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ORIGINAL PAPER

Mortality of game mammals caused by an extreme flooding event in south-western Poland

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Abstract We examine mortality in five terrestrial species of game animals resulting from an extreme flood event in Central Europe in July 1997. We present species-specific mortality rates and collate them with local abundances to show the susceptibilities of the different species to flood mortality. We also compare mortality rates in areas inundated by the main river and by its tributaries. Data were collected in the catchment area of the Odra River, south-western Poland. Mortality was estimated by surveying for drowned animals in flooded areas of 50 hunting districts (2,876 km^2). Total mortality amounted to 3,613 individuals, mostly of roe deer *Capreolus capreolus* and brown hare *Lepus europaeus*. Relative to estimates of abundance, mortality was disproportionately high in hares. Drownings of roe deer and wild boar, *Sus scrofa* were proportional to local abundance. Young individuals were particularly affected. Mortality was low in foxes, *Vulpes vulpes*, and red deer, *Cervus elaphus*. The mortality rate increased with the proportion of area flooded and the duration of flooding and was four times higher along the Odra River than along its tributaries. Our data specify, for the first time, direct losses in wild, large animals in response to an extreme flood event. Despite high overall losses, negative long-term effects on populations seemed unlikely. Nevertheless, to lessen the impact, river management focused primarily on human safety should also integrate the needs of wildlife.

Keywords Flood disturbance · Natural hazards · Mortality rate · Population dynamics · River management · Central Europe

1 Introduction

Disastrous natural phenomena are predicted to have a profound impact on wild animals (Parmesan et al. 2000; Holmgren et al. 2006). Catastrophic events cause dramatic short-term population declines or local extinctions, either from direct mortality or habitat

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destruction. Within a selected taxonomic group like mammals, the level of disruption will depend on species-specific behaviour, morphology and life history characteristics (Bunn and Arthington 2002; Robinson et al. 2002; Lytle and Poff 2004). Each individual will experience a risk of death or displacement which is determined by the interaction of the event parameters, the behavioural and physical attributes of the animal and habitat characteristics. However, these specific outcomes and the overall influence of stochastic disasters on animals are extremely difficult to document. Catastrophic disturbances are rare, ephemeral and unpredictable, and a systematic study is difficult to design. To date, most studies have evaluated the effects of ecological catastrophes indirectly, via changes in population dynamics. Direct losses are less understood because they can rarely be observed, disturbed areas are not accessible for a long time and dead animals disappear quickly, being washed away by flood waters, burnt in fires or covered by volcanic ash (Welbergen et al. 2008; McKechnie and Wolf 2009; Tryjanowski et al. 2009).

Disastrous floods have recently been recognized as a major hazard in many parts of the world. Riverine flooding may affect vast areas, occur with high and increasing frequency (Kundzewicz and Schellnhuber 2004; Palmer et al. 2008) and cause dramatic damage in human-dominated habitats (Jonkman 2008). Floods affect also animal populations, although the negative influence on wildlife is not so obvious. Post-flood diversification of habitats can offset high direct mortality, and many taxa may actually benefit from flooding (Bennetts et al. 2002; Ballinger et al. 2005; Lada et al. 2007). Vertebrates associated with aquatic and riparian habitats are usually resistant to river discharge and inundation, as confirmed by studies on beavers (Breck et al. 2001), birds (Poiani 2006), amphibians (Bateman et al. 2008) or fish (Humphries et al. 1999; Franssen et al. 2006). In contrast, severe losses can be expected in terrestrial animals in flooded areas.

Unfortunately, unlike the well-studied impact of floods on small mammals (Andersen et al. 2000; Williams et al. 2001; Jacob 2003; Thibault and Brown 2008), little is known about the influence of floods on large vertebrates (Heinen and Singh 2001; Profus 2002). There is a paucity of equivalent data collected over large areas on large animals. Nor have comparisons been made for losses of wild mammals caused by differing degrees of flooding of rivers, large and small.

