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Household measures for river flood risk reduction in the Czech Republic

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Abstract

Interviews with 304 households were used to determine flood risk reduction measures adopted in the case study of the Becva River in the Czech Republic. Uptake of measures was low, irrespective of experience with floods. Financial cost seemed to be a barrier towards implementation, but more work is needed to understand the combination of factors limiting adoption of household flood risk reduction measures. Regression analysis indicated that socio-demographic factors play an important role in household decision making. More men and more children in a household support the adoption of measures. Perception of living in a flood risk zone, rather than actual experience of flooding, also positively influenced probability of adopting some measures. When a house is elevated up from ground level by 1 metre or more, the likelihood of taking further measures decreased by 20%. Further investigation of these factors and why, not just how, they influence household choices would support flood risk reduction measures, especially under a changing climate.

Introduction

River floods have long affected humanity, and the projection under climate change is that they will become more intense and more frequent in some locations (IPCC, 2012). Often, seasonal variations will be evident, such as climate change decreasing winter flood frequency in the Elbe and Oder rivers of central Europe (Mudelsee *et al.*, 2003). As such local trends do not match global projections (IPCC, 2012), people's perceptions of their river flood risk – and their responses – can be complex and are worthy of continued study. That is particularly the case since urban development, river engineering, agriculture, and climate change, among other factors, can influence river flood risk (e.g. Szöllösi-Nagy and Zevenbergenvan 2005; Begum *et al.*, 2007; Parker *et al.*, 2008, 2009; Mechler and Kundzewicz, 2010; Djordjevič *et al.*, 2011; Quevauviller, 2011; van Ree *et al.*, 2011). Building on river flood risk reduction research and practice across Europe and around the world (e.g. Christensen and Christensen, 2003; Szöllösi-Nagy and Zevenbergenvan 2005; Mechler and Kundzewicz, 2010), in the context of complicated river flood risk trends in central Europe under climate change (e.g. Becker and Grünewald, 2003; Mudelsee *et al.*, 2003; Kundzewicz *et al.*, 2005; Huntjens and Pahl-Wostl, 2010; Quevauviller, 2011), this paper examines how households in the Czech Republic implement flood risk reduction measures (see also Kundzewicz *et al.*, 2010). The case study is the Becva River in the Czech Republic.

The Czech Republic has experienced numerous flood disasters throughout its history, the most recent at the national level being in 1997, 2002, 2006, 2010, and 2013 (Kaspar and Müller, 2008; Schanze, 2013). Although some studies on flood risk in the Czech Republic exist (e.g. Rodda, 2005; de Moel *et al.*, 2009; Dráb and Říha, 2010), little work has been done for the Czech Republic regarding individual, household, and community measures for, and perceptions of, flood risk. This paper makes a contribution to filling in this lacuna in the literature by analysing evidence from household interviews regarding experiences with, perceptions of, and measures taken for river flood risk.

This paper has four sections following this introduction. Section 2 scopes this study including a description of hypotheses and case study, followed by section 3 detailing the methodology. The final two sections are Results/ Discussion and Conclusions, indicating the key lessons and how to move forward from the new knowledge presented.

Hypotheses and case study

At the household level, numerous studies examine household measures taken for flood risk reduction in Europe to determine why some measures are adopted and others are not (Table 1). Influencing factors include culture, societal status, demography, economy, and risk perception. No clear pattern emerges regarding exactly how different influencing factors lead to different outcomes regarding specific household measures adopted or not adopted.

Consequently, this subfield within flood risk reduction research has limited theorisation despite the excellent empirical studies represented in Table 1. Part of the reason might be that many of the studies are rather disciplinary, notably from economics and psychology, so their theoretical framings and developments tend to be disciplinary. Part of the reason might be that, quite fairly, context matters. That is, culture plays an especially significant role in dictating the outcomes of hazard-related decision making and response, a point well grounded theoretically and empirically in disaster studies (e.g. Hoffman and Oliver-Smith, 2002; Krüger *et al.* 2015).

To build on the work in Table 1, to forge new ground by crossing disciplinary boundaries and to further explore context by using a new case study from a country with limited flood risk reduction literature, we designed our study to investigate household factors covering direct experience with river flooding, local knowledge of the nearby environment especially of waterways, and social and economic characteristics of the household. We tested the following hypotheses for river floods:

H1: Households experiencing more floods and more flood damage tend to implement more flood risk reduction measures.

H2: Higher perception of household flood risk leads to increased adoption of household flood risk reduction measures.

H3: Socio-demographic and economic variables influencing adoption of household flood risk reduction measures are contextual.

