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Integrated population monitoring of sand martin *Riparia riparia* - an opportunity to monitor the effects of environmental disasters along the river Tisza

T. Szép, Z. Szabó D. and J. Vallner

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From January to March 2000, the entire length of the River Tisza suffered an appallingly serious environmental disaster when the collapse of tailings dams belonging to upriver Romanian gold mines caused severe pollution by cyanide and heavy metals. This pollution was the direct cause the death of flora and fauna in the Tisza along its length and threatened the entire ecosystem of the river, one of the last remaining natural major rivers in Central Europe almost free of large-scale man-made developments. The river Tisza is such an important breeding and roosting area for large populations of several insectivorous and piscivorous bird species that several Important Bird Areas (IBAs) have been established along its course. Most of these species are migrants that fortuitously happened to be elsewhere in their travels when the pollution occurred, but the scale of the problem was such that delayed impacts can be expected. As it happens, long-term integrated monitoring work on the Sand Martin *Riparia riparia* breeding population along the river Tisza in Hungary has been running since 1986 under the aegis of MME and BirdLife Hungary. This project also happens to monitor the population size and distribution of Kingfisher *Alcedo atthis* and so was well placed to begin comprehensive monitoring of the short-, mid- and long-term effects of this disaster. The breeding populations of these two species along the river Tisza depend predominantly on the supply of their food, the fauna of the river and its flood zone. The two species, by macabre good fortune, happen to be the ideal models for studying the effects of the disaster on insectivorous and piscivorous birds. Detailed studies in 2000 following proven protocols, such as fieldwork and chemical analysis of the feathers, revealed that the pollution has had no measurable effects on population sizes, distribution and reproductive success, and that the level of heavy metals in the food chain of insectivorous birds did not increase. However, precedent and the scale of the disaster suggest that the lack of immediate effects means that there may well be secondary effects in the longer term from subsequent events, such as floods and droughts. The disaster has brought greater international awareness, which may help to reduce pollution or make such incidents less likely. Our investigation underlined the importance of monitoring in these kinds of habitats, because it showed that some assumptions about the consequences of the accident were wrong; in the absence of data, there is a risk in such circumstances of misinterpreting the outcome.

T. Szép and J. Vallner: College of Nyíregyháza, Department of Environmental Science, Nyíregyháza, Sóstói út 31/b, H-4400, Hungary. E-mail: szept@zeus.nyf.hu Z. Szabó D, Behavioural Ecology Research Group, Department of Zoology, Debrecen University, 4010 Debrecen, Egyetem ter 1, Hungary.

1. Introduction

From January to March 2000, the length of the River Tisza suffered an appallingly serious environmental disaster when the collapse of tailings dams belonging to upriver Romanian gold mines (Anon 2000) caused severe pollution by cyanide and heavy metals. The pollution was the direct cause of widespread killing of flora and fauna in the Tisza and it threatened the entire ecosystem of the river, one of the last natural major rivers in Central Europe that remains almost free of large-scale man-made developments.

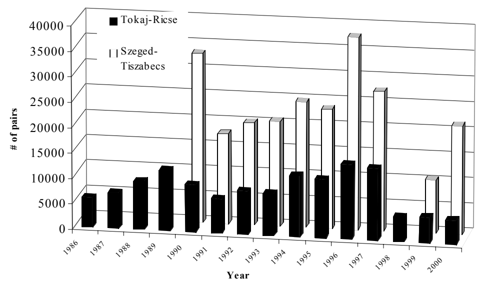

Fig. 1. Numbers of breeding Sand Martin (pairs) along the Hungarian section of the river Tisza (Szeged-Tiszabecs) and along the upper part of the Tisza (Tokaj-Ricse). In 1998 (in the upper section of the Tisza, the population size was surveyed one week before the flood in June that later destroyed these holes.

The River Tisza is a very important breeding and roosting area for large populations of several insectivorous and piscivorous bird species. Along its course lie several IBAs (Heath & Evans 2000, Nagy 1998). Most of these species are migratory birds that happened to be elsewhere in their travels when the pollution occurred, but the scale of the problem meant that delayed impacts could be expected as was the case at Dońana (Meharg *et al*. 1999).

