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Abstract In August 2002, a severe flood event occurred in Central Europe. In the following year, a poll was performed in Germany in which 1697 private households were randomly selected from three regions: (a) the River Elbe area, (b) the Elbe tributaries in Saxony and Saxony-Anhalt, and (c) the Bavarian Danube catchment. Residents were interviewed about flood characteristics, early warning, damage, recovery, preparedness and previously experienced floods. Preparedness, response, financial losses and recovery differed in the three regions under study. This could be attributed mainly to differences in flood experience and flood impact. Knowledge about self-protection, residents' home-ownership and household size influenced the extent and type of private precautions taken, as well as the residents' ability to perform mitigation measures. To further improve preparedness and response during future flood events, flood warnings should include more information about possible protection measures. In addition, different information leaflets with flood mitigation options for specific groups of people, e.g. tenants, homeowners, elderly people or young families, should be developed.

Key words flood impact; Germany; mitigation; recovery; flood warning

Faire face aux inondations: préparation, réaction et rétablissement des résidents affectés par les crues de 2002 en Allemagne

Résumé En août 2002, un grave épisode d'inondation a frappé l'Europe Centrale. Dans les années suivantes, un sondage stratifié a été effectué en Allemagne. 1697 ménages ont été sélectionnés au hasard dans trois régions: (a) la zone de la rivière Elbe, (b) la zone des affluents de l'Elbe en Saxe et Saxe-Anhalt, et (c) le bassin du Danube en Bavière. Les résidents ont été interrogés sur les caractéristiques de l'inondation, l'alerte précoce, les dommages, le rétablissement, la préparation et les inondations vécues précédemment. La préparation, la réaction, les coûts monétaires et le rétablissement diffèrent dans les trois régions étudiées. Ceci peut principalement s'expliquer par les différences d'expérience par rapport aux inondations passées et d'impact de la crue. Les connaissances sur l'autoprotection, la propriété de l'habitation et la taille du ménage ont influencé l'ampleur et le type de précaution privée prise, ainsi que l'aptitude des résidents à prendre des mesures de prévention. Pour améliorer la préparation et la réaction lors des futures inondations, les alertes devraient inclure plus d'informations sur les mesures possibles de protection. De plus, différentes brochures d'information devraient être développées, présentant les mesures de prévention des crues adaptées aux groupes spécifiques de personnes, comme par exemple les locataires, les propriétaires, les personnes âgées ou les jeunes ménages.

Mots clefs impact des crues; Allemagne; prévention; rétablissement; alerte de crue

1 INTRODUCTION

Damage due to natural disasters has dramatically increased in the last decades. In 2002, floods accounted for about 50% of all economic losses due to natural disasters worldwide (Munich Re, 2003). The most severe flood event occurred in Central Europe (Germany, Austria, the Czech Republic and Slovakia) in August 2002 along the rivers Elbe and Danube and some of their tributaries (see Ulbrich *et al.*, 2003; Engel, 2004). In Germany, 21 people died and substantial parts of the infrastructure were destroyed in some of the affected regions. The most seriously affected German federal state was Saxony, where the total flood damage amounted to €8700 million, followed by Saxony-Anhalt (€1187 million) and Bavaria (€198 million) (data from SSK, 2004; IKSE, 2004; Bavarian Ministry of Finance, personal communication). Altogether, about €11 600 million of damage was caused in Germany. This amount by

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far exceeded the damage due to other disastrous events in Germany, which emphasizes the need to improve flood risk management. Many activities have been launched at administrative and legislative levels since the 2002 event (see DKKV, 2003).

In recent years, a shift has taken place from technology-oriented flood defence towards integrated flood risk management (e.g. Takeuchi, 2001; PLANAT, 2004). Flood risk management is aimed at minimising adverse effects and at learning to live with floods (Vis *et al*., 2003). In general, it focuses on three aspects: (a) flood abatement, with the aim to prevent peak flows, e.g. by an improvement of the water retention capacities in the whole catchment; (b) flood control, aimed at preventing inundation by means of structural measures, e.g. embankments or detention areas; and (c) flood alleviation with the goal of reducing flood impacts by non-structural measures (Parker, 2000; de Bruijn, 2005). The latter can be classified into preventive, precautionary and preparative measures. Prevention is aimed at completely avoiding damage in hazard-prone areas, e.g. by flood-adapted land use regulation. Precaution and preparation help to limit and manage the adverse effects of a catastrophe, and to build up coping capacities by flood-resilient design and construction, development of early warning systems, insurance, awareness campaigns, education, training, putting rescue units on stand-by, etc. (e.g. Vis *et al*., 2003; DKKV, 2003; PLANAT, 2004; de Bruijn, 2005).

As an analysis of how disasters have affected a society, the disaster cycle offers a valuable framework. The concept has been widely used by international and national organisations and various versions have been published (e.g. DKKV, 2003; PLANAT 2004; FEMA 2004; Kienholz *et al*., 2004). In this paper, three consecutive phases are distinguished: (emergency) response, recovery and disaster risk reduction (Fig. 1). When a hazardous event occurs, immediate measures are undertaken with the priority to limit adverse effects and the duration of the event (emergency phase). During recovery, the affected society will start to repair damage and to regain the same, or a

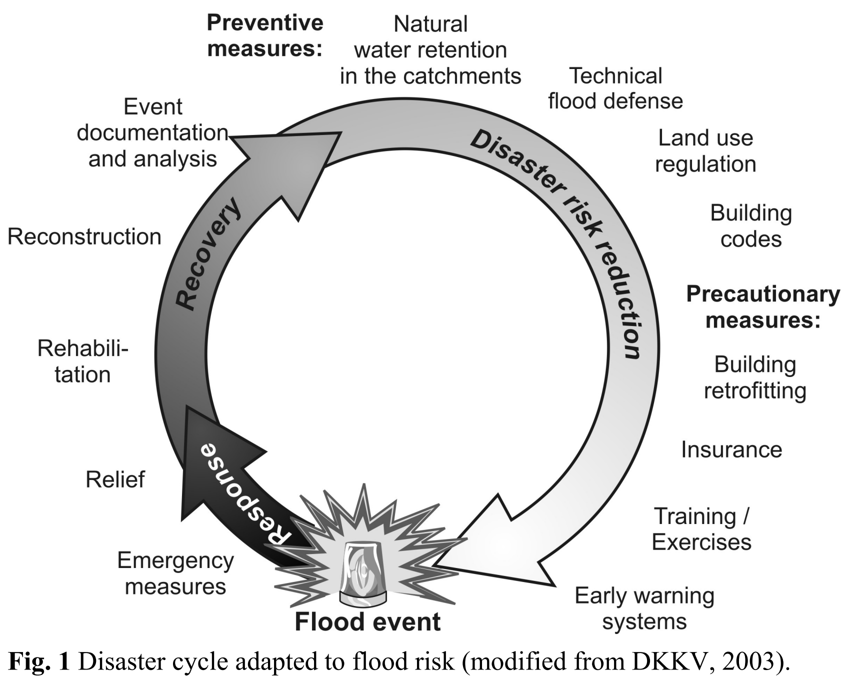

Fig. 1 Disaster cycle adapted to flood risk (modified from DKKV, 2003).

similar, standard of living as before the disaster happened. This phase sets the stage for the next "disaster" (Olson, 2000): if the affected society is willing to learn from a disaster, there will be a period of disaster risk reduction, in which measures that are aimed at minimising the vulnerability of people and their assets will be implemented. To enhance risk reduction, the disastrous event, the society's response and possibilities for prevention and preparation should be analysed carefully in the aftermath of an event (Kienholz *et al*., 2004).

This paper focuses on the coping capacities of private households in three different regions in Germany. The analysis gives some insight into what people learned from the flood in 2002, and what more could be done to stipulate private precautions and disaster preparedness.

