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Severe flooding causes a crash in production of white stork (*Ciconia ciconia*) chicks across Central and Eastern Europe

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Abstract

Recent theoretical and field studies show that stochastic, extreme ecological events may influence the dynamics of populations for many years. However, to date, studies have focused only on the short-term effect of ecological catastrophes and/or extremes on population dynamics. In this paper, we present results from the great flood of July 1997 in Central and Eastern Europe and how it affected the white stork (*Ciconia ciconia*), a long-lived bird species. Using long-term data collected in 1987–2003, we examined the effect of the great flood on population size and chick production and we focussed on the 10 years preceding and 6 years following the flood. Habitats of 18 of the 25 stork populations studied were inundated during the flood of 1997. The flooded populations had a massive loss of chicks in 1997 but quickly recovered to about 85% of expected normal chick production compared to the control populations. This suggests a relatively minor but long-term consequence on population dynamics over a large geographic scale resulting from the extreme flooding event.

Zusammenfassung

Neueste theoretische und Freiland-Studien zeigen, dass stochastische, außergewöhnliche ökologische Ereignisse die Dynamik von Populationen für viele Jahre beeinflussen können. Bis heute haben sich Untersuchungen nur auf kurzfristige Folgen von ökologischen Katastrophen und/oder Extremen für die Populationsdynamik konzentriert. In dieser Arbeit stellen wir Ergebnisse vom großen Hochwasser in Mittel- und Osteuropa im Juli 1997 vor und berichten, wie dieses den Weißstorch (*Ciconia ciconia*), eine langlebige Vogelart, beeinflusste.

Anhand von Daten, die von 1987 bis 2003 gesammelt wurden, untersuchten wir die Auswirkungen des großen Hochwassers auf die Populationsgröße und die Jungenproduktion, wobei wir uns also auf die 10 Jahre vor und die 6 Jahre nach dem Hochwasser konzentrierten.

Die Lebensräume von 18 der untersuchten 25 Storchenpopulationen wurden überflutet. Die überfluteten Populationen erlitten 1997 massive Verluste an Küken, aber sie erreichten schnell wieder 85% der Kükenproduktion,

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die nach Vergleich mit den Kontrollpopulationen erwartet wurde. Dies legt nahe, dass eine relativ kleine aber längerfristige Folgewirkung auf die Populationsdynamik im großen geographischen Maßstab aus dem extremen Hochwasser resultierte.

Keywords: Birds; Breeding effort; Ecological catastrophe; Extreme event; Flood; Long-term studies; Population size

Introduction

The negative influence of humans on habitats is well known. But natural changes in habitats, especially those caused by stochastic events such as weather extremes, may even have a greater impact (Holmgren et al., 2006; Parmesan, Root, & Willig, 2000; Scheffer, Carpenther, Foley, Folke, & Walker, 2001). The effect of extreme events, described in the context of populations, habitats and whole ecosystems, has mainly been discussed in short-term studies and at local scales (Bennetts, Kitchens, & Dreitz, 2002; Katz, Brush, & Parlange, 2005; Scheffer et al., 2001; Weatherhead, 1986; but see: Jiguet et al., 2006). But it has also been emphasised that the spatial and temporal regimes of large, infrequent disturbances are greater than the scale of typical ecological studies, which are usually limited to a few years and often conducted on a single-study plot (Dale, Lugo, MacMahon, & Pickett, 1998). Spatially broader long-term data sets are necessary for understanding the population dynamics of long-lived organisms, because the reaction of a population to extreme events may have a lag in time (Bennetts et al., 2002; Knopf & Sedgwick, 1987; Sæther et al., 2005). Understanding the impact of extreme, unpredictable events is urgent: not just from the theoretical perspective of the reaction of populations to disturbances (Holmgren et al., 2006; Katz et al., 2005; Sæther & Engen, 2002; Scheffer et al., 2001; Weatherhead, 1986). Such ecosystem perturbations may have consequences for living organisms via a bottleneck effect on populations (Soulé, 1987). It is also important from a practical, conservation perspective, where unpredictable disturbances should be included, for instance, in population viability models (Brook, 2000; Sæther & Engen, 2002).