However, considering the scale and extent of the pollution, we could not exclude the possibility of several direct and indirect mechanisms affecting the populations arriving and breeding along

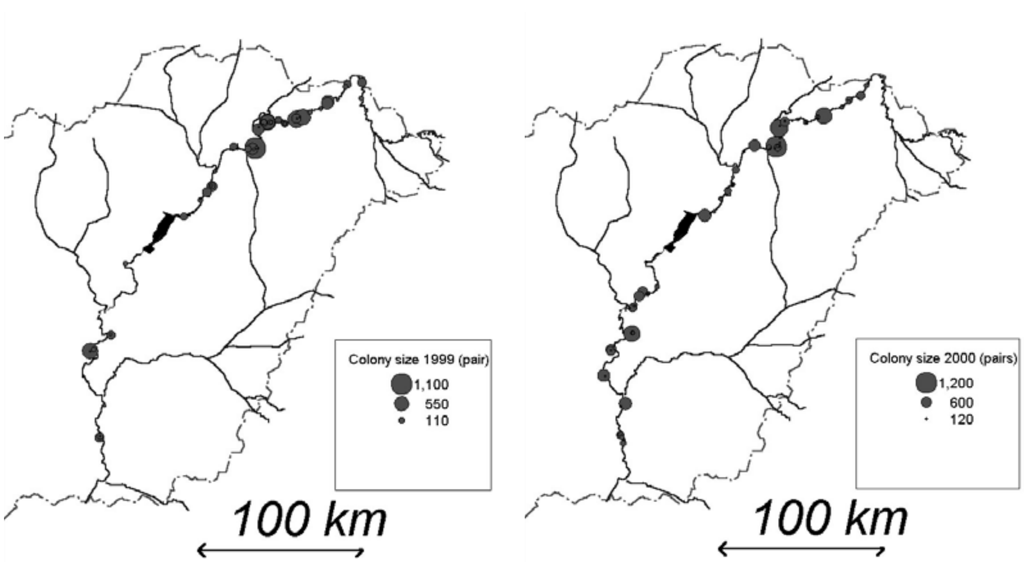

Fig. 2. Distribution and size of Sand Martin colonies along the Hungarian section of the river Tisza in 1999 (left) and 2000 (right).

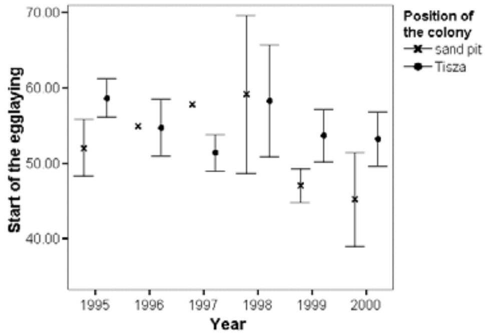

Fig. 3. Average start of egg-laying in colonies along the river Tisza and in sandpits remote from the river (with SE). Day 1 refers to 01 April. In 1996 and 1997 we include data from only one sandpit colony.

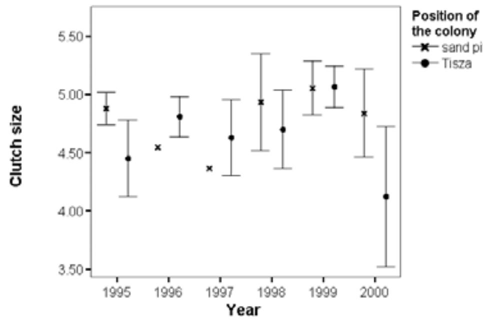

Fig. 4. Average size of the first clutch in colonies along the river Tisza and in sandpits far remote the river (with SE). In 1996 and 1997 we include data from only one sandpit colony.

the river several months after the disaster. Examples are:

1. Population decreases because drastic changes in the quality of the breeding habitat perturbed the food supply.
2. Negative effects on reproduction because of the toxic effects of heavy metal pollution and through shortage of food.

In this highly natural system, it was also important to consider natural events that could have large impacts on the flora

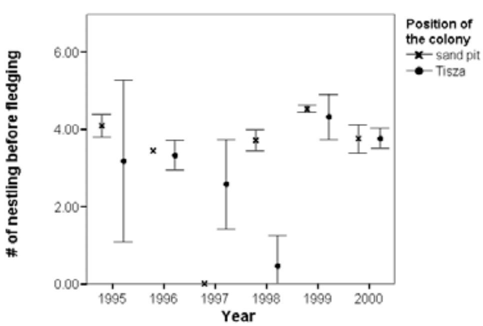

Fig. 5. Average numbers of nestling before fledging (14-18 days old) in colonies along the river Tisza and in sandpits remote from the river (with SE). In 1996 we include data from only one sandpit colony; in 1997 there was no sandpit colony with fledged nestlings.

and fauna. In April and May 2000, two months after the pollution struck, very severe floods occurred throughout the Tisza system, higher than any recorded since the 1850s, and these severely impacted on breeding bird success.

Long-term integrated monitoring work on the Sand Martin breeding population along the river Tisza (Szép 1991a) in Hungary has been running since 1986 under the aegis of MME and now BirdLife Hungary (Szép 1991b, 1995). This project provided the unwanted but valuable opportunity not only to monitor how the disaster affected the Sand Martin and the population size and distribution of Kingfisher but also to monitor the disaster's short-, mid- and long-term consequences. There would, in addition, be the chance of analysing the impacts of other natural and man-made effects on both insectivorous and piscivorous species (Furness & Greenwood 1993).