In general, homeowners who have been flooded recently are more aware of the flood risk, are interested in mitigation and willing to invest in precautionary measures (e.g. Laska, 1986; Brilly & Polic, 2005; Grothmann & Reusswig, 2006). In a survey in Illinois, USA, 68% of 1236 respondents had spent some money on some kind of flood protection. The amount spent was proportional to the property value and household size, but did not depend on the age of the respondent (Brenniman, 1994). A recent study from Japan showed that the residents' preparedness for floods depends on the ownership of a home, fear of flooding and the amount of damage from previous floods, rather than on previous experiences with and anticipation of floods (Motoyoshi *et al*., 2004). Moreover, socio-economic status is a significant predictor in pre- and post-disaster stages, as well as for the physical and psychological impacts. For example, poor people are less likely to prepare for disasters or buy insurance, but they have proportionally higher material losses and face more obstacles during the phases of response, recovery and reconstruction (Fothergill & Peek, 2004).

A survey among flood-affected people on the rivers Rhine and Danube in Germany showed that floods are perceived as a danger because of their potential damage and because the possibilities for self-protection are perceived as low (see Plapp, 2003; Werner *et al*., 2003). A further aspect that controls the perception of flood hazard is the perceived ability of the community to cope with the flood (Werner *et al*., 2003). Therefore, local governments should improve the involvement of residents in flood prevention programmes, e.g. by providing better information about the flood hazard, effective dissemination of flood warnings and communication of the possibilities for private mitigation measures (Krasovskaia *et al*., 2001, 2007; Werner *et al*., 2003). To encourage precautionary behaviour in the residents of flood-prone areas, it is essential to communicate not only the flood hazard and its potential consequences, e.g. by flood hazard/risk maps, but also the available private precautionary measures, their effectiveness and their costs (Grothmann & Reusswig, 2006). For example, Kreibich *et al*. (2005) showed that different precautionary measures can reduce flood losses up to 50%, even during severe flood events.

Besides long-term precautionary measures, how people react during the disaster and their response to flood warnings can help to limit losses. For example, flood damage due to the Meuse flood in 1995 was 35% lower than that in 1993, when a similar flood hit the same municipalities (Wind *et al*., 1999). The loss reduction in 1995 may be explained by the increase in warning time and the experiences gained from the 1993 flood. However, Penning-Rowsell & Green (2000) found that only about 13% of potential damage was avoided by flood warnings, since damage reducetion depends on the reliability of the flood warning system, and on the proportion of residents (i) available to respond to a warning, (ii) able to respond to a warning and (iii) who responded effectively. They concluded that the benefits of early warning systems can only be realised when the total system of forecasting, warning and responding operates effectively. Therefore, more attention needs to be given to the design of the whole system. Ensuring public response to flood warnings should be just as much the responsibility of the agencies concerned as their role in flood forecasting and warning dissemination (Penning-Rowsell *et al*., 2000).

The nature of people's reaction to an event might also depend on the type of flooding. People face slow-onset flooding (riverine floods) with elaborate responses, which are not very limited by warning, delay or "labour force" (Torterotot *et al*., 1992). For fast-onset flooding (flash floods), flood-proofing appears to be the most immediate response, but necessitates a minimum warning because of the speed at which the water rises (Torterotot *et al*., 1992).

Research from Canada revealed that reduction measures based on designation and mapping of flood plains have had no impact on the occupancy of flood plains, have failed to reduce flood damage, and have not even halted increases in damage (Robert *et al*., 2003). Successful integrated risk management has to involve different stakeholders (water management, spatial planning, insurers, emergency management, fire brigades, etc.), scientists, NGOs, as well as local residents and companies (e.g. Weichselgartner & Obersteiner, 2002; Pearce, 2003). Disasters—and their mitigation—have to be seen as the products of the social, political and economic environment, as well as the natural events that cause them (Blaikie *et al*., 1994, p. 3).

Although there are several studies that deal with the vulnerability of people and their willingness and ability to prepare for disasters, we need further knowledge about the vulnerability of people (Brilly & Polic, 2005). Fothergill & Peek (2004) propose—among other things—that in-depth, comparative studies be conducted regarding vulnerability issues in different regions, and that more research be done on risk perception, preparation and warning communication. Therefore, a large survey was conducted following the August 2002 flood in Germany. The main aim of the survey was to identify factors that influence flood damage in the residential sector. This paper investigates how flood-affected private households in three different regions in Germany, which varied in flood type, flood severity, previously experienced floods and socio-economic structure, were able to cope with the flood in 2002. Following the phases of the disaster cycle (Fig. 1), we analysed how private households contributed to disaster mitigation in the three different regions and how preparedness, response and recovery are correlated to socio-economic variables, flood experience and flood impact. The analysis gives some insights into the weaknesses and strengths of the preparedness of residents in the three regions, what people learned from the flood, and, further, what could be done to stipulate private precautionary behaviour.

2 DATA AND METHODS

2.1 Procedure of sampling flood-affected private households

The data set contains information obtained from private households which suffered from property damage due to the August 2002 flood. In April and May 2003,

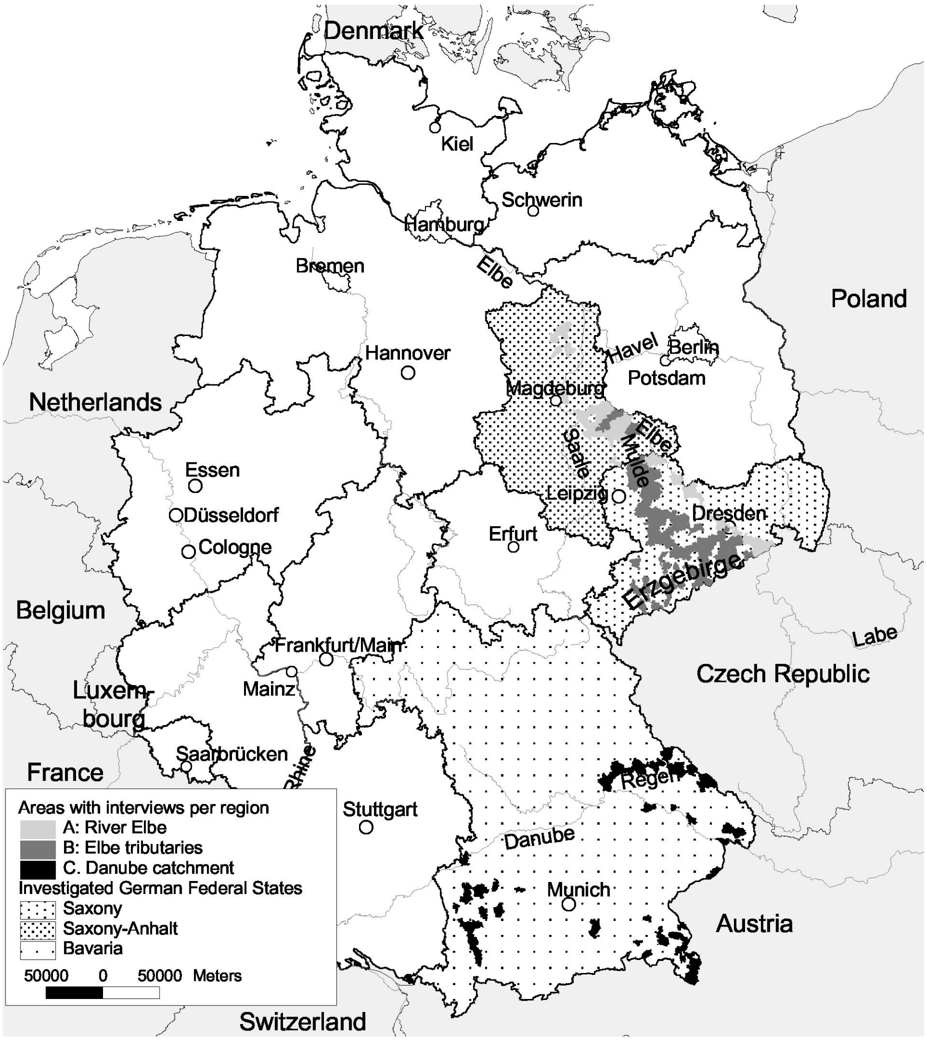

Fig. 2 Areas in which interviews were conducted (Data sources DLM1000, VG250 © BKG, Frankfurt am Main, 2004; ESRIDATA).

interviews were carried out in 1697 private households in the most affected German federal states, i.e. Saxony, Saxony-Anhalt and Bavaria (Fig. 2). The survey was conducted in three regions according to differences in flood type, flood experience and socio-economic structure:

A the River Elbe and the lower Mulde River;

B the *Erzgebirge* (Ore Mountains) and the River Mulde in Saxony; and

C the Bavarian Danube catchment.

