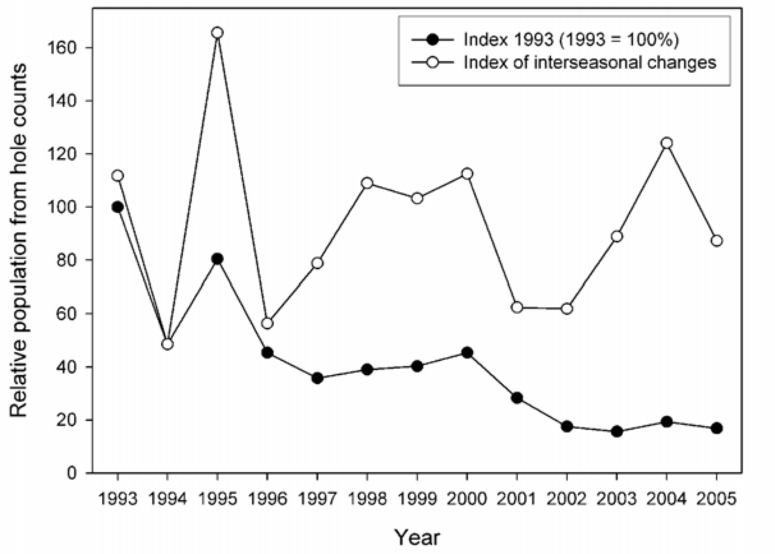

Fig. 1. Population trends of the sand martin in the Czech Republic during 1992-2005. "Index of interseasonal changes" shows the relative change in the number of holes in the relation to the previous year. Included are holes from all the colonies monitored for at least two subsequent years. "Index 1993" shows the rapid decrease of sand martin population during the period surveyed. Amount of holes in 1993 is marked as 100 %; included are all the colonies monitored for at least two subsequent years. All discontinuously occupied localities are also included in both indexes.

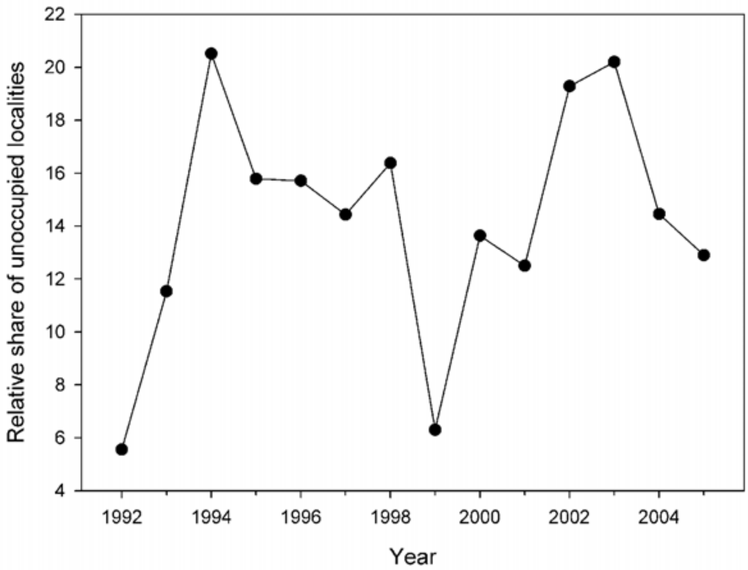

Fig. 2. Relative share of unoccupied localities found during the sand martin monitoring. Amount of unoccupied localities appropriate for nesting of sand martins according to HJERTAAS (1984) was compared with the total amount of all appropriate localities available.