In July 1997, Central Europe experienced a flood believed to be the most extensive on record, in both hydrological and economic terms (Kundzewicz et al. 1999). Hundreds of square kilometres in the middle and upper Odra/Oder and Wisła/Vistula rivers were inundated, with a strong impact on humans, habitats and animal communities. The influence of this catastrophic event on animals was only partially recognized (Ważna and Gabryś 1998; Ogielska et al. 1999; Jakubiec and Wuczyński 2002; Profus 2002; Tryjanowski et al. 2009). Unfortunately, there is no thorough understanding of the global impact of this flood on any taxa, particularly because of the unpredictability of the disruption of such a magnitude and the lack of analysis of pre-flood data.

Hunting statistics are a valuable source of information due to the temporal continuity of data collection, standard methodology, inclusion of several species, and coverage of large and constant areas (Ericsson and Wallin 1999). The availability of censuses of game populations in pre- and post-flood periods within identical spatial units can be considered the basis for a serendipitous large-scale investigation. The disastrous scale of the event in 1997 in south-western Poland triggered several field activities immediately after the flood to assess game mortality.

In this study, we have taken the opportunity provided by archival data to examine the effects of the flood on local game populations. Specifically, the aims of the study were (1) to present the magnitude of flood-related losses in wild mammals, (2) to compare the susceptibility of selected mammal species to flood mortality and (3) to compare the mortality in areas inundated by the main river (Odra River) and by its tributaries. We also discuss the possible long-term influence of flood mortality on populations of the species studied.

2 Methods

2.1 Study area

Data were collected in the catchment area of the Odra River, one of Europe's great rivers, with a length of 871 km. The section studied, ~220 km long, is situated in the middle course of the river, between Kędzierzyn-Koźle and Ścinawa (south-western Poland). The section has been regulated, embanked and navigable since the nineteenth century. The adjoining lowlands are dominated by intensive agricultural landscapes interspersed with strongly fragmented woodlands.

The study was carried out in 50 hunting districts, the basic units in our analysis, with an area of 2,876 km^2. Twenty-eight districts (1,493 km^2) were situated in the Odra River valley, and the other 22 districts (1,383 km^2) were situated along 12 tributaries of the main channel (Fig. 1). Districts situated along the Odra River (ORD) were smaller and more wooded than the districts adjoining tributaries (TRD), but the differences were not significant (Table 1). In ORD the proportion of area flooded was three times greater, and the period of inundation was twice as long as in TRD. Overall, more than 30 % of the study area was inundated.

2.2 Flood characteristics

The flood started in the study area on 7 July 1997 and lasted until the end of the month (with two rainfall peaks). It was generated by exceptionally heavy rainfall between 4 and 10 July. The rainfall constituted 150–250 % (locally more than 300 %) of a month's mean rainfall and 20 % (locally up to 40 %) of a year's mean. A second, slightly smaller rainfall peak occurred between 17 and 22 July (Dubicki et al. 1999; Kundzewicz et al. 1999). The maximum flows on the Odra River in Wrocław, which is within our study area, amounted to 3,640 m^3/s and were 25 times greater than the average annual flow (145 m^3/s). The depth of flood waves outside the river bed was several metres, and water stagnation lasted up to 3 months in lower locations. The Odra River has experienced tens of floods described as 'great' since the thirteenth century, but usable quantitative data have been known only since the nineteenth century. On their basis, the July 1997 flood was the greatest of all documented (Dubicki et al. 1999; Kundzewicz et al. 1999).

2.3 Source of data on flood mortality

To evaluate the losses in game mammals within each hunting district, we used results from surveys carried out by hunters as organized by the regional boards of the Polish Hunting Association. These were implemented immediately after the water had receded, at the end of July and early August 1997. Records were taken of the number of dead animals found, and the estimate of total mortality was made by hunters on this basis. The totals given