The distinction of these regions was based on the following ideas: during the August 2002 flood, two flood types could be distinguished: slow-onset river floods along the big rivers, and flash floods in the headwaters (see Ulbrich *et al.*, 2003). While riverine floods were predominant along the Elbe and the lower Mulde River (Region A), severe flash floods dominated on rivers in the *Erzgebirge* (Region B). In Region C, the Bavarian Danube catchment, both flood types occurred.

The flood event was more severe in the Elbe catchment than in the Danube catchment. Return periods in the Elbe tributaries reached 200–500 years (IKSE, 2004).

Along the River Elbe, the return period was estimated to be about 100–200 years at the Dresden gauge (IKSE, 2004), but became shorter further downstream due to levee breaches, water detention, etc. (Engel, 2004). In the Danube catchment, the flood was most severe on the River Regen, where a return period of 100 years was assigned to the discharge (Gewässerkundlicher Dienst Bayern, 2002).

Furthermore, experiences of previous floods were likely to differ in the three regions. In the Danube catchment, severe flooding occurred in December 1993 ("Christmas Flood") and particularly in May 1999 ("Whitsun Flood"). The Whitsun Flood caused €347 million damage in Bavaria (Müller, 2000). In contrast, the last severe floods on the River Elbe occurred in 1940, in 1954 and in winter 1974/75. However, the water levels on the Elbe in August 2002 were more extreme than before. In the *Erzgebirge,* widespread flooding occurred in 1954 and 1958. Apart from these events, more localized flooding occurred in several years, e.g. in July 1957 along the River Müglitz, and in winter 1974 on the River Mulde (see Fügner, 2003; Pohl, 2004, for details).

The regions also differ in socio-economic structure, i.e. in income, purchasing power and building structure. For example, the average purchasing power in Bavarian communities amounted to €17 841 per person in 2001, whereas it was €11 555 in Saxony and €11 702 in Saxony-Anhalt, according to census data of INFAS Geodaten GmbH (2001).

On the basis of information from the affected communities and districts, lists of affected streets in the investigated areas were compiled. A random sample was generated on the condition that each street should be represented in the data set at least once and that each building should be included only once. Thus, only one household was selected in multiple-occupancy houses, so that the sample is representative for buildings. In total, 11 146 households (with telephone number) were selected. Computer-aided telephone interviews were undertaken using the VOXCO software package by the SOKO-Institute, Bielefeld, Germany, between 8 April 2003 and 10 June 2003. In each case, the person in the household who had the best knowledge about the flood event was questioned. Tenants were only asked about their household and the content damage. To complete the interview, the building owner was questioned about the building and damage to it. In total, 1697 interviews were carried out; on average, an interview lasted 30 minutes.

2.2 Contents of the questionnaire and data processing

For this investigation, a new questionnaire was designed following the phases of the disaster cycle (Fig. 1) and including suggestions taken from Parker *et al*. (1987), Penning-Rowsell (1999), Statistisches Bundesamt (1999), Grothmann (personal communication: questionnaire on risk awareness and private precautionary behaviour in flood affected private households used by Potsdam-Institute for Climate Impact Research, Potsdam, Germany), and Schmidtke (personal communication: questionnaire used for recording flood damage for the HOWAS database at the Bavarian Agency of Water Resources, Germany). Altogether, the questionnaire contained about 180 questions addressing the following topics: flood impact, contamination of the flood water, flood warning, emergency measures, evacuation, cleaning-up, characteristics of and damage to household contents and buildings, recovery of the affected household, precautionary measures, flood experience, as well as socio-economic variables.

In a number of questions people were asked to assess qualitative or descriptive variables on a rank scale from 1 to 6, where "1" described the best case and "6" the worst case. The meaning of the end points of the scales was given to the interviewee. The intermediate ranks could be used to graduate the evaluation. For flow velocity, contamination, flood warning, emergency measures, precautionary measures (flood-proofing), flood experience and socio-economic variables, indicator variables were generated by aggregation of several items concerning one particular topic. A detailed description of the survey, the data processing and the development of indicators can be found in Kreibich *et al*. (2005) and Thieken *et al*. (2005). The variables and indicators chosen for this paper are listed in Table 1.

Data analysis in this paper comprised the following steps: first, tests were done to establish which variables significantly differ between the three data groups; this was done using the Mann-Whitney U test for two samples and the Kruskal-Wallis H test if all three samples were compared. Significantly differing variables were then analysed in detail for the three regions. Correlations between variables were determined by Spearman's rho (i.e. rank correlation). Only correlation coefficients that were significant at a level of 0.05 and that were equal to or higher than 0.20 are presented herein.

3 RESULTS AND DISCUSSION

3.1 General characteristics of the three strata

According to the Kruskal-Wallis H test, all variables listed in Table 1 differ between the three data groups at a significance level of ≤0.05, except for the number of elderly people in a household, the perceived quality of the building and the perceived credibility of the flood warning.

To characterise the three groups, statistics of the flood impact, socio-economic variables and flood experience are summarised in Table 2. As expected, socio-economic variables differed less between groups A and B in comparison to group C (Bavaria). In Group C, the respondents were a little younger than those in groups A and B, fewer of them had a high school graduation (*Abitur*), but more owned the buildings they lived in. The households in Bavaria were also slightly bigger, as was the mean living area per person. Further, there was a considerably smaller proportion of households with less than €1500 monthly net income (Table 2).

Significant differences in flood experience were also found in the data. Whereas only 9.5% in the group of the River Elbe (A) and 20.2% in the Elbe tributaries group (B) had experienced at least one flood before August 2002, this applied to 41.9% of the people interviewed in the Bavarian Danube catchment (Group C) (Table 2). The proportion of people who had experienced a flood in the last ten years was also considerably higher in Group C (Table 2). Moreover, only 9.8% of the people with flood experience in Group A had already had flood losses of more than €1000, whereas this share amounted to 37.4% in Group B and 47.3% in Group C. Altogether the experience of floods was highest in Group C (recurrent experience), it had been gained more recently, and was combined with financial losses more often than in the other two regions.

Table 1 Items of the survey that were used in this paper.