Widespread flooding is a good example of an ecological catastrophe destroying whole ecosystems over a large area (Bennetts et al., 2002; Holmgren et al., 2006; Kundzewicz et al., 2005; Scheffer et al., 2001), and it is a typical large, infrequent disturbance (Holmgren et al., 2006; Katz et al., 2005). One such flood took place in Central Europe in July 1997 and it was the greatest flood in the region for at least 1000 years (Kundzewicz et al., 2005). The flood of 1997 was the most extreme event on record, both in hydrological terms (peak stage, flow, inundated area) and economic terms (financial losses). The flood covered hundreds of square kilometres and had a strong impact within the region on river ecosystems and human environments (Kundzewicz et al., 2005), and it obviously also affected animal populations (Heitmeyer, 2006; Holmgren et al., 2006; Wilson & Peach, 2006). To date, however, this influence has only been examined at a local scale and over a short-time period (Heitmeyer, 2006; Wilson & Peach, 2006). To better understand the influence of the flood on populations, data collected from a broader temporal and spatial scale are necessary (Parmesan et al., 2000).

Among the vertebrates which have been studied long-term is the white stork *Ciconia ciconia*, an icon of nature conservation in Europe and elsewhere (Creutz, 1985; Schulz, 1998). For several reasons the white stork is an especially good species on which to test the influence of a major habitat disturbance. Establishing both the population size and breeding success is relatively easy in the field, it follows international standard methods, and, therefore, the obtained data are of a good quality (Creutz, 1985; Sæther et al., 2005; Schulz, 1998; Tryjanowski, Sparks, et al., 2005). White storks also live in river valleys, where flooding may occur typically before the breeding season, and agricultural landscapes (Creutz, 1985; Dallinga & Schoenmakers, 1987; Tryjanowski, Jerzak, & Radkiewicz, 2005).

The main aim of this paper is to examine how the great flood of 1997 affected populations of white stork across Central and Eastern Europe, both in terms of chick production and population size. To the best of our knowledge this is the first study examining the response of a species to a large scale event at so large a temporal and spatial scale. Because the number of extremes, especially floods, is predicted to increase under rapid climate change (Easterling et al., 2000; Kundzewicz & Schellnhuber, 2004), we believe our findings will be useful towards an understanding of animal population dynamics in the future.

Methods

The study sites were located throughout Central and Eastern Europe (Poland, Slovakia, the Czech Republic and Ukraine (see Appendix A), which is the geographical centre of the white stork distribution range (Creutz, 1985; Schulz, 1998). In total 25 populations were monitored, and data were collected in 1973–2003, but not all study sites were monitored for the entire period. We, therefore, decided to use only data for the common period (1987–2003). Basic data on the population size in local populations have been published already (Daniluk, Korbal-Daniluk, & Mitrus, 2006; Grischenko, 2004; Rejman, 2004; Sæther et al., 2006; Tryjanowski, Sparks, et al., 2005; Tryjanowski, Jerzak, et al., 2005; and references therein). In the present paper, population sizes and chick production from all study sites have been analysed collectively.

The white stork builds large, perennial nests that are typically located close to human settlements, and which are therefore relatively easy to find and to observe during the breeding period (Creutz, 1985; Schulz, 1998). The size and chick production of the local populations were established in early July every year using standard methods (Creutz, 1985; Schulz, 1998; Tryjanowski, Sparks, et al., 2005).

In the great flood of 1997 areas were flooded in late June (Kundzewicz et al., 2005), when storks raise chicks, for over 1 month, with vegetation destroyed for a longer time. The studied stork populations were divided into two groups; those flooded and those not flooded (control group; Appendix A) during the 1997 breeding season (cf. Knopf & Sedgwick, 1987). Records were made of the number of nesting pairs (population size) and the number of chicks. The mean number of chicks per nest was calculated from single nest records. Because the white stork is a long-lived species, with sexual maturity reached at 3–4 years, the breeding population size may not be directly affected by an external event, but affected with a time lag (Sæther et al., 2005, 2006). Therefore, to properly examine the impact of the extreme event on the breeding population, data were examined for 1987–2003, representing 10 years preceding and 6 years following the flood.