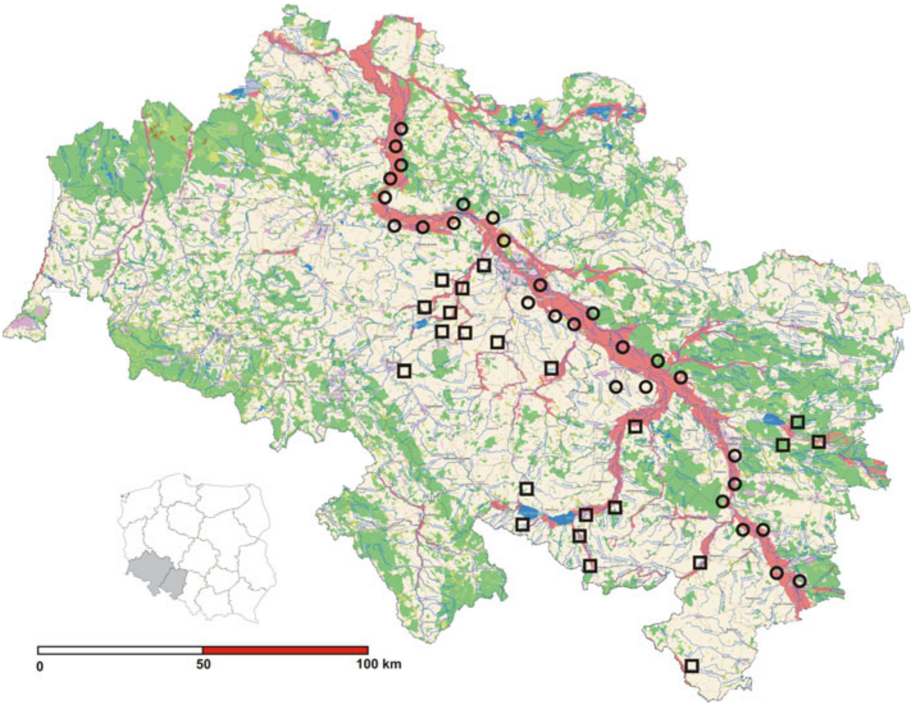

Fig. 1 Location of the studied hunting districts adjoining the Odra River (*circles*) and the tributaries (*squares*), against a background of the main topographical features of the two administrative units of Poland (Dolnośląskie Province and Opolskie Province) where the survey was conducted. The extent of the July 1997 flood is also presented

Table 1 Characteristics of the studied hunting districts

	All districts	Odra River	Tributaries
No. of districts	50	28	22
Area of district (ha)	5,752.5 ± 1,734.4 (50)	5,331.8 ± 1,428.8 (28)	6,287.9 ± 1,964.3 (22)
Wooded area (%)	23.5 ± 21.6 (25)	28.1 ± 24.7 (13)	18.4 ± 17.2 (12)
Flooded area (%)	31.5 ± 26.9 (47)	**44.4 ± 27.3**** (27)	**14.1 ± 13.5**** (20)
Days of inundation	13.7 ± 8.6 (15)	**20.2 ± 8.8*** (6)	**9.3 ± 5.2*** (9)

The values are mean ± SD, calculated on the number of districts for which data were available, provided in parentheses

Significant differences are marked bold (Mann–Whitney *U* test, ** $P < 0.001$, * $P < 0.05$)

below are the sums of the estimates. Some records listed the age and gender of drowned animals, as well as the area and period of inundation.

2.4 Selection of species

Deaths of eight species of game mammals were recorded: roe deer *Capreolus capreolus*, red deer *Cervus elaphus*, fallow deer *Dama dama*, wild boar *Sus scrofa*, fox *Vulpes vulpes*, badger *Meles meles*, brown hare *Lepus europaeus* and European rabbit *Oryctolagus* *cuniculus*. In our analyses, we omitted *D. dama* and *O. cuniculus* due to their highly localized distribution, and *M. meles* due to incomplete data. Estimated losses in game birds provided in some districts were also disregarded. In the end, we analysed the impact of the flood on five species of game mammals which were common in the study area, and whose recorded mortality rate allowed for statistical evaluation. None of these species was connected with river valleys as their primary habitat.

2.5 Susceptibility to flood mortality

We expected that the five species would differ in their susceptibility to flood-induced mortality. To check this expectation, we compared the mortality in particular species with their local abundance. The comparison was restricted to the 38 hunting districts for which data on both mortality and pre-flood abundance were available (28 ORD and 10 TRD, 1,982 km^2 in total). Local abundance was estimated during the game census carried out each March by hunters and foresters to plan game management in Poland. The estimate was based on standard methods of year-round observation of animals in hunting districts (Fruziński 2002). The alternative method of counting snow tracks (Pucek et al. 1975) commonly used in other parts of the country can rarely be used in south-western Poland because of snowless winters.