Item	Units and labels
Socio-economic variables:	
Age of the interviewee	Years
Education	Rank from 1 (no graduation) to 5 (high school graduation—*Abitur*)
Household size	Number of people
Children (< 14 years)	
Elderly people (> 65 years)	
Monthly net income of the household	€ (Euro)
Living area per person	m^2
Ownership structure	1: tenant of a flat, 2: tenant of a house, 3: flat-owner, 4: homeowner
Perceived quality of the building/household contents	Rank from 1 (building/household contents are of very good quality or luxurious) to 6 (building/household contents are of poor quality)
Flood experience BEFORE August 2002:	
Previously experienced floods	Number of events
Time period since the last flood event	Years
Indicator of flood experience	Rank from 0 (no experience) to 10 (very well experienced)
Knowledge about the flood hazard of the residence/plot	0: no knowledge, 1: knowledge of flood hazard
Preparedness (BEFORE/AFTER the flood) and risk awareness:	
Acquisition of information about precaution	Number of measures (range: 0 to 3)
Flood insurance	0: no insurance, 1: insurance
Flood-proofing measures and retrofitting	Number of measures (range: 0 to 7)
Perceived efficiency of private precaution	Rank from 1 (flood damage can be significantly reduced by private precautionary measures) to 6 (flood damage cannot be reduced at all by private precautions)
Perceived risk of future floods	Rank from 1 (it is very unlikely that I will be affected by future floods) to 6 (it is very likely that I will be affected by future floods)
Characteristics of the flood in 2002:	
Water level	cm above top ground surface
Flood duration	Hours
Flow velocity	Rank from 0 (no flow) to 3 (very high flow velocity)
Contamination of the flood water	0: no contamination, 1: sewage, 2: chemicals (and sewage), 3: oil (and chemicals or sewage)
Warning and response in 2002:	
Flood warning source indicator	Rank from 0 (no warning) to 4 (official flood warning)
Flood warning information indicator	Rank from 0 (no information) to 14 (detailed information about flood event and advice for damage reduction)
Lead time	Hours
Perceived credibility of the warning	Rank from 1 (warning was absolutely believable) to 6 (warning was absolutely unbelievable)
Perceived knowledge about self-protection	Rank from 1 (I knew exactly what to do) to 6 (I did not know what to do)
Time spent on emergency measures	Hours
People involved in emergency measures	Number of people
Overall assessment of efficient emergency measures (indicator)	Rank from 0 (no emergency measures performed) to 78 (several efficient emergency measure were successfully performed)
Adverse effects of the flood in 2002:	
Duration of evacuation	Days
Time spent on cleaning-up	Hours
Damage to the building	€
Damage to household contents	€
Recovery:	
Perceived status of restoration of the building/replacement of household contents at the time of the interview	Rank from 1 (buildings/household contents are already completely restored/replaced) to 6 (there is still considerable damage to the building/to household contents)
Compensation received for losses	€

Table 2 Description of the three strata with respect to socio-economic variables, previously experienced floods and flood impact in 2002.

Data group	A	B	C	All
Name of the group/region	River Elbe	Elbe tributaries	Danube catchment	
Total number of interviews	639	609	449	1697
Socio-economic variables:				
Mean age of the interviewees (years)	54	52	49	52
People with high school graduation (*Abitur*) (%)	24.5%	24.2%	15.8%	22.1%
Mean household size (number of people)	2.7	2.7	3.2	2.8
Households with a monthly net income <€1500 (%)	38.6%	44.4%	25.1%	37.4%
Mean living area per person (m^2)	47.85	44.41	52.84	47.87
Homeowners (%)	74.8%	69.0%	86.6%	75.8%
Flood experience BEFORE August 2002:				
People who experienced at least one previous flood (%)	9.5%	20.2%	41.9%	21.9%
People who experienced a flood in the last ten years (%)	3.6%	7.4%	33.0%	12.7%
People without flood experience, but with knowledge about the flood hazard of their property (%)	35.1%	25.5%	30.1%	30.6%
Characteristics of the flood impact in 2002:				
Mean water level above top ground surface (cm)	113.24	78.57	-25.29	64.22
Mean flood duration (h)	256	102	39	143
Interviews that reported very high flow velocity (%)	1.1%	5.4%	0.7%	2.6%
Interviews that reported oil contamination (%)	49.5%	39.8%	23.3%	39.1%

The knowledge about being at risk among people without experience of floods was lowest in Group B: only 25.5%, in contrast to 35.1% in Group A, and 30.1% in Group C who knew that they lived in a flood-prone area (Table 2).

The impact of the 2002 flood in terms of water level, flood duration and additional contamination was the most severe in Group A. Very high flow velocities were most frequently recorded at the Elbe tributaries (Table 2). Altogether, a broad variation of socio-economic and hydrological conditions was captured by the survey.

3.2 Preparedness before the flood event in August 2002

Before the flood event in August 2002, 71.2% of the interviewed households in Group A, 72.6% in Group B and 65.3% in Group C had undertaken at least one precautionary action. However, the kind of the measures differed considerably in the three regions (Fig. 3). In the Elbe catchment, there was a large proportion of people who were insured against flood damage—in fact 49.5% in Group A and 49.9% in Group B, in contrast to only 17.8% in Group C. This has historical reasons: flood loss compensation was generally included in the household insurance in the former GDR (German Democratic Republic) of which Saxony and Saxony-Anhalt were part. Many people in eastern Germany still have similar contracts. In the rest of Germany, except for Baden-Württemberg, flood insurance is not widespread (Thieken *et al*., 2006).

Acquisition of information, i.e. by gathering advice about flood precautions or by participating in (neighbourhood or flood) networks, was more popular than precaution by flood-proofing or building retrofitting (Fig. 3). Acquisition of information and particularly flood-proofing measures were undertaken to a higher percentage in the Danube catchment. The most frequently performed measures were flood-adapted

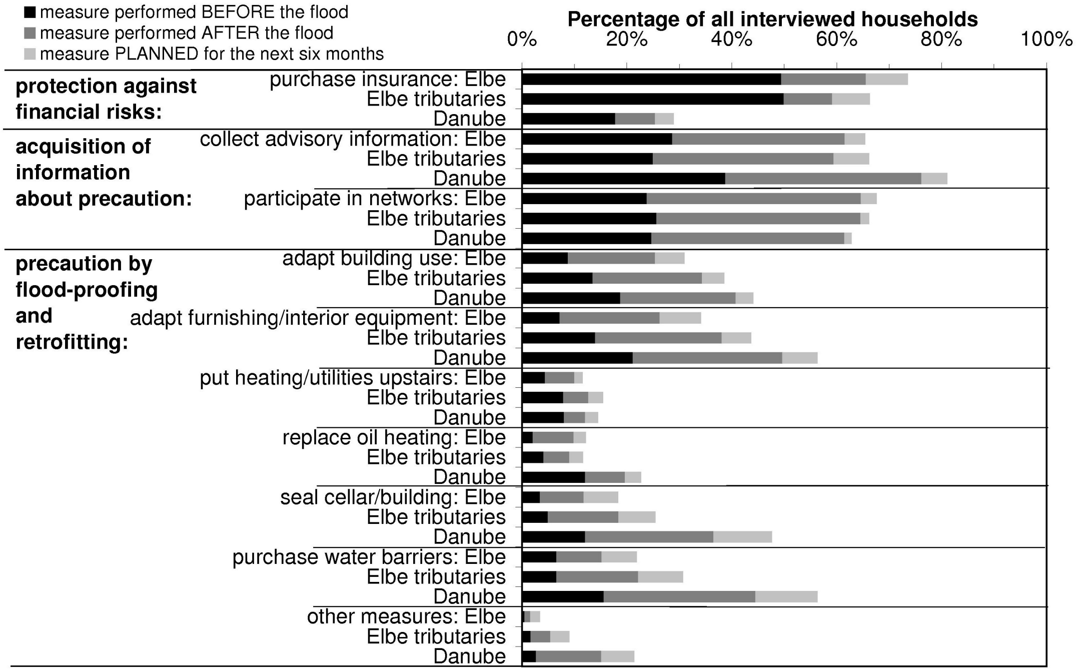

Fig. 3 Precautionary measures undertaken in private households before and after the flood event in August 2002, and measures that are planned for the next six months. Results are given as a percentage of all interviews per region (A: River Elbe: n = 639, B: Elbe tributaries: n = 609, C: Danube catchment: n = 449).

interior arrangement and furnishing of storeys at risk, flood-adapted building use and the purchase of water barriers (Fig. 3). In general, the level of precaution dropped sharply if only flood-proofing or retrofitting measures were considered: the percentage of households that had undertaken at least one of these precautionary actions before August 2002 decreased to 21.0% in the Elbe group (A), to 28.2% at the Elbe tributaries (B) and to 39.6% in the Danube catchment (C). This is alarming since only flood-proofing or retrofitting measures significantly reduce flood damage (see ICPR, 2002; Kreibich *et al*., 2005).