The variables selected are not tied to any specific discipline or theory, instead covering a wide range of factors from across the literature (e.g. Table 1). H1 and H2 represent that cross-disciplinary approach by examining self-reported experience and perception, rather than relying on a discipline. H3 explicitly explores contextuality.

The new case study is in the east of the Czech Republic, in the foothills of the Beskid Mountains, on the middle part of the Becva River that flows into the Morava River (Figure 1). The river is 61.6-km long with its river basin extending to 1613 km^2. The Becva River drains water from a forested, hilly, and precipitation-rich area that has small retention capacity due to bedrock, leading to a highly fluctuating flow rate. The water level tends to be highest during the spring in March and April and lowest during September. Historically, the local people lived with the fluctuating level, but from the end of the 19th century, projects were implemented to regulate the water flow. Particularly in the early 20th century, the river was altered, shortening meanders and smoothing the channel, meaning that people moved closer to the river, with industry, infrastructure, and homes then being located in the floodplain (Pavelka and Trezner, 2001).

This rural region remains economically disadvantaged, even for the Czech Republic and Central Europe (Povodí Moravy, 2009). In addition to the world's financial crisis hitting rural areas hardest in the Czech Republic, the towns located in the foothills along the Becva River still suffer from a post-industrial, post-Communist economy while trying to develop livelihoods in mainly tourism, wood processing, food processing, and a chemical industry.

The case study area here is approximately 184 km^2, its height above sea level ranges from 260 to 800 m, and its average annual precipitation ranges from 650 to 800 mm. The selected area involves about a 30 km stretch of the Becva

Table 1 Examples of studies examining household flood risk reduction measures in Europe

Study	Location	Categories of measures investigated by the study
Botzen *et al.* (2013)	The Netherlands	Behavioural and economic: willingness to pay
Green *et al.* (1991)	UK mainly	Any measure undertaken by those who had experienced flooding
Grothmann and Reusswig (2006)	Germany	Socio-psychological and socio-economic
Jaeger *et al.* (1993)	Switzerland	Socio-demographic and socio-cultural
Kreibich (2011a)	Germany	Socio-economic and psychological: risk perception
Miceli *et al.* (2008)	Italy	Psychological and socio-environmental
Parker *et al.* (2007)	England and Wales	Behavioural and economic: responses to flood warnings.
Siegrist and Gutscher (2006)	Switzerland	Psychological: risk perception and expert assessment
Terpstra and Gutteling (2008)	The Netherlands	Psychological: perceived responsibility and risk perception
Whitmarsh (2008)	UK	Psychological: experience, risk perception, and behavioural response

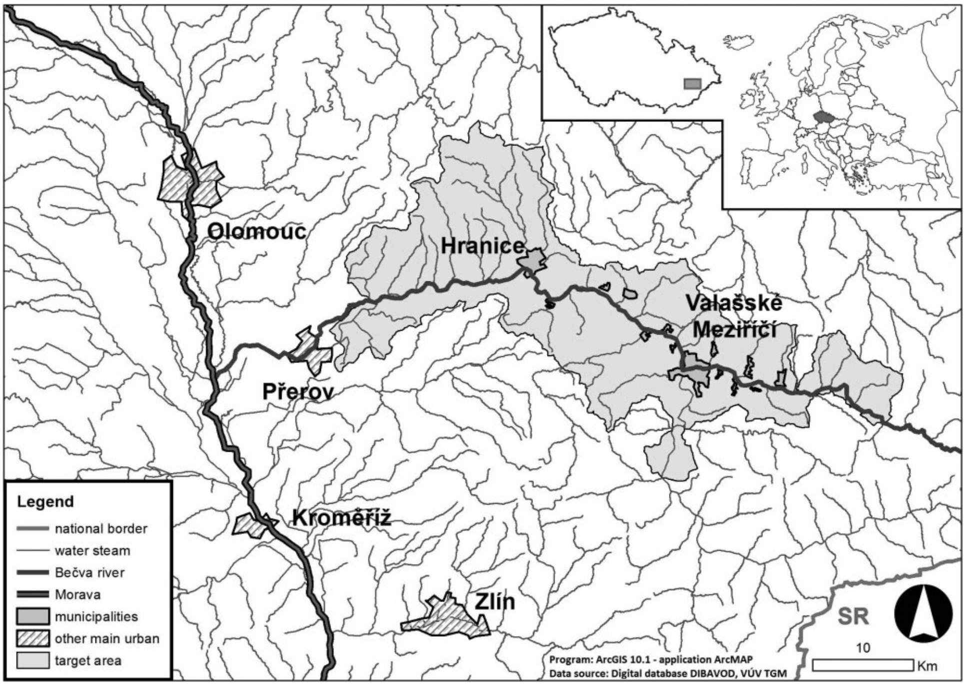

Figure 1 The case study of the middle part of the Becva River, the Czech Republic.