Analysis focused on annual mean chick numbers and annual mean population sizes calculated for the flooded and control groups. Flooded and control groups were compared using paired *t*-tests over appropriate time periods.

Results

An examination of mean population size suggested an increasing trend for both groups with a decline in the last 3–4 years (Fig. 1). A dip in population size in 1997 for the flooded group is apparent followed by a rapid recovery. The effect of the flood was most apparent in a reduction in chick production, which collapsed in the flood year to about half the expected value in flooded populations (Fig. 2). Chick numbers (means ± SE) of control populations were not significantly different from mean flooded populations prior to 1997 (2.18 ± 0.05 cf. 2.17 ± 0.07, paired $t_9 = 0.09$. $P = 0.93$), but were greater after 1997 (2.42 ± 0.06 cf. 2.05 ± 0.06, paired $t_5 = 4.76$, $P = 0.005$) (Fig. 2). Having been approximately equal before the flood, chick production in the flooded group was about 15% lower than the control group after the flood.

Mean population size (means ± SE) of control populations was significantly smaller than that of flooded populations prior to 1997 (23.0 ± 0.9 cf. 34.3 ± 1.2, paired $t_9 = -23.03$, $P < 0.001$) and thereafter (31.3 ± 0.6 cf. 39.7 ± 0.8, paired $t_5 = -11.52$, $P < 0.001$) (Fig. 1). Repeating the latter test with the mean under the null hypothesis set to −11.3 (the pre-flood mean difference) failed to achieve significance (paired $t_5 = 0.01$, $P = 0.992$) suggesting a similar mean difference post-flood.

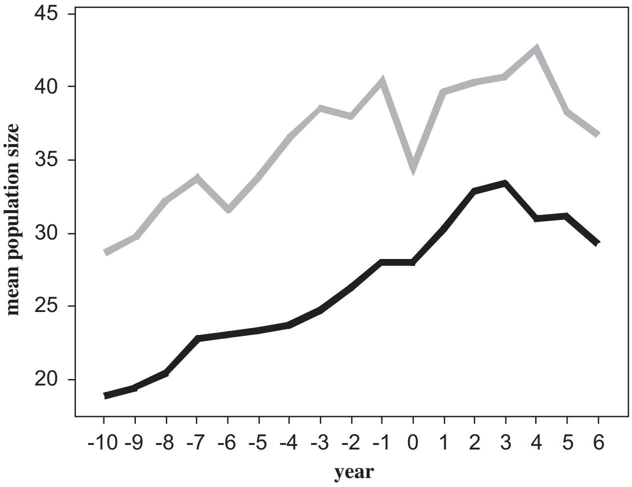

Fig. 1. Mean population sizes for 10 years before and 6 years after the flood year (1997, represented by zero) for flooded (grey line) and control populations (black line).

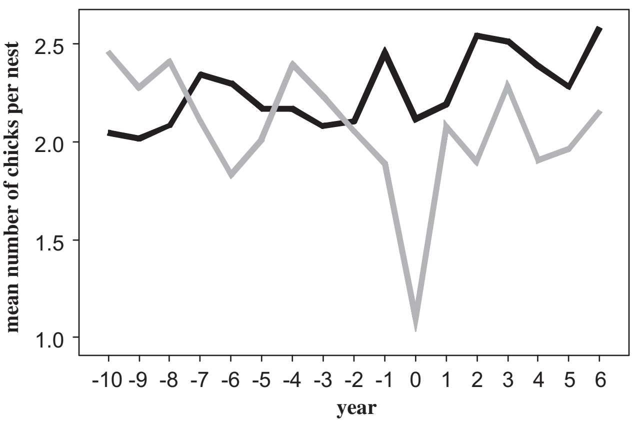

Fig. 2. Mean chick numbers per nest for 10 years before and 6 years after the flood year (1997, represented by zero) for flooded (grey line) and control populations (black line).