Moreover, the people surveyed in the Elbe catchment evaluated the effectiveness of private precautionary measures lower than those in the Danube catchment. On a scale from 1 (= private precautionary measures can reduce flood damage very effectively) to 6 (= private precautionary measures are totally ineffective for flood damage reduction), 31.1% of the households interviewed in the River Elbe region and 36.1% from the Elbe tributaries gave a score of "1" or "2", whereas, in the Danube catchment (Group C), this percentage increased to 50.6%. Furthermore, the interviewees in Group C estimated a higher probability of being affected by future floods than those in the Elbe catchment (groups A and B): on a scale from 1 (= it is very unlikely that I will be affected by future floods) to 6 (= it is very likely that I will be affected by future floods), only 18.5% in Group A (Elbe) and 22.8% in Group B (Elbe tributaries) chose a rank of "5" or "6", while 40.8% in Group C (Danube catchment) gave this answer.

A correlation analysis was performed to investigate which factors influenced precautionary behaviour. For flood insurance, no coefficient was higher than 0.16.

Table 3 Rank correlation (Spearman's rho) between precautionary behaviour (BEFORE the flood event) and other parameters; only coefficients significant at the 0.05 level and ≥0.2 are shown.

Item (see Table 1 for units and labels)	Acquisition of information about precaution BEFORE the flood			Flood-proofing and retrofitting BEFORE the flood		
	A	B	C	A	B	C
Ownership structure					0.26	
Experience of floods			0.28			0.30
Knowledge about flood hazard	0.23		0.28			
Perceived risk of future floods			0.20			
Acquisition of information (BEFORE)	1.00	1.00	1.00	0.24	0.32	0.51

Data groups: A: River Elbe, B: Elbe tributaries, C: Danube catchment.

Table 4 Relationship between experience of floods, knowledge about the flood hazard and precautionary behaviour (only flood-proofing measures or retrofitting).

Sub-group description		A	B	C
Residents with experience of floods	Proportion in group	9.5%	20.2%	41.9%
	thereof: precautionary behaviour	23.0%	38.2%	54.8%
Residents without experience of floods, but with knowledge about the flood hazard	Proportion in group	31.6%	20.4%	17.4%
	thereof: precautionary behaviour	25.7%	33.1%	37.2%
Residents without experience of floods or knowledge about the flood hazard	Proportion in group	58.2%	59.3%	40.1%
	thereof: precautionary behaviour	17.7%	23.3%	25.0%

Data groups: A: River Elbe, B: Elbe tributaries, C: Danube catchment.

However, in Group C in particular, acquisition of information was positively correlated with experience of floods, knowledge about the flood hazard and the perceived risk of future floods (Table 3).

In all three regions, flood-proofing and retrofitting of buildings was significantly correlated with the acquisition of information about self-protection. Further, the ownership of a flat or building was important for flood-proofing of the building in Group B, as was flood experience in Group C (Table 3).

Precaution in the Danube catchment refers more clearly to experience of floods or to the knowledge of being at risk than in the other two regions. People with experience of floods showed more precautionary behaviour (54.8%) than people without experience of floods, but with knowledge about being at risk (37.2%), and much more than people without experience of floods and without knowledge of being at risk (25%). In all three sub-groups, the percentage of people who undertook some flood-proofing action is the highest in Group C and the lowest in Group A (Table 4).

The overall level of precaution is comparable to that in an investigation in Illinois, USA (Brenniman, 1994), where 68% of the respondents had spent some money on some kind of flood precaution. However, a correlation between precautionary behaviour and socio-economic variables is not noticeable in our data.

The regional differences in precautionary behaviour in the three areas can best be explained by the differences in experience of floods and the historical circumstances, rather than by the wider spread of flood insurance in Saxony and Saxony-Anhalt. Thieken *et al.* (2006) showed that there is no significant difference in precautionary behaviour between insured and uninsured households in the Elbe catchment. Experience of floods seems to be the most important motivation for gathering information about private precautions. Precaution by flood-proofing and retrofitting of buildings relies on the extent of the acquisition of such information and to a lesser degree on experience of floods. Since the simple knowledge about the flood hazard also stimulates people to inform themselves about precaution—in the case of the Elbe region it is as effective as experience of floods (Table 4)—the publication of flood hazard maps is an important part of flood risk management. However, the dissemination of hazard maps should be accompanied by information material about possible precautionary actions. The material should be prepared for different groups, i.e. building/flat owners and tenants.

3.3 Response to the August 2002 flood

Flood warning Flood warnings disseminated by the authorities reached more than 40% of all surveyed people (Table 5). These warnings were spread mainly by loudspeakers, sirens, flyers or posters, followed by local radio stations (data not shown). One third of the people became aware of the danger of flooding by their own observation. Nationwide news and warning by neighbours, friends or relatives each contributed about 13%. However, more than a quarter of the people were not warned at all (Table 5).

According to the Mann-Kendall U test, flood warning differed significantly between all three regions with respect to the warning source and information, lead time and the people's knowledge of how to protect themselves and their property. While the percentage of people who were not warned at all is about 11% in Group A, this figure rose to 28.5% in Group C and even 42% in Group B (Table 5). Furthermore, warnings were disseminated in large parts of regions B and C only a few hours before the houses were flooded, whilst, along the River Elbe (A), a lead time of several days was achieved (Table 5). The different lead times are explained by the different hydrological boundary conditions, e.g. the fast response of the mountainous catchments in region B.

Table 5 Answers to the question: "How did you become aware of the danger of flooding?"; given as a percentage of all interviewed people per region (multiple answers possible) and average lead time per data group.

	A	B	C	Total
Flood warning by authorities	63.4%	23.2%	31.6%	40.5%
Own observation	29.7%	34.8%	36.5%	33.4%
Nationwide news	23.0%	6.9%	10.5%	13.9%
Warning by neighbours, friends etc.	14.7%	9.4%	16.5%	13.3%
Warning and evacuation at the same time	2.2%	1.1%	0.0%	1.2%
Other warning sources	0.5%	0.2%	0.4%	0.4%
No warning received	11.0%	42.0%	28.5%	26.8%
Not specified / no answer	0.8%	0.8%	0.4%	0.7%
Number of relevant interviews	639	609	449	1697
Average lead time (h)	65	11	17	37
Number of relevant interviews	464	284	257	1005

Data groups: A: River Elbe, B: Elbe tributaries, C: Danube catchment.

Table 6 Information content of official flood warnings (multiple answers possible).

	A	B	C	Total
Residential areas at risk	60.3%	50.8%	53.3%	57.0%
Advice on damage reduction	33.4%	32.6%	43.3%	35.1%
Maximum water level	29.9%	20.5%	57.5%	33.1%
Time-to-peak water level	22.5%	17.4%	46.7%	26.0%
Information about evacuation	30.6%	18.2%	0.8%	22.6%
Other useful information (levee breaches, streets etc.)	2.8%	2.3%	0.0%	2.2%
None of this information	8.4%	17.4%	8.3%	10.2%
Not specified / no answer	4.8%	6.1%	6.7%	5.4%
Number of relevant interviews (i.e. people warned by authorities)	395	132	120	647

Data groups: A: River Elbe, B: Elbe tributaries, C: Danube catchment.