River. Among the most important tributaries are the Loucka River in Valasske Mezirici and the Juhyne River near Choryne village. Although the impacts of climate change on river floods in the Czech Republic have some research (e.g. Dubrovsky *et al*., 2005; Yiou *et al*., 2006; Brázdil *et al*., 2011a, b), the work has principally been on larger river basins. For the smaller waterways, researchers and authorities suffer from a lack of data (see Borga *et al*., 2011).

The case study area is hilly with a relatively ragged relief, although the developed floodplain is flat – which is the reason for it having been developed. The floodplain width varies from about 150 m to more than 2.2 km near Lhotka nad Becvou village. Both erosion and accretion processes are continually evident along the river, and floods have led to geomorphological and ecological changes (Klečka, 2004; Demek *et al*., 2006).

The most recent flood disasters in the case study area occurred in July 1997 and May 2010 due to heavy rainfall lasting several days across the entire area (CHMI, 1997, 2010; Brázdil *et al*., 2006; see also Table 4, later). More locally, recent and smaller floods occurred in places in 2006, 2007, and 2009. Properties in the floodplain were inundated by flood water, but farther away from the river, damage was caused by the high water table flooding cellars. The 2006 and 2009 flood water came from a combination of precipitation and snow melt. In addition to flood water from the Becva River directly, many properties in the case study have been repeatedly flooded from nearby streams when intense, highly localised precipitation leads to quickly rising floods. The streams are small, and the soil is often saturated from previous rainfall, so water can spread quickly over the landscape with limited warning time.

Methodology

In the case study area, we chose 12 villages located along the Becva River and its tributary the Roznovska Becva River (Figure 1; Table 2). The main criterion for selecting villages and households was equal distribution across the three risk zones of the Czech national system of designating flood risk areas, which are labelled no risk, low risk, and high risk (see below for definitions). For major rivers, maps and data are publically available from the Czech authority DIBAVOD (Digital Water Management Information) based on Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 (the Water Framework Directive) as incorporated into the Czech Water Act No. 254/2001. The main criteria for selecting households within each flood risk zone were permanent residence in and ownership of the house. That ensures that the property occupiers have responsibility for the condition of the property and an incentive to keep the property in good condition.

In 2012, we implemented door-to-door interviews that used both closed questions and open-ended questions about the household measures used for river flood risk reduction. The total number of interviewees was 304, with each interview lasting between 30 and 60 min. All houses within the high risk and low risk zones were visited. Across all three

Table 2 The villages where interviews were completed

Municipality	Rivers and streams	Population (CSI, 2011)	Total number of Interviews	*Very low flood risk zone*	*Low flood risk zone*	*High flood risk zone*
Hrachovec	Becva: Hrachovecky Stream	900	28	3	14	11
Hustopece nad Becvou	Becva: Loucsky Stream	1721	12	2	6	4
Choryne	Becva: Juhyne	738	30	10	9	11
Jurinka	Becva	447	14	3	4	7
Krhova	Becva: Srni Stream, Rybnickovy Stream	2002	31	2	4	25
Lhotka nad Becvou	Becva:	231	18	4	11	3
Milotice nad Becvou	Becva: Miloticky Stream	288	10	4	3	3
Policna	Becva, Vsetinska Becva: Loucka Stream	1718	32	9	17	6
Stritez nad Becvou	Roznovska Becva: Cerny Stream	810	29	15	8	6
Usti	Becva Opatovicky Stream	560	31	14	8	9
Zasova	Roznovska Becva	2913	31	8	11	12
Zubri	Roznovska Becva Hodorfsky Stream Hamersky Stream	5422	38	11	12	15
Total			304	85	107	112

zones, an estimated 110 households did not answer their door, despite repeated visits. Additionally, approximately 40 households answered, but then declined to participate. The interviews were completed by Czech native speakers in Czech, and the interviewers wrote the answers into the form from verbal answers given by household members.

For defining flood risk zones, DIBAVOD calculates the return period of a watercourse's peak discharge rate (Q). Q20 means a return period of 20 years for peak discharge rate. High risk zones are defined by the inundation extent of Q20, low risk zones are between Q20 and Q100, and no-risk zones are outside Q100. No location truly has zero flood risk, since Q200 and Q5000 still have calculable flood risk. Consequently, even though 'no-risk' is the formal designation in the Czech Republic for areas outside Q100, in this paper, the term 'very-low-risk zone' is used (it would be clearer if the zones were designated low-, medium-, and high-risk).