The breeding populations of these two species along the river Tisza depend predominantly on their food supply that originates mainly from the river fauna and the associated flooded areas. On the basis of past investigations of the foraging behaviour of breeding Sand Martin (Alves & Johnstone 1994) we could expect that the pattern of the parents collecting a large percentage of their food within a one-kilometre radius would also exist for the Kingfisher (Cramp 1990). Sand Martin and Kingfisher populations along the river could fulfil the criteria for indicator species for insectivorous and piscivorous birds respectively, because:

1. A large percentage of their food is collected above or in the river and its flood area.
2. Both species exhibit a strong dependence on the food supply associated with the river.

In the case of Sand Martin, there are methods and studies available to check the potential effects of food supply on reproduction (Szép & Moller 1999). Furthermore, methods of analysis of the chemical composition of feathers have been developed, techniques that could provide relevant information about the accumulation of heavy metals (Vallner *et al.* 1999, 2000).

The aim of this paper is to present:

1. How a long-term integrated monitoring study on breeding bird species could provide information about the effects of a drastic environmental pollution incident.
2. The importance of detailed investigations for the identification the effects of natural and man-made events on the ecosystem of a natural river.

2. Study area and methods

2.1 Surveying nesting habitats and breeding populations

In the framework of integrated monitoring of the Sand Martin population, we surveyed all potential breeding walls (whose perpendicular height forming part of the bank is >0.5 m) in three areas:

1. Along the Hungarian section of the river Tisza between Tiszabecs and Szeged (*c*580 km) once per year (since

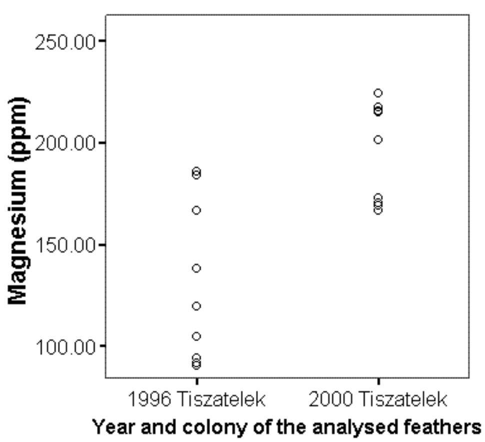

Fig. 6. Concentrations of magnesium (ppm) in the tail feathers of juvenile Sand Martin hatched at Tiszatelek colony along the river Tisza in 1996 and 2000.

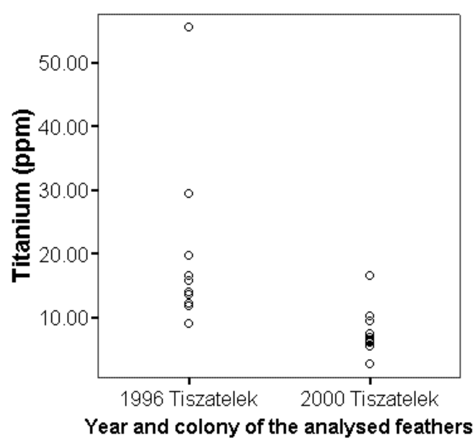

Fig. 7. Concentrations of titanium (ppm) in the tail feathers of juvenile Sand Martin hatched at Tiszatelek colony along the river Tisza in 1996 and 2000.

1990) from a motorboat during July and August.

2. Along the upper section of the river Tisza between Tuzsér and Tokaj (72 km) twice per week (since 1986) between mid-April and mid-August.
3. In sand pits located in a 20 km-wide belt along the studied upper section (2. above) of the river Tisza twice per week (since 1995) between mid-April and mid-August. During our survey, we identified all Sand Martin holes and colonies and all Kingfisher holes. Because each species forms its entrance holes differently, the constructor's identity is straightforward. However, in large and dense Sand Martin colonies, it is difficult to pick out a Kingfisher hole from the mass of Sand Martin holes, but over a 15-year period, we have found that the Kingfisher is very strongly disinclined to breed in large and active Sand Martin colonies.

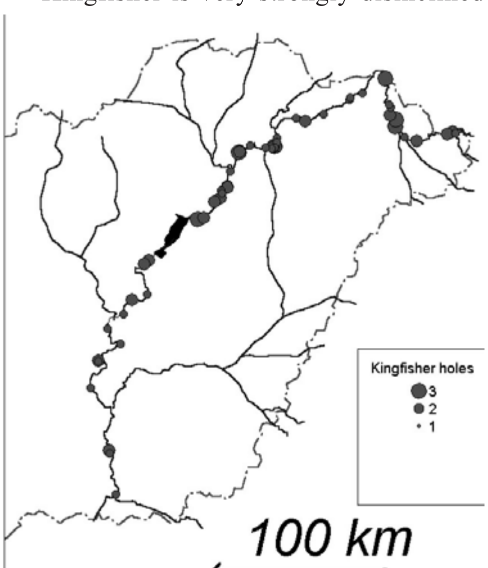

Fig. 8. Distribution of Kingfisher holes along the river Tisza in 2000. The circles indicate the location of the holes, and the circle diameters indicate the number of holes in one location (within 100 m).