Table 7 Reasons why people did not perform emergency measures (multiple answers possible).

	A	B	C	Total
It was too late to do anything	60.3%	72.1%	59.6%	65.1%
Nobody was at home	17.6%	18.0%	19.1%	18.3%
I thought emergency measures wouldn't be necessary	10.3%	6.6%	10.6%	8.8%
I did not think the flood would become so severe	5.9%	2.5%	8.5%	5.3%
I did not know what to do	2.9%	2.5%	5.3%	3.5%
I was not capable of doing anything	8.8%	1.6%	0.0%	2.8%
I thought emergency measures would be useless	2.9%	0.0%	4.3%	2.1%
Others	2.9%	1.6%	1.1%	1.8%
Not specified / no answer	1.5%	4.1%	3.2%	3.2%
Number of relevant interviews	68	122	94	284

Data groups: A: River Elbe, B: Elbe tributaries, C: Danube catchment.

Warnings from the authorities were investigated in more detail. Warnings in the Danube catchment included information about the maximum water level and the time–to-peak water level, as well as advice for damage mitigation, more often than in the other two regions, where considerably more information about evacuation was disseminated (Table 6). The information content was the worst along the Elbe tributaries: more than 17% of the warnings contained no detailed information about the flood and possible mitigation measures (Table 6). An indicator that assessed the most reliable warning source (ranging from 0: no warning to 4: warning by local authorities) and an indicator that summarized the warning information as introduced by Thieken *et al*. (2005) were further used in this paper.

The broad information content of warnings in the Danube catchment supported people's knowledge about how to protect themselves and their households against the flood. On a scale from 1 (= I knew exactly what to do) to 6 (= I had no idea what to do), 43% of the people in Group C chose "1" or "2", while in groups A and B this percentage dropped to 24.4 and 25.4%, respectively. Nonetheless, 21% (94 interviews) of all people interviewed in Group C did not undertake any emergency measures, while this amounted to only 11% in Group A (68 interviews), but 20% in Group B (122 interviews). This might be due to the dominance of fast-onset floods in the

Danube catchment, as well as to the fact that the flood happened during the summer holiday season. Accordingly, the main reason why people did not perform emergency measures was lack of time, followed by the fact that people were not at home (on vacation, business trips, etc.; see Table 7).

Of the people along the River Elbe (A) who did not carry out emergency measures, 30% had not been warned. This applied to 58% along the Elbe tributaries (B) and 57% in the Danube catchment (C). Forty-two percent of the interviewees in Group A, 64% in Group B and 47% in Group C affirmed that they could have done more if they had been warned earlier. This confirms that official flood warnings are an important pre-condition for the performance of emergency measures. The highest potential for further damage reduction is in mountainous regions; however, flood warning in such areas is difficult.

Emergency measures Emergency measures that were undertaken by more than 50% of all respondents consisted of safeguarding movable household contents, vehicles, documents and valuables, as well as protecting the building against inflowing water. Figure 4 reveals that there was a higher percentage in Group A, who accomplished measures for their own safety (e.g. switching off electricity or gas). In contrast, in Group C, there was a larger proportion of people who performed actions that were aimed at keeping the water out of the building, e.g. by installing barriers or water pumps. Moreover, oil tanks were protected more often in this group (Fig. 4). This might be explained by the experience during the Whitsun-flood in May 1999, where severe damage was caused by oil (Müller, 2000). Furthermore, the proportion of buildings that are heated with oil was much higher in the Danube catchment (53% of the interviews) than in the other two groups (16%).

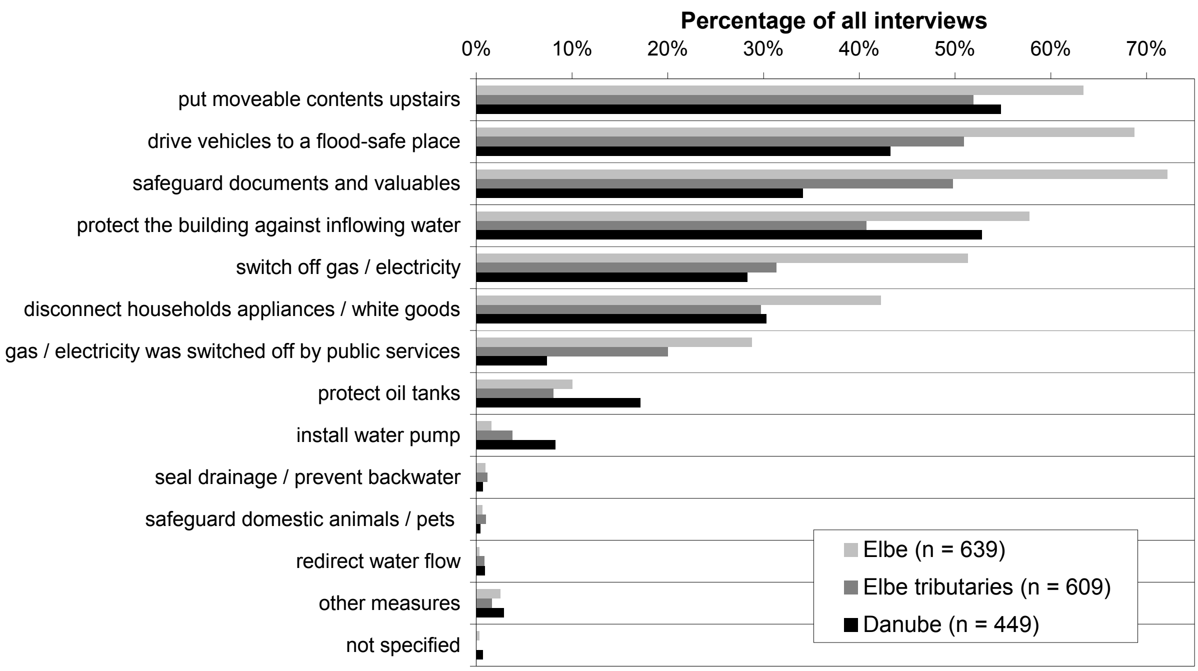

Fig. 4 Emergency measures performed (in descending order), as a percentage of all interviewed people per group (multiple answers possible).

Whether emergency measures can reduce flood damage also depends on their effectiveness. People who accomplished emergency measures were asked to evaluate the effectiveness of each activity on a scale from 1 (= very effective) to 6 (= totally ineffective). Figure 5 illustrates the effectiveness as an average rank per measure in the three areas of interest. Actions such as safeguarding important documents and valuables, as well as switching off electricity and gas, were easy and effective to perform, whereas it was more difficult to make effective arrangements for safeguarding household contents, or for the protection of the building. Figure 5 highlights that the latter measures were more effective in the Danube catchment, where people had more experience of floods and where water levels were not as high as in the other two regions (see below).

For an overall assessment of the emergency measures, the following indicator was calculated: each measure performed received seven points from which the respective rank for efficiency was subtracted. Further, the individual measures were weighted in relation to their damage reducing effect (see Thieken *et al.*, 2005). Table 8 shows how this indicator correlates with other parameters.