This method is used to define flood risk for the main rivers across the Czech Republic, with the Becva River being the main one in our case study area. For this study, we also sought to define the risk zones for smaller waterways. That was completed by using the information from households' experiences with small floods, consulting with local experts, and applying any further data available locally. Using this material, we labelled high-risk zones as households affected by several major floods over the past 15 years; low-risk zones as households affected to a lesser degree and sometimes indirectly from water table rise; and very-low-risk zones as the remaining areas.

Drawing on the literature (e.g. Kreibich *et al.*, 2005, 2011b; Begum *et al.*, 2007; Travis, 2010; Weber, 2010; Kreibich, 2011a; Quevauviller, 2011; Botzen *et al.*, 2013) in addition to observed local conditions in the interview locations, the following data were collected:

- Household characteristics, including household members' ages, education levels, incomes, and family structures.
- Flood experiences, including timing, frequency, level of impact, and damage.
- Flood risk reduction measures adopted internally and externally to the structure (see Table 3) including economic aspects of households selecting measures.
- Flood risk preparedness, awareness, and perception, including forecasting and warning information sources, use of those sources, perception of local quality of life, and perception of flood risk reduction measures and systems.

Table 3 mentions insurance, which is a frequently touted and analysed flood risk management measure (e.g. Crichton, 2002, 2008). Flood insurance in the Czech Republic is provided in different ways by private insurance companies only, not by government, as part of different insurance packages, such as household/contents insurance, life insurance, liability insurance, and insurance against natural calamities including flooding. Almost all the companies are foreign, not Czech, and most policies require some level of co-pay for any

Table 3 Examples of household flood risk reduction measures

Internal to the structure or part of the structure	External to the structure, including planning approaches
• Changing floor material on the ground floor to be water resistant. • Elevating the ground floor (at least 1 m or above the Q100 flood level) or having garages or simple cellars as the ground floor. • Installing mobile window and door flood barriers. • Using materials and finishes that are water resistant. • Designing and constructing to withstand flood forces and energies (e.g. Kelman and Spence, 2004). • Purchasing contents and property insurance against flood damage (as well as other perils). • Using information from external local forecasting and warning systems. • Formulating and testing household evacuation plans. • Moving valuables on upper storeys in case of flood occurrence.	• Not building in flood-prone areas. • Implementing hydro-isolation of the walls to avoid water contact in inundated ground. • Implementing water drainage systems around the house. That can be as simple as basic landscaping and as complex as engineered yards and drives including some or all of drainage pipes, gravel, sewers, earthworks, slopes, and retention basins. • Having personal meteorological and hydrological stations.

Sources include Begum *et al.* (2007), Haque *et al.* (2012), Kreibich *et al.*, (2005, 2011b), and Szöllösi-Nagy and Zevenbergen (2005).

Table 4 Household flood experiences and impacts in years with flooding (1997–2012; bolded rows are years with major flooding)

Year	% households flooded out of 304 interviewed	% households flooded at least in the cellar	% households with the ground floor affected	Total losses in millions of CZK	% affected houses which had insurance before the flood date
1997	**184**	**142**	**82**	**15.225**	**75**
2000	2				
2002	**37**	**27**	**12**	**1.7**	**82**
2006	**23**	**12**	**11**	**2.375**	**86**
2007	1				
2008	1				
2009	**57**	**35**	**14**	**2.275**	**91**
2010	**66**	**50**	**21**	**2.5**	**95**
2012	2				

claim. Flood insurance was cheap until the 1997 floods, after which many insurance companies refused to pay out by disputing the definition of 'deluge'. Then, they implemented steep price hikes for premiums while, from 2000–2003, they developed a system of flood risk maps. A further jump in premiums occurred after 2005 when insurance companies developed a more sophisticated system of evaluating flood risk, basic information from which is available in the public domain. Many properties in high flood risk zones or those that have suffered from repeated flooding are, today, almost uninsurable, but the insurance companies do not provide public information regarding their risk calculations, their refusal to insure, their payouts, or their profits/losses from flooding specifically.

Results and discussion

Interview responses

Out of the 304 households interviewed, 72% (220) had experienced floods (corresponding with the actual high- and low-risk flood zones) with Table 4 indicating the flooding frequency. Table 4 also gives total financial losses, but the respondents' estimates should be viewed with caution, partly due to a long time period since some of the flooding occurred and partly due to their unwillingness to fully discuss financial issues during the interviews. Concerning repeated flooding, 36% (109) of the households interviewed had experienced one flood, 28% (86) had experienced two floods, and 8% (25) had experienced at least three floods (the remaining households had not experienced flooding). Given the respondents' reluctance to talk about financial issues, a further data limitation is possible in terms of the respondents not remembering or not fully reporting all the flooding that they had experienced.