The regular and intense spring floods (and more irregularly at other times) destroy most of the river walls where Sand Martin and Kingfisher breed. In most cases, previously used holes disappear or change in appearance, and so are easy to discriminate from new or reconstructed holes, making the annual surveys of active holes straightforward. Sand Martin population and colony sizes were estimated from the number of counted holes, the assumption being that 60% of the holes contain a nest (Szép 1990).

Such a simple technique does not work in estimating Kingfisher pairs along the river, because the male Kingfisher makes or re-uses many holes, most of which are not used during the breeding season. We carried out intense surveys along the upper section of the river between Tiszatelek and Tokaj (1997) and between Tuzsér and Tokaj (2000) when we checked all (100%) the potential breeding walls for Kingfisher holes, each hole being checked by endoscope for usage. In our analysis we handled separately the surveys of Kingfisher holes carried out, firstly of those of the Sand Martin colonies (1994-2000) and secondly that focussed on Kingfisher holes only (1997 & 2000). During the Sand Martin survey, the speed of the survey along the river is higher than in the case of the Kingfisher survey, which in the former could cause a lower detection rate for Kingfisher holes, for these are often in concealed places. For analysing trends in the Kingfisher population we consider the data collected during the Sand Martin survey, but only the detailed Kingfisher survey data were used for calibrating the frequency of nests in the holes. Holes with nests were identified when we found in them eggs or nestlings, or the remains of nestlings, faeces and fish scales. By this intense study we were able to identify in which holes Kingfishers were nesting in given years and we were able to estimate the ratio of holes with nest to excavated or reconstructed holes without nests. We present here the number of nests, because the estimation of breeding pairs from the number of holes with eggs and nestlings is confounded by the Kingfisher's opportunistic propensity for polygamy. Cramp (1990) indicates that one male may pair and breed with two, or more rarely three females. In 2000, after the ice had broken up, we mounted several surveys from motorboats in February and March along the upper section of the Tisza, to determine the presence of Kingfisher or to find evidence of fatalities from the cyanide pollution.

2.2. Surveying breeding success of the Sand Martin

Between 1995 and 2000, we checked twice a week 5617 Sand Martin holes with an endoscope. These holes were on randomly selected 2-5 m wide sections of 51 colonies along the upper Tisza or in sandpits adjacent to the river. This way we

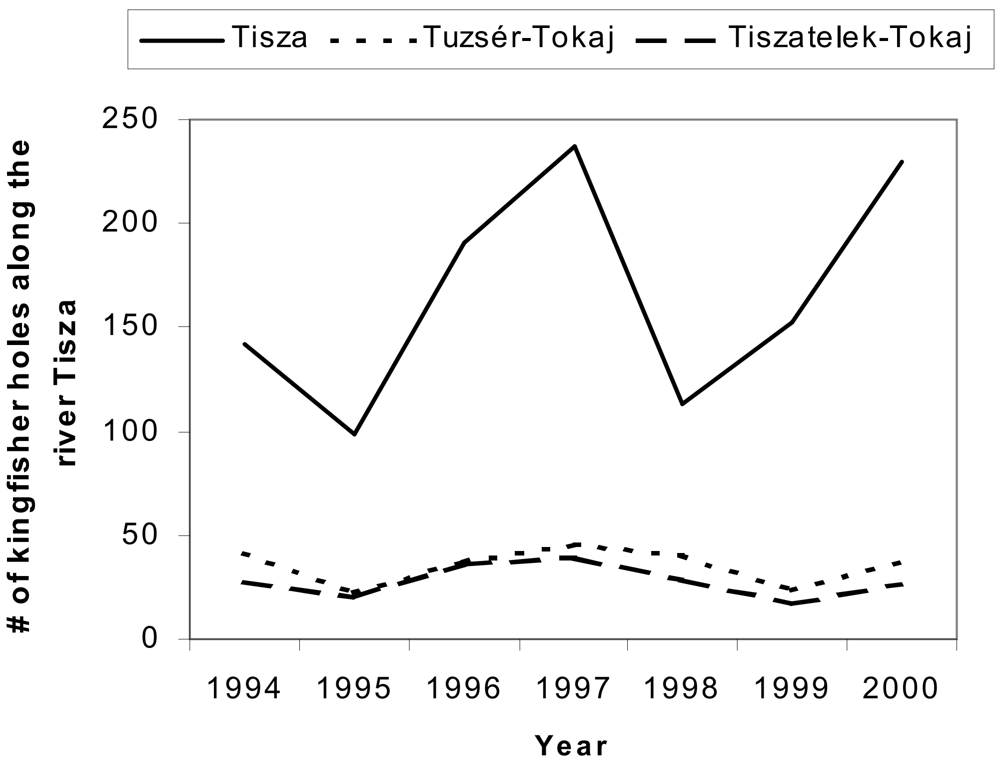

Fig 9. Number of Kingfisher holes along the river Tisza between 1994-2000. Three data sets are presented: a. Tisza: for the entire Hungarian section between Tiszabecs-Szeged (574 km) counted during the survey of Sand Martin. b. Tuzsér-Tokaj: along the Upper Tisza (72 km) counted during the detailed Kingfisher survey. c. Tiszatelek-Tokaj: along the Upper Tisza (42 km) counted during the detailed Kingfisher survey.