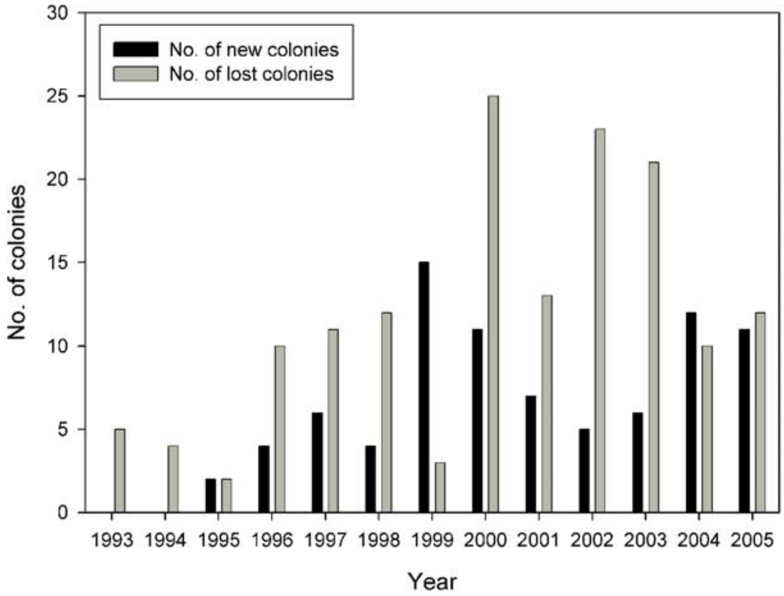

Fig. 3. Number of disappeared colonies outnumbered the number of newly emerging localities occupied by sand martins in all years except of 1999 and 2004. It signalizes the rising limitation in the number of available localities during last years.

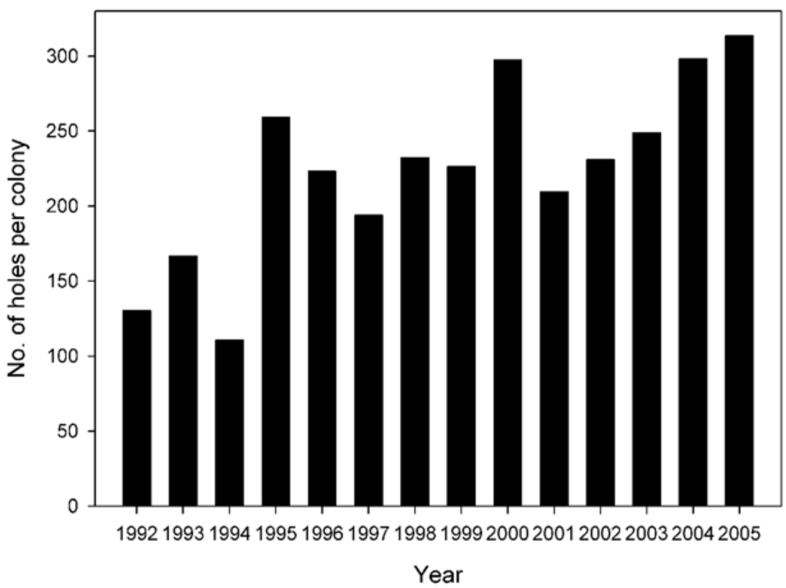

Fig. 4. So far increasing colony size compensates decreasing number of localites. Colony size increased currently from 130 holes per colony to current 314 holes per colony.