From the households interviewed, 75% (227) were located on flat land, 22% (67) on moderate slopes, and 3% (10) on steep slopes. A percentage of 78 (236) have a cellar. Houses are constructed of various building materials: 67% (203) from fired bricks and 19% (57) from either non-fired bricks or a combination of fired and non-fired bricks. The other 14% (44) of houses are constructed from other materials, such as timber or breeze blocks. Seven per cent (20) of houses have a stone cellar that is an old, traditional flood risk reduction measure, because it is easy to clean after flood waters have receded; however, there are now modern dangers in the form of pesticides, fertilisers, and chemicals that often contaminate flood waters and leave a harmful residue.

Approximately half of the houses have a ground floor up to 1 m above the ground level, whereas 30% (91) have an elevated ground floor higher than 1 m. The 1-m height does not necessarily mean that house is protected against the Q100 flood, since Q is peak discharge rate, but it is a tool to evaluate household measures. In comparing the age of the houses with their ground floor elevation (Figure 2), the proportion of houses with elevated ground floors has substantially decreased over the past 20 years after peaking during Communist times. This decrease has occurred despite the frequent flooding. Moreover, the proportion of houses with elevated ground floors is similar for all risk zones. The developers and owners of new houses are following the fashionable or short-term lower cost choices of houses that are not raised, despite the flood risk.

Czech legislation recommends, rather than demands, that building authorities elevate the ground floor for new houses in the Q100 zone. Current regulations in the Czech Water Act No. 254/2001 forbid new houses in Q20 zones. In practice, monitoring and enforcement are not strict – especially when political and development interests simply ‘delay’ implementation. Yet the cost of elevating houses might nonetheless be acceptable, as shown by Botzen *et al.* (2013) in the Netherlands who found that 52% of those interviewed stated that they would be willing to pay a substantial investment of approximately €10 000 to elevate a new house to a level that would be deemed safe from flooding. The differences with the Czech Republic might be the level of affluence in the Netherlands alongside a culture highly aware of and respectful about flood dangers.

During our field work, we found another example of ‘house elevation’ through constructing an artificial mound that elevated the terrain on which the house is built by more than 1 m. Although the house was effectively at ground level, it stands on its own artificial hill, elevating it from flood waters. It is possible that this elevation was completed for the view rather than, or in addition to, flood risk reduction.

In terms of other measures, only one household (comprising two families) indicated that they decided to move as a result of flood risk. They did not migrate away from their home, but instead, with municipal support, they built a new house in the same community but on a hill. Another two households declined even this short move, despite the municipality offering them financial support. A strong connection to one’s house, land, and place of birth is indicated by the reluctance to consider migration as an option – at least in this community, considering that rural communities around the Czech Republic display much more migration, mainly for economic reasons (Macours and Swinnen, 2005). A limitation of this analysis is that the financial support offered by the municipality might not have been deemed to be enough. Perhaps offering a substantial supplement to costs incurred would convince people to break their attachment to their land.

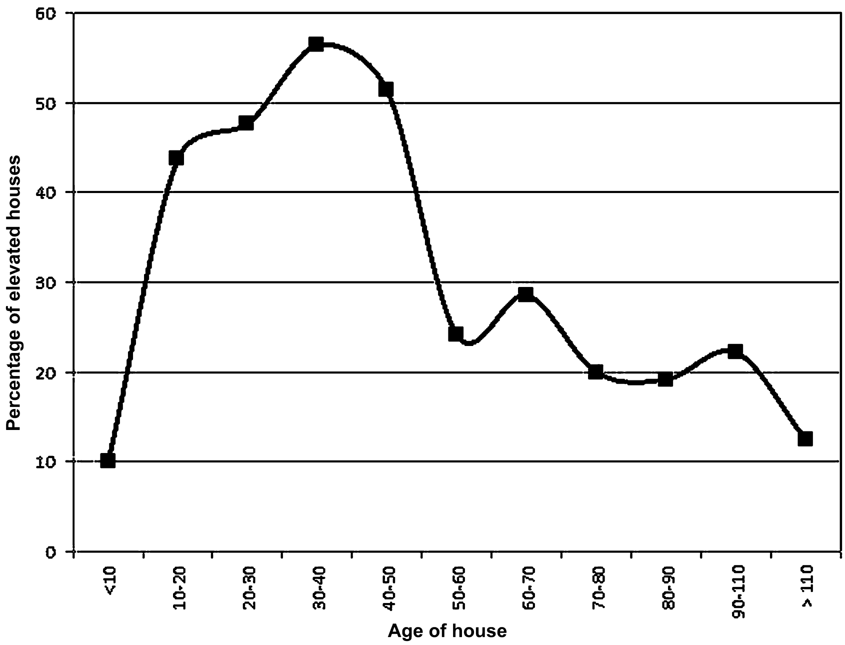

Figure 2 House age and ground floor elevation.