were able to identify the percentage of holes containing a nest (at least one egg laid), the start of the egg laying period, the clutch size, hatching success and the number of nestlings before fledging, which occured 14-18 days after hatching. The date of the first egg laid was recorded as being the number of days elapsed since 31 March (in the given year), day 1 being 01 April. Only those nests whose observations (of the above parameters) had been recorded with certainty had their data analysed. During the nest checking data analysis, we calculated and used the average values of the studied parameters for each colony, thus avoiding the statistical problems that arise from pseudoreplication.

2.3 Analysis of heavy metals in the feathers

We had collected one pair of the second outermost tail feathers from nine juvenile Sand Martins at a colony at Tiszatelek (48°12'N, 21°47'E) in June 1996, and we took the opportunity to do so again, from ten juveniles, in June 2000 after the pollution incident. The primary wing feathers of the sampled juveniles were undergoing moult, and so we could expect that these individuals had hatched and grown their tail feathers at the studied colony. The removal of one pair of tail feathers does not affect the bird's behaviour, survival nor dispersal characteristics measurably, and had been carried out under license of the appropriate nature conservation authorities. The removed feathers were stored in separate pairs in small sealed plastic bags, avoiding any feather contamination during collection and transportation, and were kept in boxes until the analysis. We used one tail feather of each pair for chemical analysis, and this was analysed but once, due to the small sample size. Concentrations of these elements were measured in the samples: As, Cd, Mg, Mn, Mo, Se, Sr, Co, Fe, Zn, Li, P, Ti, V, Ag, Cr, Ba, Hg, Pb, S, Ni and Cu. During this analysis, concentrations (in ppm) of control samples were examined, and these underwent the same handling protocols as did the samples (Vallner *et al.* 1999). The detailed descriptions of the preparation of the samples and the measurement of element concentrations (by inductively coupled plasma optical emission spectrometer, or ICP-OES) are given in Vallner *et al*. (1999, 2000).

2.4. Flood pattern along the river during 1995-2000

Along the Tisza the main flooding period is March-April, depending on the weather. The spring flood creates numerous extensive large new nesting walls. Flooding during the breeding period (called 'green flood') is rare and during the study years occurred only in 1998 when an exceptionally high level of flooding occurred between the end of June and mid-July. It covered and in most cases destroyed nearly all Sand Martin and Kingfisher nests along the river. Because this 'green' flood occurred before the main fledging period for both species, most first clutches were lost. The majority of the nest holes surveyed subsequent to the flood were holes that had been excavated after the flood, for second or replacement broods. In 1999, there was a moderate but long-lasting flood between April and June, which until mid-June had overtopped potential nesting places in the middle and lower Tisza.

After the pollution incident in 2000, we also needed to take into account the effects of the large spring flood, which submerged the potential breeding walls until early May along the Upper Tisza and until late May downstream. Early migrant Sand Martins were thus prevented from excavating nest holes and had to delay breeding. Statistical analysis of the data was carried out using the SPSS 9.0 statistical package (Norusis 1988).

3. Results

3.1 Population size and distribution of the Sand Martin

The population size changed markedly during 1990-2000 (Fig. 1). The average size of the breeding population along the Hungarian Tisza is 23 700 breeding pairs (bp) (SD=7761, n=10). In 2000, the population size increased by 102% in comparison to 1999, from 10 528 bp to 21 365 bp, which value was close to the average (Fig. 1).

We did not find a similar large increase along the upper Tisza, where no large changes have occurred since 1998. In contrast, this section in 2000 hosted a population whose size was only half (4746 bp) the average for the 1986-2000 period (mean=8985 bp, SD=3320, n=15) (Fig. 1).

The most significant factor influencing the large increase in population size along the Hungarian Tisza is the improved size and quality of prime nesting places in the form of perpendicular walls that had been created by the floods, mainly in the middle and lower sections (Fig. 2). In 2000, the total (vertical) surface of these riverbanks increased by 28%, from 4533 m^2 to 5820 m^2. Several large and substantial riverbanks had formed in the middle and lower section of the river (Fig. 2). It is important to bear in mind the adverse 1999 conditions that had prevailed, when the sustained flood along the middle and lower river sections had affected breeding to the extent that many pairs had been forced to breed in colonies remote from the river that year (Fig. 2). It is highly probable that many of these temporarily displaced breeding birds returned to the Tisza in 2000, thus explaining the large 'blip' in the annual breeding statistics.