Discussion

The flood of 1997, described as the heaviest in the last 1000 years (Kundzewicz et al., 2005), occurred during the breeding season and was thus unlike the typical inundation of flood plains, which takes place earlier in the year. It affected large parts of Central and Eastern Europe and we have taken the opportunity provided by multiple monitoring programmes to examine the effect of the flood on an iconic species.

In white storks, differences in chick production and population size among populations are probably related to changes in weather conditions and/or food supplies in the breeding areas, during migration and in the wintering grounds (Creutz, 1985; Dallinga & Schoenmakers, 1987; Schaub, Kania, & Koppen, 2005; Schulz, 1998; Tryjanowski, Jerzak, et al., 2005). A previous study showed white stork population dynamics were strongly density dependent and had a relatively low environmental stochasticity (Sæther et al., 2006). Our study yielded a different result: a rare stochastic event, the flood of 1997, affected white stork local populations across Central and Eastern Europe.

The effect of the flood was most apparent in a reduction in chick production, which collapsed to about half the expected value in flooded populations. Chick numbers of control populations were not significantly different from flooded populations prior to 1997 but were greater after 1997. As the flood was a consequence of heavy rainfall and temperatures (Kundzewicz et al., 2005; Profus & Cichocki, 2002) at that time were relatively low, chicks faced difficulties in thermoregulation and lack of food (Profus & Cichocki, 2002; Tortosa & Castro, 2003).

In general, it is assumed that high water levels influence changes in food resources and, therefore, have a positive effect on the white stork. In years with a higher spring water level in rivers, local white stork numbers were higher and achieved better breeding success (Creutz, 1985; Tryjanowski, Jerzak, et al., 2005). Normal spring floods may have a positive effect on birds, other animals and biodiversity in general (de Nooij, Verberk, Lenders, Leuven, & Nienhuis, 2006). In years of high water levels there are substantial changes in vegetation structure, because the water halts or reverses vegetation succession thus providing good foraging patches (Dallinga & Schoenmakers, 1987; Sera & Cudlin, 2001; Tryjanowski, Jerzak, et al., 2005; Wijnhoven, Van Der Velde, Leuven, & Smits, 2005) and improved food availability of prey such as fish and amphibians (Holčik & Bastl, 1976; Ogielska, Kazana, Pałczyński, & Tomaszewska, 1999), which are important for foraging storks (Alonso, Alonso, & Carrascal, 1991). On the negative side, flooding can adversely affect earthworms, other invertebrates (Plum, 2005) and small mammals (Jacob, 2003), which make up a significant part of the diet of the white stork in Poland (Kosicki, Profus, Dolata, & Tobółka, 2006).

From our findings it is difficult to say definitively how important was the long-term negative effect of the great flood on the studied populations. Despite a major reduction in chick production in 1997 there was little subsequent effect on population size. The reduction in chick production appeared to last longer, although the reduction was only some 15%. Perhaps because the wetlands that flood annually provide better conditions for white storks, they were better able to recover after the 1 year crash. In fact, population size of flooded populations were significantly larger than control populations both prior to 1997 and afterwards. While the white stork results thus support a rather optimistic view that populations can recover from an extreme event, this may not necessarily be true for other animals (Holmgren et al., 2006; Jacob, 2003; Parmesan et al., 2000; Plum, 2005; Wijnhoven et al., 2005; Wilson & Peach, 2006).

What lessons can managers learn from large infrequent floods? These extremes can definitely and substantially affect animal populations. For the studied white stork populations the impact in subsequent years does not appear to be very large because this is a long-lived species; shorter-lived species would be expected to be less resilient. The great flood of 1997 has been referred to as a millennium flood and, by definition, this kind of extreme event is very rare. However, due to climate change, extreme events such as tsunamis, typhoons, cyclones, and floods may become more common worldwide (Easterling et al., 2000; Holmgren et al., 2006; Kundzewicz & Schellnhuber, 2004). The consequences of two extreme events occurring in close succession may be less easy for white stork populations to recover from.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.baae.2008.08.002.

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