In all three regions, the time that was spent on emergency measures, the lead time and the number of people involved in emergency measures were positively correlated to emergency measures, i.e. the more time and people were available to take action, the more successful were emergency measures. Additional factors were determined in Group B: here, the household size and the ownership of the house influenced emergency measures positively, whereas the flood impact in terms of water level and duration hampered the effectiveness of emergency measures. In Group C (Danube catchment), the indicators for the flood warning source and information, as well as the knowledge about being at risk, showed considerable correlation with the overall indicator for emergency measures (Table 8). Only the perceived knowledge about how to protect against floods had a negative correlation coefficient, i.e. the more people

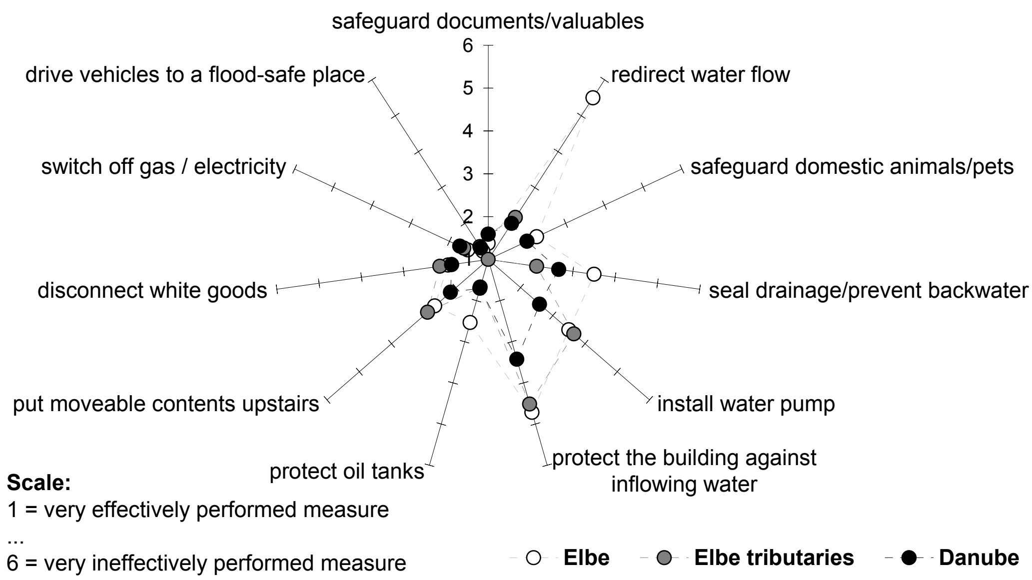

Fig. 5 Average effectiveness of emergency measures as evaluated by the people interviewed on a scale from 1 (= measure was very effective) to 6 (= measure was very ineffective).

Table 8 Rank correlation (Spearman's rho) between effectively performed emergency measures (indicator) and other parameters; only coefficients significant at the 0.05 level and ≥0.2 are shown.

Item (see Table 1 for units and labels)	A	B	C
Household size		0.20	
Ownership structure		0.23	
Knowledge about flood hazard			0.23
Flood water level		–0.24	
Flood duration		–0.20	0.20
Warning source			0.31
Warning information			0.23
Lead time	0.22	0.28	0.38
Perceived knowledge about self-protection			–0.22
Time spent on emergency measures	0.38	0.47	0.24
Number of people involved in emergency measures	0.20	0.24	0.25

Data groups: A: River Elbe, B: Elbe tributaries, C: Danube catchment.

knew (rank 1), the better they succeeded in performing emergency measures effectively. Socio-economic variables, such as household characteristics, age, education, net income etc., influenced the performance of emergency measures only slightly (coefficients were smaller than 0.2, though significant). However, there was a tendency that younger people, or those with better education and higher incomes, were more capable of performing effective emergency measures, whereas households with elderly people had more difficulties (data not shown).

The analysis shows that flood warnings are an important pre-condition for the performance of emergency measures. However, their effectiveness is better in an area where people have more knowledge about self-protection, e.g. where flood warnings contained detailed information about the hazard in terms of water levels and time to peak flow, as well as information on appropriate actions. Besides warning characteristics, the number of people available to take action also determines the success of emergency measures. Efforts to improve early warning systems, especially in mountainous regions, should be done with regard to longer lead times, but also with regard to the warning content. Only if people know how to react in the case of flooding, how high the water levels will be and how much time they have in which to react, can damage be prevented or reduced to a considerable degree.

3.4 Flood damage and recovery

Adverse effects of the flood In 1273 of the 1697 households surveyed, respondents specified the cost of damage to household contents and 1079 the cost of building damage, in terms of repair and replacement. The mean damage amounted to €16 335 and €42 093, respectively (cf. Table 9). Losses significantly differed between the three data groups: the damage to household contents and particularly to buildings was highest in Group A, followed by Group B. The cost of damage in Group C was considerably lower (Table 9). In all regions, the cost of damage was correlated with other adverse effects, such as duration of evacuation and cleaning-up (Table 9).

In addition, Table 9 reveals which parameters most influenced the amount of financial loss. Damage to household contents was particularly influenced by the flood

Table 9 Mean flood damage and rank correlations (Spearman's rho) between flood damage and other parameters; only coefficients significant at the 0.05 level and ≥0.2 are shown.

Item (see Table 1 for units and labels)	Damage to household contents A	B	C	Damage to residential building A	B	C
Mean damage (€)	20 770	13 088	13 536	57 829	45 824	16 834
Duration of evacuation	0.49	0.43	0.24	0.33	0.48	0.20
Duration of cleaning-up	0.44	0.37	0.35	0.28	0.45	0.45
Ownership structure	0.52	0.32			–0.23	
Perceived quality of household contents	–0.21		–0.21			
Knowledge about flood hazard				0.20		
Perceived efficiency of private precautions	0.24				0.23	
Flood-proofing / retrofitting (BEFORE)					–0.30	
Flood water level	0.47	0.47	0.50	0.53	0.66	0.52
Flood duration	0.26				0.23	
Flow velocity			0.22		0.31	0.25
Contamination of the flood water	0.28	0.30	0.33	0.30	0.43	0.32
Perceived credibility of the warning			0.31			
Overall assessment of emergency measures				–0.20	–0.26	

Data groups: A: River Elbe, B: Elbe tributaries, C: Danube catchment.

water level, the contamination of the flood water and, in groups A and B, by the ownership structure, whereas in Group C the credibility of the warning was more important. Damage to buildings was also considerably influenced by the water level and the contamination of the flood water, followed by knowledge about the flood hazard in Group A and the flow velocity in groups B and C (Table 9).

In groups A and B, emergency measures, as well as flood-proofing and retrofitting of buildings, were negatively correlated to damage to buildings indicating the potential to reduce flood damage by private precautions also during extreme events. This was analysed in detail by Kreibich *et al*. (2005). More details about the relationship of several parameters to flood damage are given in Thieken *et al*. (2005).

Recovery After the August 2002 flood, the German government launched an emergency fund for reconstruction (*Sonderfond Aufbauhilfe*) of €7100 million. Furthermore, money from the European Union (€444 million), donations (€350 million) and insurance compensation (€1800 million) were available for loss compensation and enabled a rapid recovery (Mechler & Weichselgartner, 2003; Schwarze & Wagner, 2004; DZI, 2004).

In our survey, people were asked to compare the state of their household contents and their building before the flood and at the time of the interview, and to evaluate the difference on a scale from 1 (= household contents/buildings are already replaced/ restored completely) to 6 (= there is still considerable damage to household contents/to the building). At the time of interview, i.e. about 8–9 months after the flood, 31.5% of the people in Group A evaluated the building status with "1" or "2", i.e. had already recovered well. For the household contents this share increased to 56.0%. In Group B, recovery was a little faster: 46.9% reported a good recovery of the building, 60.6% a good recovery of the household contents. Recovery was at best in Group C: more than 60% evaluated their recovery with "1" or "2" for both building and content damage.

Table 10 Rank correlation (Spearman's rho) between recovery and other parameters; only coefficients significant at the 0.05 level and ≥0.2 are shown.