We compared the mortality in particular species with their pre-flood abundance in March and July 1997. Since both analyses gave similar results, we present only the comparison with the July data, that is, when the flood happened. To obtain these data, we estimated the increase in population size from March as a result of the proportion of females breeding, birth rates and mortality rates of young based on other research in Poland; the following population growth rates were estimated: *C. capreolus*—1.8 (Pielowski 1988), *S. scrofa*—1.9 (Fruziński 1992), *V. vulpes*—2.5 (Goszczyński 1995), *C. elaphus*—1.3 (Bobek et al. 1992), *L. europaeus*—1.5 (Krupka 1989). The number of females in the population of *C. capreolus* and *C. elaphus* was determined during the counts. The proportion of females in *S. scrofa*, *L. europaeus* and *V. vulpes* was assumed to be 50 %.

2.6 Statistical analyses

Sample sizes in our analyses were restricted by the availability of archive data. In many hunting districts, zero values were noted (no mortality), particularly for species with low overall mortality. Consequently, most variables had skewed distributions, and we were obliged to use nonparametric tests. The Spearman rank correlation coefficient was used to test the relationships between total mortality and the flood parameters, that is, area and duration of inundation. The differences in mortality between the districts adjoining the main river and the tributaries were tested with the Mann–Whitney *U* test, chi-squared test of independence or Fisher's exact test. Flood mortality and pre-flood abundance in particular species were compared based on proportions. To determine significance, we used the chi-squared test of goodness-of-fit with species abundance treated as the expected value, and species mortality treated as the observed value. Additionally, we calculated the Jacobs selectivity index (index *D* in Jacobs (1974), usually used in habitat selection studies) to evaluate synthetically the susceptibility of the studied mammals to flood mortality. The Jacobs index was calculated according to the formula $D = (r - p)/(r + p - 2rp)$, where r = the proportion of mortality in particular species, and p = the proportion of abundance in particular species compared to the total abundance of the five

Table 2 Mortality rates of five mammal species in studied hunting districts (N)

Species	Total mortality (no. of individuals)	Frequency (%)			Mortality per district (mean ± SD per district)			Density of mortality (mean ± SD per 1 km^2 of flooded area)		
		All districts ($n = 50$)	Odra River ($n = 28$)	Tributaries ($n = 22$)	All districts ($n = 50$)	Odra River ($n = 28$)	Tributaries ($n = 22$)	All districts ($n = 50$)	Odra River ($n = 27$)	Tributaries ($n = 20$)
Lepus europaeus	1,737	68.0	67.9	68.2	34.74 ± 49.96	47.43 ± 62.12	18.59 ± 19.37	3.04 ± 3.87	1.96 ± 2.34	4.51 ± 4.98
Capreolus capreolus	1,556	96.0	100.0	90.9	31.12 ± 47.03	**49.57 ± 56.10****	**7.64 ± 9.15****	1.69 ± 1.70	1.91 ± 1.79	1.37 ± 1.55
Sus scrofa	186	28.0	39.3	13.6	3.72 ± 8.65	6.00 ± 10.83	0.82 ± 2.82	0.26 ± 0.90	0.23 ± 0.52	0.30 ± 1.26
Vulpes vulpes	122	28.0	35.7	18.2	2.44 ± 5.54	4.04 ± 6.98	0.41 ± 1.05	0.13 ± 0.27	0.20 ± 0.33	0.04 ± 0.12
Cervus elaphus	12	6.0	10.7	0.0	0.24 ± 1.30	0.43 ± 1.73	0.0	0.00 ± 0.03	0.01 ± 0.04	0.0
Total	3,613				72.26 ± 92.21	**107.46 ± 109.90***	**27.45 ± 23.53***	5.13 ± 4.57	4.31 ± 3.18	6.23 ± 5.88

Values denote total no of drowned individuals (Total mortality), percentage of the hunting districts where the species mortality was recorded (Frequency), mean (±SD) no. of drowned individuals per district (Mortality per district), and mean (±SD) no. of drowned individuals per km^2 of flooded area (Density of mortality)

Significant differences are marked bold (Mann–Whitney *U* test for Mortality per district and Density of mortality, chi-squared test of independence or Fisher's exact test for Frequency, ** $P < 0.001$, * $P < 0.01$)

species under study. D varies from -1 (lack of susceptibility to flood-related mortality) to $+1$ (strong susceptibility), and values close to zero indicate that the species' mortality is in proportion to its abundance. The probability of $P < 0.05$ was assumed as statistically significant. The statistical calculations were performed with STATISTICA for Windows (StatSoft Inc. 2010).