In terms of other flood risk reduction measures, the share of households that has purchased insurance for environmental hazards has gradually increased up to 95% in 2010 (see also Table 4). Yet a few respondents claimed that they could not obtain insurance, because the insurance companies refused to sell it to them or offered high premiums, claiming that the occurrence of floods in their area is more of a trend than of random events. One household gave up trying to restore their damaged ground floor and moved upstairs permanently. Even those with insurance stated that they usually did not receive enough of a pay-out to cover their financial losses.

Many factors could be at play here, including under-insuring due to inadequate pre-flood loss estimation or lack of affordability of higher coverage; underestimating the cost of repair and reconstruction; being subject to post-flood price gouging; financial priorities other than full insurance coverage or full reconstruction; or wishing to avoid the disruption entailed by full reconstruction – which could be dangerous for the occupants' health and for the new materials and finishes if the property is not dried out properly after the flood. Because so many respondents were unwilling to discuss financial matters in great depth, it was hard to glean a deep understanding of these factors.

Nonetheless, Tables 5 and 6 show a trend of progress for implementing household measures for flood risk reduction. There are two provisos indicating data and interpretation limitations. First, people might not remember what they did several years ago or might not know what happened prior to their ownership of the house. Second, no one admitted to taking away or reducing measures but that might have happened. Irrespectively, Tables 5 and 6 show that households tend to prefer simple and cheap measures such as moving possessions upstairs or using mobile barriers, rather than changing their floor. In Table 6, the high uptake of hydro-isolation can be explained by it not usually being considered to be a special river flood risk reduction measure. Instead, it is a standard and basic way of avoiding dampness in the house from wet ground. Co-benefits from other measures are not so straightforward to identify, but the nature of the interviews in highlighting floods might have focused respondents on flood-related reason, even where other drivers dominated their decision to implement a measure.

Additionally, the number of measures adopted per household was limited. Fifty-nine per cent of households adopted one measure, 27% adopted two measures, 11% adopted three measures, and 4% adopted four measures. A pattern emerged of measures taken based on awareness. Table 7

Table 5 Number of households taking internal household flood risk reduction measures

Time period	Moving possessions to higher storeys	Changing the floor material	Using mobile window and door flood barriers
Before the 1997 flood	28	5	12
1997–2006	+22	+12	+12
2007–2010	+16	+1	+13
After the 2010 flood	+12	+6	+14
Total	78	24	51

Table 6 Number of households of external household flood risk reduction measures

Time period	Hydro-isolation of the house and walls	Hydro-isolation, through drainage around the house	Water management of the plot	Terrain and vegetation adjustments
Before the 1997 flood	30	45	20	4
1997–2006	+7	+16	+16	+10
2007–2010	+3	+7	+2	0
After the 2010 flood	+6	+13	+6	+8
Total	46	81	44	22

Table 7 Number of households taking external flood risk reduction measures taken in different flood risk zones

Time scale	Hydro-isolation of the house and walls	Hydro-isolation, through drainage around the house	Water management of the plot	Terrain and vegetation adjustments
Very low risk (85 interviewees total)	8	19	12	5
Low risk (107 interviewees total)	13	24	12	8
High risk (112 interviewees total)	25	38	20	9

shows that the higher the flood risk zone in which a house sits, the more measures the household tends to take. For comparison, Miceli *et al.* (2008) found in Italy that, the higher the flood risk perception, the higher the number of household measures taken to reduce flood risk. The factors creating the difference could be cultural or could be local, but none of the studies explored in depth with interviewees the reasons why flood risk perception did or did not influence flood risk reduction measures adopted. A table equivalent to Table 7 for internal measures is not entirely meaningful, since the main internal measures considered could be implemented and then easily reversed or changed multiple times suggesting that the number of households adopting a measure cannot be given accurately. That contrasts with the main external measures listed that are easy to observe as existing and that are not easily altered.

Despite the data in Table 7, and the increases over time in flood risk reduction measures taken in the Becva River Basin (Tables 5 and 6), it is hard to claim that flooding inevitably influenced household choices. Subject to the provisos mentioned above, the number of households adopting measures increases as a continuing trend over time, not simply immediately after floods. As well, some respondents mentioned that they implemented other measures; for example, applying plaster and other finishes that are water resistant; not applying any plaster or other finishes because frequent floods rendered it useless; building a private wall to keep flood water away from the property; and installing a pump and a mobile boiler.