3.2. Breeding success in Sand Martin colonies

An average of 63.82% of holes contained nest in the studied colonies (SD=16.20; n=51). This parameter does not show significant changes year on year (F=0.844; df= 5, 45; P=0.526; ANOVA) and it does not differ between Tisza colonies (mean=64.42; SD=15.95; n=32) and those remote from the river (mean=62.80; SD=17.01; n=19) (F=0.117; df=1, 49; P=0.734; ANOVA). The average value of the commencement of egg-laying is at day 53.08 (SD=6.39, n=51). This parameter does show significant changes year on year (Fig. 3) (F=3.146; df=5, 45; P=0.016; ANOVA) and it differs between Tisza colonies (mean=54.83; SD=4.93; n=32) and those remote from the river (mean=50.14; SD=7.54; n=19) as well (F=7.203; df=1, 49; P=0.010; ANOVA). Breeding began earlier in 1999 and 2000 than it did in earlier years (Fig. 3). In 2000, breeding in sandpits began earlier than in the river colonies (Fig. 3).

The average clutch size is 4.73 (SD=0.405; n=51). This parameter does not show significant changes year on year (Fig. 4) (F=1.718; df=5, 45; P=0.150; ANOVA) and neither does it differ significantly between Tisza colonies (mean=4.67; SD=0.429; n=32) and those remote from the river (mean=4.844; SD=0.346; n=19) (F=2.151; df=1, 49; P=0.149; ANOVA). However, in 2000 there was a slight difference; in colonies along the Tisza, the clutch size was smaller than at sandpit colonies (Fig. 4). The significant negative correlation between the start of egg-laying and clutch size at the studied colonies (r=-0.38; n=51; P=0.006; Pearson) could explain the lower clutch size at the delayed Tisza colonies.

The average hatching rate (at least one egg hatching per nest) is 0.749 (SD=0.24; n=51). This parameter does not show significant changes year on year (F=1.410; df=5, 45; P=0.239; ANOVA), nor does it differ between Tisza colonies (mean=0.721; SD=0.247; n=32) and those remote from the river (mean=0.796; SD=0.261; n=19) (F=1.071; df=1, 49; P=0.306; ANOVA).

The average value of the number prefledging nestlings is 3.265 (SD=1.329; n=42). This parameter does show significant changes year on year (Fig. 5) (F=7.363; df=5, 36; P<0.001; ANOVA). In general there is no significant difference between Tisza colonies (mean=2.970; SD=1.438; n=25) and those remote from the river (mean=3.70; SD=1.041; n=17) (F=3.219; df=1, 40; P=0.080; ANOVA). However in 1998, because of the 'green' flood, far fewer nestlings fledged from the Tisza colonies than from sandpit colonies (Fig. 5).

3.3. Accumulation of heavy metals in feathers of juvenile Sand Martins

Among the studied 23 chemical elements, only for magnesium (Fig. 6) did we find a significant increase from 1996 to 2000 for juvenile tail feathers collected at any one colony (1996: Mg=130.903 ppm; SD=39.474; n=9. 2000: Mg=196.976 ppm; SD=24.026; n=10; t=-4.461; df=17; P<0.001, t-test), but for lithium and nickel there were only weak increases (P=0.07). The amounts of titanium (Fig. 7) (1996: Ti=19.806 ppm; SD=14.59; n=9. 2000: Ti=7.570 ppm; SD=3.773; n=10; U=8; P=0.001, Mann-Whitney), cadmium (1996: Cd=0.767 ppm; SD=1.077; n=9. 2000: Cd=0.174; SD=0.09; n=10; U=17; P=0.022, Mann-Whitney) and selenium (1996: Se=10.518 ppm; SD=3.154; n=9. 2000: Se=6.991 ppm; SD=3.582; n=10; t=2.267; df=17; P=0.037, t-test) were significantly higher in the feathers collected in 1996 than in the 2000 feathers. For all other elements there were no significant differences between the two years of comparison.

3.4. Distribution of Kingfisher holes along the river Tisza

Kingfisher distribution is uneven along the Tisza (Fig. 8). The highest density of nest holes occurs on river sections that have the greatest incidence of breeding walls (mostly in the upper Tisza). In 2000, that the middle section held more nest holes than usual was very probably due to the severe 2000 floods creating additional large vertical banks suitable for nest holes.

3.5. Number of Kingfisher holes along the river Tisza

The number of Kingfisher holes along the studied 574 km-long Hungarian section of the river Tisza varied between 98 and 237 (mean=162.8 holes) (Fig. 9). The average density of the holes along the river is 0.29 holes/km (min: 0.17 holes/km; max: 0.41 holes/km).