3 Results

3.1 Magnitude of mortality

Total mortality amounted to 3,613 individuals in 50 hunting districts. The density of mortality was 5.13 individuals per km^2 of flooded area (Table 2). More than 90 % of dead animals were *L. europaeus* and *C. capreolus*. Even in these two species, the mortality was unequally distributed among districts, probably reflecting differences in flood severity. Drownings of *C. capreolus* were noted in most districts (96 %), whereas drownings of *L. europaeus* occurred only in 68 % of districts. The mortality rate (all species combined) increased with the proportion of area flooded ($r_s = 0.51$, $df = 47$, $t = 4.03$, $P < 0.001$), and the duration of flooding ($r_s = 0.55$, $df = 15$, $t = 2.38$, $P < 0.05$). Mortality affected an average 2.3 species per hunting district; mortality in all five species was reported from one district only. Drownings were mostly of young individuals; based on ten districts for which quantitative data on the age of drowned animals were available, young constituted 25 of 30 *S. scrofa* recorded (83 %) and 33 of 44 *C. capreolus* (75 %). The other 11 of adult *C. capreolus* included nine females and two males.

3.2 Susceptibility to flood mortality

The highest mortality affected species which were most common in the study area, *C. capreolus* and *L. europaeus*. However, observed mortality significantly departed from expected results based on the relative abundance of particular species (chi-square = 627.8, $df = 4$, $P < 0.001$). The Jacobs index confirmed differing susceptibility of the mammals studied to flood mortality (Fig. 2). The index revealed disproportionately high mortality in *L. europaeus*, low mortality in *V. vulpes* and *C. elaphus*, whereas the number of drownings of *C. capreolus* and *S. scrofa* was proportionate to their local abundance.

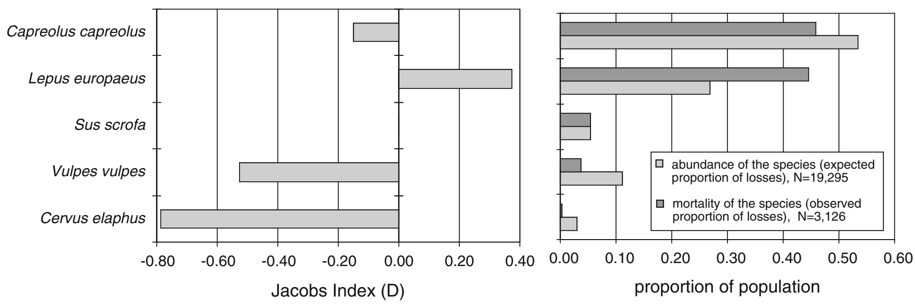

Fig. 2 Susceptibility of game mammals to flood-related mortality expressed by Jacobs *D* Index (*left panel*), and the relative abundance and relative mortality of particular species in the study area (*right panel*). Results obtained from 38 hunting districts for which data on both abundance and mortality were available

3.3 Flood mortality in areas adjoining the main river and tributaries

Total mortality was four times higher in ORD than in TRD (Table 2). The highest, tenfold, difference related to *V. vulpes* and the lowest difference related to *C. capreolus*; however, only in the latter species was the difference significant. Mortality of *C. elaphus* was reported only in districts adjoining the Odra River. Densities of losses did not differ significantly between ORD and TRD, although in the case of *L. europaeus*, the value was more than twice as low in ORD as in TRD.

4 Discussion

4.1 Magnitude of mortality

The results of our study demonstrate a major, albeit short-term, impact of an extreme climate event on wild animals. Absolute numbers of drowned individuals were high (>3,600), particularly in *L. europaeus* and *C. capreolus*, and most game species temporarily disappeared from affected floodplains. Anecdotal observations indicated that it is probable that some individuals could survive in floodplains by moving to higher locations. The families of *S. scrofa* survived the inundation period by staying on flood embankments that had become islands. *V. vulpes* were observed climbing up trees sticking out of the water. Despite these examples, it was emphasized that vast areas were covered with the deposits of sediments that hindered movement and restricted food availability. Consequently, during the first months after the water had receded (until October/November), the area of inundation was practically devoid of animals.