Multi-scalar contexts – such as national culture, local affordability, and regulations and media at each governance level – influence flood risk reduction decision-making in all locations, with a cross-case study set of factors or contextual aspects rarely being identifiable (e.g. Parker *et al.*, 2008, 2009; Kuhlicke *et al.*, 2011). Factors that could be explored further include how a neighbour's or relative's measures taken influence a household's choice and how many measures, ostensibly for flood risk reduction, were undertaken as part of wider maintenance or renovation work. A cultural studies perspective, such as through focus groups or unstructured interviews, could glean insights into reasons underlying the observations of specific trends, but authors such as Parker *et al.* (2008, 2009) warn against trying to impose the transferability of conclusions from one context to another.

Regression

This section uses a probit model as a regression technique through the statistical software STATA, Data Analysis and Statistical Software, StataCorp LP, USA, Texas, to investigate the link among various factors and the probability of household flood risk reduction measures being applied. The equation used is:

$$y_i = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 \xi_i$$

The variables are:

y_i equals 1 if a household has undertaken any flood risk reduction measure and 0 otherwise.

X_1 is a vector measuring the level and intensity of the household's exposure to floods, such as the total number of the floods experienced and the total financial losses from the floods.

X_2 is a vector of dummy variables describing characteristics and the location of the house, such as having a cellar or an elevated ground floor.

X_3 is a vector describing household characteristics, such as gender distribution, education, income, occupation, and family status.

X_4 is a vector measuring individual perception of the household's flood risk and the flood risk reduction measures adopted by the local government.

ξ_i is a stochastic error term that is assumed to be distributed normally, $\xi_i \sim N(0,\delta^2)$.

We model the decision tree for regression as YES/NO for taking any flood risk reduction measure. If the decision is YES, then we distinguish between interior and exterior measures (Table 3). Table 8 shows the selection (probit) equation for the risk reduction measures.

Among the household characteristics, the most significant correlations were found for gender, number of children, and number of people in a household. Having more children or more males in the household tended to lead to more flood risk reduction measures being adopted. The presence of one more man increased the number of measures by nearly 25%. A vast literature analyses socio-economic and demographic characteristics in relation to flood risk reduction behaviour (e.g. Table 1), with some results matching our findings here. Yet Thompson and Rayner (1998) and Jaeger *et al.* (1993) among others found weak or limited relations between socio-demographic characteristics and risk reduction measures for weather-related events. The differences are likely to be contextual to each case study, in that factors not present in the Czech Republic dominate socio-demographic characteristics elsewhere. Such factors could be floods experienced at the national scale (e.g. the UK), a culture keen to avoid flood damage (e.g. the Netherlands), or comparatively strong government-mandated programmes for disaster risk reduction (e.g. Switzerland).

Owning an elevated house decreased the adoption of other flood risk reduction measures by 20%. It is likely that households felt that elevation would be sufficient for flood risk reduction, so further measures were not felt to be needed. Yet according to the regression, experience did not influence measures adopted. The small positive correlation between the total number of floods experienced and measures adopted was not statistically significant, which was the

Table 8 Estimate from probit regressions

	Exterior measures				Interior measures			
	Coefficient	Robust standard error	Marginal effect	Standard error	Coefficient	Robust standard error	Marginal effect	Standard error
floor2	–0.606	0.211***	–0.198	0.067***	–0.008	0.258	–0.001	0.049
floor3	–0.299	0.235	–0.098	0.076	0.057	0.317	0.011	0.060
Total floods	0.116	0.132	0.038	0.043	–0.177	0.164	–0.033	0.031
tot_loss	0.020	0.079	0.007	0.026	0.186	0.097*	0.035	0.018*
perc2	0.588	0.187***	0.193	0.059***	0.013	0.251	0.002	0.047
perc3	0.726	0.304**	0.238	0.098**	–0.090	0.368	–0.017	0.069
perc_mun2	0.407	0.306	0.133	0.099	1.185	0.480**	0.223	0.087***
perc_mun3	0.432	0.241*	0.141	0.078*	0.558	0.270**	0.105	0.050**
perc_mun4	0.394	0.265	0.129	0.086	0.865	0.326***	0.163	0.060***
perc_mun5	0.340	0.335	0.111	0.109	0.246	0.379	0.046	0.072
share	–0.004	0.002**	–0.001	0.001**	0.010	0.004***	0.002	0.001***
one_kid	–0.035	0.271	–0.011	0.089	0.011	0.329	0.002	0.062
two_kid	0.302	0.244	0.099	0.079	0.738	0.380*	0.139	0.071**
three_kid	1.398	0.705**	0.458	0.227**				
two_pers	0.498	0.329	0.163	0.106	0.330	0.325	0.062	0.061
three_pers	0.304	0.357	0.100	0.116	0.337	0.360	0.063	0.068
four_pers	0.285	0.367	0.093	0.119	0.041	0.400	0.008	0.075
avg_age	0.005	0.007	0.002	0.002	–0.002	0.008	0.000	0.002
avg_gender	0.759	0.456*	0.249	0.147*	–0.772	0.502	–0.146	0.093
avg_educ	0.003	0.078	0.001	0.026	0.109	0.115	0.021	0.022
avg_income	0.007	0.010	0.002	0.003	0.015	0.012	0.003	0.002
_cons	–2.687	1.051			–0.107	1.090		
Region FE	yes			yes				
N obs	304			304				
log-likelihood	–175.3			–102.3				