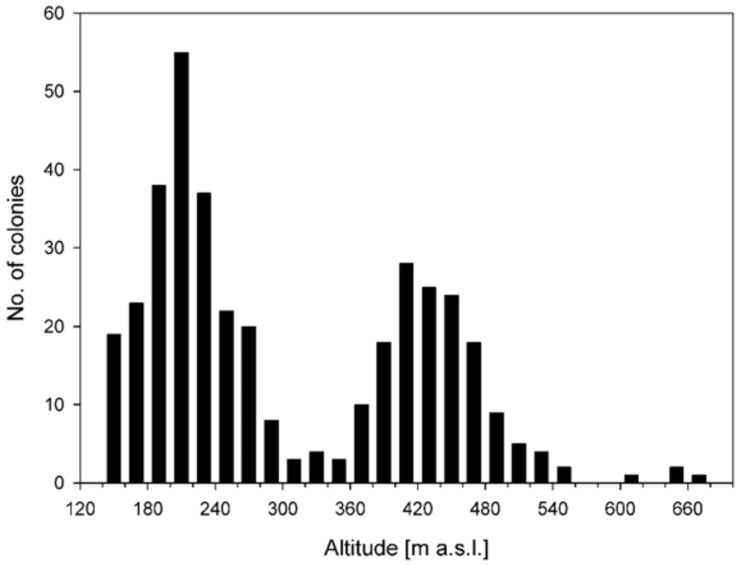

Fig. 5. Distribution of altitude of sand martin nestplaces in the Czech Republic. In discordance with previously published results, sand martins created numerous colonies in altitudes over 400 m a.s.l.

Tables

Table 1. Relative numerousness of breeding biotops in the Czech Republic compared with data from other countries. **1** – sand martin monitoring in the Czech Rep. 1992-2005 (this study); **2** – Switzerland 1980 (SIEBER 1982); **3** – Westphalen (Germany) 1983 (LOSKE 1986); **4** – Pennsylvania and Vermont (U.S.A.) 1959-1960 (SPENCER 1962).

Habitat	**1**	**2**	**3**	**4**
Sandpit or gravelsandpit	63.6	97.6	79.4	44.0
Claypit	5.3	0.8	1.0	8.0
Slope	3.7	0.8	1.0	20.0
Heap of the soil	3.7	-	2.1	-
Face of the trench	3.0	-	-	20.0
River shore	3.0	-	15.5	4.0
Heap of the sand	2.3	-	-	-
Ashdump	2.1	-	-	-
Bank of the pond or dam	1.2	-	-	-
Erosion cut	0.9	-	-	-
Heap of the crushed concrete	0.9	-	-	-
Gravel pit	0.9	-	-	-
Heap of the scoria	0.9	-	-	-
Others (each 0.7 % or less)	8.5	-	-	-
Wall of the vineyard	0.0	0.8	-	-
Artifical nestbank	0.0	-	1.0	-
Heap of the coal	0.0	-	-	4.0
Σ of colonies	431	123	97	25

Table 2. Changes of the sand martin colony size. Distribution of the colony size is showed as the relative shares (in %) in each time period. Data for years 1992-2005 were calculated based on results of this study. Data for the period 1976-1986 were pooled from STREICHERT (1984) – Niedersachsen, WAWRIN (1980) – south Belgium, BERNDT (1980) – Schleswig-Holstein, LEIBL (1981) – Bayern, RANFTL & DORNBERGER (1983) – Bayern, DIEHL (1985) – Hessen, LOSKE (1983) – Kleve-Wezel and Westfalen, SIEBER (1982) – Switzerland, GASSLING (1983) – Switzerland, LEYS (1987) – Netherlands. Data for 1966-1975 were calculated from MARIAN (1968) – Hungary, WAGNER (1969) – Switzerland, KUYKEN & ROGGEMANS (1969) – Flandern, ALTRICHTER et al. (1969) – Bayern, KOHL et al. (1975) – Romania, KUHNEN (1975) – Lower Rhein, HOOGLAND & SHERMAN (1976) - Michigan, BILLEN & TRICOT (1977) – south Belgium, MØLLER (1979) – Jutland, STREICHERT (1984) – Niedersachsen, DIEHL (1985) Hessen. Data for 1951-1965 were grabbed from JÓZEFIK (1962) – Poland, and from OELKE (1969) – Niedersachsen. Data for 1945-1950 originated from BERGSTROM (1951) – Connecticut and for year 1930 were found in SCHLECHTER (1932) – Sachsen.

Colony size / Year	1930	1945-50	1951-65	1966-75	1976-86	1992-2005
1-10 holes	53	26	30	27	20	16
11-100 holes	44	65	52	51	53	39
101-250 holes	3	9	14	15	20	16
251-500 holes	-	-	4	7	5	15
> 500 holes	-	-	-	-	2	14
N	82	102	640	3120	1191	1190