3.6. Number of Kingfisher holes along the Upper Tisza

The number of Kingfisher holes along the 42km-long section of the Upper Tisza between Tiszatelek and Tokaj, where the intensive survey was done in 1997, varied between 17 and 39 (mean: 28.0 holes) (Fig. 9). The average density of the holes along this section is 0.67 holes/km (min: 0.41 holes/km; max: 0.93 holes/km). The number of Kingfisher holes along the 72 km-long section of the Upper Tisza between Tuzsér and Tokaj, where the intensive survey was done in 2000, varied between 22 and 46 (mean=35.1 holes) (Fig. 9). The average density of the holes along this section is 0.49 holes/km (min: 0.31 holes/km; max: 0.64 holes/km)

3.7. Frequency of holes containing nests

In 1997, out of the 74 Kingfisher holes investigated along the 42 km-long section of the Upper Tisza, breeding took place in 39, a nesting frequency of 52.7%. That year, nest density along this stretch was 0.93 nests/km. In 2000, out of the 37 holes investigated along the 72 km-long section of the Upper Tisza, breeding took place in 18 holes, a nesting frequency of 48.6%. That year nest density along the same (1997) section was only 0.29 nests/km.

3.8. Estimation of the Kingfisher population size along the river Tisza

Based on the detailed studies of 1997 and 2000, we can assume that *c*50% of the surveyed holes contain nests. From this value, we can estimate the number of nests varies between 119 and 49 (mean: 81 nests). The average nest density along the river is 0.15 nests/km (min: 0.09 nests/km; max: 0.2 nests/km). Along the Upper Tisza, nest density could reach 0.5 nests/km.

3.9. Kingfisher breeding season in 2000

We did not find any evidence of pollution-induced fatalities during our visits before and during the breeding season. We found that there were considerable delays in the arrival of prospecting birds and in the start of breeding, but the lengthy and heavy flood in 2000 was very probably the cause.

4. Discussion

The sudden and heavy cyanide pollution along the river Tisza in February 2000 caused mass fatalities, amounting to several tonnes of fish and created serious concern about the potential impact, from the immediate to the long-term, on the unique, highly natural ecosystem of this river. Because this pollution occurred at the biologically most inactive period of the year in this area, the overall damage, though considerable to local invertebrate and fish populations, was probably much less than it would have been at any other time of year. However, given precedents such as the similar disaster at Donana, it is reasonable to expect further and serious delayed impacts on the fauna and flora of this highly natural riverside ecosystem, whose diversity and abundance in the temperate European biome is almost unrivalled in scope. Had the cyanide pollution occurred only one month later, heavy metal pollution could have had the most devastating effect on the migrant and resident breeding fauna whose food supply is almost totally dependent on the immense diversity and abundance of invertebrate (mainly insects) and vertebrate (mainly fish) species. Only by the narrowest of margins (one month) did severe heavy metal poisoning fail to spread throughout this precious habitat in the spring-induced annual acceleration of biological activity. A vigorous spring flood did much to replenish the losses. The diverse and abundant bird fauna along the river is potentially one of the most vulnerable groups under threat from pollution incidents such as this. The very vulnerability of this group, through its strong dependence on the quality of its breeding environment, makes it one of the best candidates to indicate the negative effects of pollution; in other words, it contains ideal species to act as monitors of environmental quality.

The long-term integrated monitoring of the insectivorous Sand Martin population along the river Tisza could provide a near-ideal source of analysing the negative delayed effects of pollution, not only because the food supply of the studied breeding population is strongly related to the diversity and abundance of the invertebrate fauna, but also because detailed long-term data are available for the analysis.

The intensive studies on this population did not reveal any negative effects of the pollution on population size, distribution, and breeding performance in 2000. We found only that the clutch size in that part of the population along the upper Tisza was smaller than in populations breeding far from the river, but this difference very probably was due to the 2000 flood. One important effect of that unseasonably lengthy flooding was that only the later returning migrants were able to breed along the river (the early migrants having sought other sites), as is shown by the breeding data start dates. Later returning migrants usually have a smaller clutch size (Moller 1994), which proved to be the case with the Tisza Sand Martin population in 2000, as shown by the negative correlation between the start of egg laying and clutch size.

From our chemical analysis of tail feathers of juvenile birds, we could not show that the pollution-deposited heavy metals caused changes in the level of those heavy metals in the food chain of insectivorous birds. However, comparisons of these feathers with feathers grown in 1996 suggest that in earlier decades levels of various heavy metals were higher in this group's food chain, thus correlating with information that the polluting industries in the Romania-Ukraine watershed region had been working at higher production rates than recently.

The Sand Martin population size increased significantly in 2000, as did the species' distribution along the river, but we need to probe beyond these findings to consider which other factors might have compensated for, or hidden the effects of the pollution.