Assessment of the long-term influence of the flood on game populations is difficult because the dynamics of the population numbers is strongly regulated by harvest and/or release of game animals. Moreover, the census techniques can be inaccurate (Okarma and Tomek 2008). Nevertheless, it seems that the long-term effect of the flooding event in July 1997 on game mammals was insignificant. Despite high overall losses, only a small proportion of the numerous game population in this part of Europe was affected. Moreover, high movement abilities apparently allowed the studied species to resettle the abandoned areas quickly. To test these suppositions, we had previously compared the pre- and post-flood game censuses in areas affected and not affected by the floods (Jakubiec and Wuczyński 2002). No long-term decreases in population size, nor deviations from the general regional trends were observed in the flooded areas. It confirms that wild species have life history strategies that buffer them from the negative effects of naturally recurring events, such as floods, and that conclusions drawn from the short-term effects can be misleading (Lytle and Poff 2004; Finkelstein et al. 2010; Gerisch et al. 2012).

We argue that the impact of floods and other natural disasters on wild populations should not be seen only from the perspective of changes in population size. Catastrophic events are forces able to change the social organization of many species and the way animals exploit their environment. Sudden removal of a large number of individuals initiates complex density-dependent processes which in turn influence the genetic make-up of the population (Newton 1998; Loveridge et al. 2006; Ranta et al. 2006). These processes are accompanied by severe habitat transformations modifying patterns of habitat use. For example, flooding events are responsible for delivering nutrients and detritus to the floodplain (Ward et al. 2002); thus, floods enhance biological productivity and food availability for animals. Heterogeneity of habitats caused by floods affects the dispersal of animals in the floodplain and shapes species-specific recolonization patterns (Wijnhoven et al. 2006). Anthony et al. (2003) recognized a group of insectivores and rodents associated with early successional vegetation produced by episodes of flooding and other disturbance in riparian zones. In the end, natural disasters have diverse functional consequences for populations, and it is crucial that we understand whether the long-term effect of these disturbances is advantageous or not for wildlife.

4.2 Susceptibility to flood mortality

None of the five mammals studied is riparian obligate nor a riparian-associated species *sensu* Anthony et al. (2003), with life history strategies that have evolved to inhabit the riparian zone and deal with altered flow. However, all these species comprise relatively big and highly mobile animals. They regularly use both wooded and agricultural landscapes, which prevent them from being trapped within their primary environment (e.g. forests) by rising floodwaters. Nevertheless, we noted diverse susceptibility to flooding in the mammals studied. The highest relative mortality rates, in *L. europaeus*, and the lowest mortality, in *C. elaphus,* suggest a relationship with body size. Dimensions of the animal seem to be crucial during the initial phase of the flood. Small animals (like *L. europaeus*) were less likely to survive the sudden strike of flood waves, particularly in the vicinity of places where the levees were broken. Slowly rising waters in the remaining area could also be critical for small animals if the waters blocked their retreat. Relatively, low mortality was revealed in *V. vulpes*, the second smallest of the studied species, but the mortality was probably underestimated. Many individuals were probably drowned in burrows, which could have had an effect on the low detectability of dead *V. vulpes*. For the same likely reason low losses concerned also *M. meles*, another burrowing carnivore occurring in the studied area (Jakubiec and Wuczyński 2002).

All the species studied are good swimmers which occasionally voluntarily swim (Yeager and Anderson 1944; Gittleman 1996). Drownings of these species are rarely recorded in usual situations (Peris and Morales 2004; García 2009). However, under exceptional conditions of disastrous floods, even the largest species can be affected. Observations of *S. scrofa* (see above) and other animals that were concentrated on the levees (Yeager and Anderson 1944; Stickel 1948) confirm that the ability to swim may not be sufficient to rescue. In July 1997 particularly high flow energy occurred in places where flood embankments were broken, resulted in high number of drowned animals found in the vicinity of these places. The death ensued there probably because of the overtaking by the sudden water rise outside the embanked area.