Item (see Table 1 for units and labels)	Perceived level of replacement of damaged contents			Perceived level of repair of damaged building		
	A	B	C	A	B	C
Flood water level			0.23		0.31	0.23
Flood duration			0.20	0.20		0.23
Contamination of the flood water				0.25	0.24	
Perceived credibility of the warning		0.27				
Perceived knowledge about self-protection					0.24	
Perceived efficiency of private precaution					0.20	0.21
Duration of evacuation						0.23
Duration of cleaning-up					0.23	
Damage to household contents	0.25	0.26	0.30	0.20	0.27	0.21
Damage to building	0.26	0.27	0.29	0.25	0.43	0.32
Received loss compensation					0.25	

Data groups: A: River Elbe, B: Elbe tributaries, C: Danube catchment.

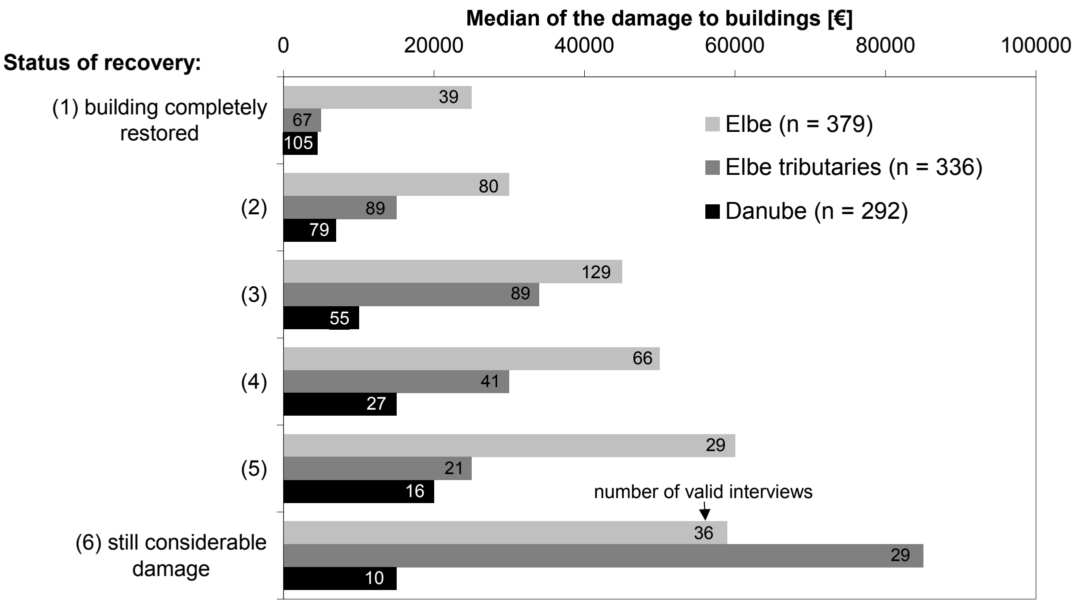

Fig. 6 Relationship between the status of recovery at the time of the interview (evaluated on a scale from 1 to 6) and the median of the building damage.

Besides the characteristics of the flood (water level, flood duration and contamination), the amount of damage had the highest correlation with the level of recovery in all three data groups (Table 10). This is further illustrated by Fig. 6: recovery decreases with an increasing median of building damage.

Moreover, knowledge about self-protection and perceived efficiency of private precautions were also advantageous for fast recovery, e.g. slow recovery was connected to a lack of knowledge about self-protection in Group B. This demonstrates that recovery is affected not only by the degree of flood impact, but also by people's preparedness and their knowledge about flood mitigation.

3.5 Lessons learned: will people be better prepared for future floods?

The interviewees were also asked whether they undertook any precautionary measures after the flood and whether they were planning to undertake some within the next six months. The extent of the acquisition of information about precaution and of flood-proofing and retrofitting of buildings, as well as the number of insured households, increased enormously. For some precautionary actions, the percentage of involved households nearly doubled (Fig. 3). In total, only about 4% of all households interviewed had not undertaken, or were not planning to undertake, any precautionary action. However, the differences between the three regions outlined in Section 3.2 remained. Flood insurance is still more important in the Elbe catchment, i.e. in groups A and B (Fig. 3), whereas people in the Danube catchment (Group C) concentrated more on building retrofitting, particularly on flood-adapted building use and furnishing, building sealing and the purchase of water barriers (Fig. 3).

Table 11 shows what influenced the different kinds of precautionary action. In Group A (River Elbe), no significant correlation higher than 0.16 was found. All kinds of precautions tended to correlate with the age of the interviewee (the younger they were, the more precautions were taken), and the household size, i.e. particularly young families seem to invest in flood insurance and flood-proofing or retrofitting measures (data not shown since correlation coefficients were lower than 0.20). In Group B, building owners were more willing to invest in building retrofitting, as were people who believe that private precautions are effective (Table 11). In Group C, the amount of damage and the compensation for loss were important for flood-proofing and retrofitting of buildings. Moreover, people who had not been affected by floods before, or who did not know enough about the hazard and about self-protection, informed themselves about precautions after the flood and were also willing to flood-proof their buildings (Table 11).

About 3% of all households interviewed wanted to avoid flooding in the future and decided to move to a flood-safe area. Table 11 reveals that this option was particularly considered by those who were tenants.

Table 11 Rank correlation (Spearman's rho) between the changes in precautionary behaviour after 2002 and other parameters; only coefficients significant at the 0.05 level and ≥0.2 are shown.

Item (see Table 1 for units and labels)	Change in flood insurance			Change in acquisition of information on precautions			Change in flood-proofing and retrofitting			Moving to a flood-safe area		
	A	B	C	A	B	C	A	B	C	A	B	C
Ownership structure								0.22		–0.24	–0.21	–0.22
Experience of floods						–0.20						
Knowledge about flood hazard						–0.20						
Perceived efficiency of private precautions								–0.20				
Perceived knowledge about self-protection			0.23			0.21			0.31			
Damage to building									0.21			
Received loss compensation									0.22			
Change in acquisition of information on precautions			0.20	1	1	1		0.20	0.30			

Data groups: A: River Elbe, B: Elbe tributaries, C: Danube catchment.

To further improve the level of precautions and to motivate people to invest in flood-proofing measures, it seems to be important to provide information about the options for precautions that can be taken. In particular, after a flood event, there is a window of opportunity for initiating precautionary measures. In order to convince people, the effectiveness of private precautionary actions, i.e. the potential damage reduction, should gain more attention in the discussion of flood risk management. Besides providing different recommendations for homeowners and tenants, special information for elderly people might also be necessary.

4 RECOMMENDATIONS AND CONCLUSIONS

The analysis of how preparedness, response and recovery of residents in three different regions in Germany are correlated to socio-economic variables, experience with previous floods and flood impact of the event in 2002 leads us to the following recommendations:

The pure knowledge of living in a flood-prone area stimulates the acquisition of information about self-protection. However, this does not necessarily lead to flood-proofing or retrofitting measures. Therefore, more information is needed about the effectiveness and the cost–benefit ratios of different precautionary measures. Further, specific information, e.g. different information leaflets with flood mitigation options for different groups of people, would be helpful. Tenants, homeowners, elderly people, or large households all have different abilities to perform precautionary and emergency measures. Therefore, information about private precautions has to meet people's interests and capabilities in order to convince them that they will be able to reduce their potential flood damage significantly.

Despite the potential to mitigate flood losses, the flood impact, particularly the water level and the contamination of the flood water, affect the cost of damage and degree of recovery to a great extent. Therefore, financial precautions, i.e. flood insurance, should be strongly recommended, especially in areas with low insurance cover.

People's knowledge about the flood hazard and about self-protection, as well as good warning information, would help them to better perform emergency measures. Therefore, flood warnings should be released with more detailed information about expected water levels, time to peak flows and recommendations for appropriate response. However, the time and the number of people available to undertake emergency measures are the most important factors during the response phase. Therefore, longer lead times of early warnings are needed, especially in mountainous regions. Further, it would be worthwhile to think about improved response capacities in flood situations, e.g. by activating neighbourhood help or disaster management assistance.

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