Earlier studies of the effects on survival rate of conditions en route and in the wintering areas of this long distance migrant species revealed that survival rate and, in part, the population size are highly dependent on the weather they experienced in Africa (Szép 1995). The 1999-2000 migration and wintering season was more typical than average, because of generally favourable weather along the migratory route in Africa. The very early return to the breeding area in 2000, allowing breeding to begin early, is an indicator of good wintering conditions. Such favourable circumstances would improve not only the likelihood of an increase in the breeding population, but also that breeding individuals would be in good average physical condition.

Flooding along the Tisza has a number of positive and negative impacts on the breeding population. Flooding mainly occurs in March-April and has a very important positive effect by creating a fresh pristine perpendicular riverbanks for breeding colonies. That walls with previously occupied holes (that still contain several active ectoparasite species) are washed away regularly is a very important factor in reducing or eliminating ectoparasite load, thus minimizing its high cost and threat to individuals and colonies (Szép & Moller 1999, 2000). Heavy and sustained flooding, as in 2000, can create new and extensive breeding habitats in those stretches of the river that normally hold few or mainly small walls. Flooding occurring during the fish breeding period has an important positive role in the reproductive success of several fish species and possibly is beneficial for several other aquatic animals. The 2000 flood was very important because it diminished the effects in the polluted areas by the widespread translocation of numerous non-vertebrate and vertebrate species from the adjacent uncontaminated wetland habitats of the Tisza floodplain.

However, flooding during the birds' breeding period could have several adverse impacts. Flooding that extends beyond the normal spring period, as happened in 1999 and to a lesser extent in 2000 makes it impossible for early returning Sand Martins and Kingfishers to breed, and this causes a large scale dispersal to secondary breeding habitat in sandpits where natural threats (digging predators, wall collapse, lower food availability in windy and cold weather) and human impact (illegal sand removal) are greater than along the river. Flooding occurring when nestlings are feeding could wipe out most first clutches in the breeding population, which natural disaster happened in 1998. Historically, the frequency of such abnormal flooding has been low but recently, the incidence has been much higher, and if this change is sustained, the putative link to climate change becomes more substantive.

From these studies, we found that along the river Tisza a large population of Kingfisher breeds whose size varied between 50-120 bp, if polygamy remained at a low level. This population density approaches the highest values cited in the literature (Cramp 1990) reaching 0.5 bp/km in some sections.

Considering and comparing the population processes before the 2000 pollution and those just after, we could not find immediate post-pollution serious effects on Kingfisher. We did not find evidence of fatalities caused directly by pollution. To explain the low population size and density found in 2000, which were very low in comparison with 1997 data (the first detailed study), we can show that the primary causes were the effects of the flood of 1998 on reproduction and of the flood in 2000 on delaying the onset of breeding; the pollution incident had no such immediate effects. When we consider the huge importance to the Kingfisher of small fish as food, we can show that the pollution did not cause a large negative impact on this piscivorous species.

Based on our experience along the river and on the results since 1995 from our intensive fieldwork in the breeding seasons, we know that some cases of several *Chyronomous spp* species swarming in 2000 were particularly abnormal in their abundance and time schedule, in that they were not typical of the prevailing conditions, whereas they had been so in the previous decade. These odd circumstances, by providing a potentially ample food supply for insectivorous birds, could explain the very successful breeding performance at the colonies along the river, where although the clutch size was smaller than at sandpit colonies, there was no difference in the numbers of nestlings produced. There is no research evidence for any connection between the pollution and the abnormal swarming. However, neither can the role of pollution be excluded as contributory to the abnormal swarming, which also has had positive effects on insectivorous animals in 2001. It may be that this perturbation may have longer-term negative impacts.

In summary, our study, which has the longest-term data series for the entire Hungarian section of the Tisza, did not find evidence for any negative impact in 2000 of the pollution on breeding insectivorous and piscivorous bird species. However, that does not preclude a long-term, insidious perturbation of the Tisza's ecological system, as the abnormal *Chyronomous spp* swarming behaviour might indicate. This conclusion accords with the results of investigation of other animal groups, but much further work is to determine what, if any, the medium- and long-term middle and long-term effects of the pollution are.

Our work underlines the importance of detailed and long-term investigation of bird species that can act as indicators of environmental change, particularly that suffered through the impact of human-induced-made environmental disasters. Such impacts are likely to be quickly obvious where large groups of breeding insectivorous and piscivorous birds occupy the course of rivers possessing numerous extensive natural habitats of high biodiversity and biological productivity. Work such as ours can discriminate between natural and human-induced causes of bird population changes, and without this ability, it is all too easy to reach the wrong conclusions. It is important to reiterate that these types of studies provide one the most cost-effective, large scale and long-term opportunities to investigate the effects of pollution on insects and fish, the other two main groups of animals that inhabit the European riverine environment.

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