There was disproportionately high mortality among young animals as might be expected of small relative body size, low resistance and lack of experience (Heinen and Singh 2001; Welbergen et al. 2008). Along with the young, females could also die, as they tend to stay with their offspring even when floodwaters are rising (Pielowski 1988). Sex-biased mortality in *C. capreolus* was confirmed in our data; females predominated among adults noted. In this context, the timing of the flood was crucial. Summer floods generated by intensive precipitation are particularly common and destructive in Central Europe (Kundzewicz 2005). These events coincide with the reproduction period of many taxa. Therefore, summer floods cause severe losses in first-year individuals which predominate in many populations (Tryjanowski et al. 2009). In contrast, winter rainfall floods and spring snowmelt floods predominantly affect adults and full-grown young. Combined with a generally lower incidence in Central Europe, these floods do not generate such a high mortality in animal populations as summer floods.

4.3 Flood mortality in areas adjoining the main river and tributaries

Differences in mortality between ORD and TRD corresponded with differences in flood severity and landscape structure. The percentage of areas flooded was four times bigger in ORD, as was the magnitude of mortality. Pronounced mortality of *L. europaeus* in TRD was connected with the predominance of cropland in these districts. In turn, higher amount of forests in the Odra River valley could have increased the losses of primarily forest species, *C. elaphus* and *S. scrofa*, in ORD. Common fencing of forest cultures probably contributed to the high mortality level. Dead *C. capreolus* were found hanging on wire nets used for fencing, probably pressed against them by the flowing water.

Differences in mortality between ORD and TRD were not significant when calculated per unit of flooded area. It suggests that the level of mortality is primarily shaped by the size of inundated areas, and the associated parameters (flooding duration or depth) are of secondary importance. Therefore, mild discharges which are less destructive in economic terms can also be disastrous for local animal populations, particularly for taxa of limited movement capabilities. High density of mortality revealed for *L. europaeus* in TRD suggests that local flooding episodes can be meaningful for several other taxa. Since these episodes are frequent, their total impact on animal communities can be no less important than the impact of rare but well-publicized floods described as catastrophes.

5 Conclusion

We specified quantitatively, for the first time, direct losses in wild, large animals over vast areas in response to a catastrophic flood. Data refer to a limited set of game mammals, though the findings may give some wider insight into the naturally functioning river-floodplain ecosystems. River valleys represent areas of great ecological richness and diversity and are used by many species disproportionately higher than other areas (Tomiałojć 1993; Sabo et al. 2005). In the landscape context, river valleys act as ecological corridors allowing connectivity between suitable habitat fragments across the landscape (Jankowski and Świerkosz 1995; Ward et al. 2002). The corridor function is also provided for a range of mammals, including large species, especially when spatial cohesion of semi-natural habitats (riparian forests, island) is preserved (Romanowski 2007). Riverine landscapes are also a product of disturbances that affect structure and function of these areas and the associated fauna, although understanding this impact still provides a major challenge for the future.

In modern times, the influence of natural disastrous phenomena on wildlife cannot be examined in isolation from human activity. River valleys have been substantially transformed (Schinegger et al. 2012) and have become inhabited by upland organisms not adopted to altered flow, but particularly vulnerable to extreme events. Our data refer to species which are numerous in Poland and elsewhere in Europe and not threatened. Rare and/or localized species may experience flood disturbance in a different way, so that the relative losses could be meaningful for their populations (Heinen and Singh 2001; Finkelstein et al. 2010). However, there is little evidence on the long-term effects of the natural disturbances on animal communities, in either a positive or negative sense (Tryjanowski et al. 2009). The ambiguity of the mechanisms responsible for these effects demands caution, but any mitigation actions should nevertheless consider the minimization of losses in biodiversity. Recent evidence is growing that management options focused primarily on human safety and water security should also integrate conservation issues

(Poff et al. 2003; Vörösmarty et al. 2010). In large spatial scales (e.g. watersheds), many measures have been proposed to reach balance between ecological and human needs (Boon et al. 2000; Pedroli et al. 2002; Paredes-Arquiola et al. 2011). To lessen flood mortality in biological populations, proactive management interventions are particularly indicated (Palmer et al. 2008). Their general aim would be to restore the natural capacity of rivers, thus to reduce flood incidence, to absorb high flow energy and to truncate the peak flow. Local river management practices focused on wildlife also seem possible, for example fencing cultivated forests and roads should be abandoned in those parts of floodplains which are subject to frequent floods. Yet the elimination of mortality in wild populations caused by catastrophic events is not possible. The minimization of losses and better understanding of the magnitude of mortality and its real effect on populations are tasks for future research.

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