***means significance at 1%;
**means significance at 5%;
*means significance at 10%.
floor2, floor3, dummy variables for whether a house contains an elevated ground floor of up to 1 m (floor 2) or higher than 1 m (floor 3). The base category is no elevation.
Total floods, total number of floods that a household has experienced, 1–3.
one_fl, two_fl, dummy variables for one and two floods, respectively.
tot_loss, total financial loss from floods experienced, categorical variable, 1 (less)–5 (more) losses.
perc2, perc3, dummy variables for whether a household perceives that their house is located in zone of medium or high risk, respectively. The base category is perception of being in a very-low-risk area.
perc_mun2 to perc_mun5, set of dummy variables for individual perception of flood risk reduction measures done by the local government, for which perc_mun2 compared with perc_mun5 means that fewer measures are perceived and that worse flood risk is perceived. The base category is perceiving the poorest measures.
share, a continuous variable for the share of total financial losses covered from the family budget.
one_kid, two_kid, three_kid, dummy variables for the number of kids. The base category is no kids.
two_pers, three_pers, four_pers, dummy variable for the number of people in the household. The base category is one person.
avg_age, avg_gender, avg_educ, avg_income, variables measuring average age, gender distribution, education level, and household income. For gender distribution, the baseline is one woman and one man in the household and the base shifts depending on how many men and women are in the household.

same case when checking total flood financial losses. That matches the results in section 4.1 that uptake of flood risk reduction measures increased after a flood, but it was hard to link that increase with the flood experience. One limitation of this analysis is any possible time delay, such as if homeowners take several years after a flood to decide to implement flood risk reduction measures.

Also for financial variables, the more financial resources required for post-flood property rehabilitation or reconstruction, the fewer flood risk reduction measures that were adopted. This result is likely because people have a fixed budget for post-flood reconstruction, such as an insurance pay-out or loans. Basic reinstatement of a liveable house must be completed. Then, if flood risk reduction measures cost more or are assumed to cost more than the money available, the opportunity might not exist for spending on, or for investigating the costs of, further measures. This result is useful to compare with Botzen *et al.*'s (2013) data from the Netherlands. That study found a high level of willingness-to-pay in a country where flood risk reduction is part of the culture. Perhaps homeowners might expect that they would be willing to pay, since they are brought up to believe that, but in reality, they cannot afford the measures or, ultimately, choose not to pay for them.

The need to invest one's own resources into post-flood reconstruction was confirmed by the responses. Even if a household had insurance, it generally contributed to the reconstruction costs, with respondents stating that, on average, they contributed 39%. On the other hand, the responses might have been affected by people not wishing to take responsibility for flood risk reduction, as floods are often considered to be someone else's responsibility.

Perceptions of the flood risk zone in which a household sits influence flood risk reduction measures taken. Households perceiving that they are in low-risk or high-risk flood risk zones, when compared with perceiving to be in a very-low-risk zone, saw the likelihood of taking a measure rise by 19% and 24%, respectively. The literature on Europe presents varying results. For Germany, Grothmann and Reusswig (2006) showed a strong correlation between experience of flood threats and flood risk reduction measures undertaken. The strong correlation indicated the influence of socio-economic characteristics such as age, household income, and house ownership. Conversely for Germany, Kreibich (2011a) found that, even though respondents revealed strong worries about climate change and flood risk, that was weakly connected to motivation to take measures. Instead, Kreibich (2011a) found socio-economic factors being more important for adopting flood risk reduction measures.

Perception might not be the same as reality with regard to flood risk. When we compared the actual flood risk zone in which a house sits with the household's perception of the zone that they inhabit, risk underestimation was prominent for the Becva River Basin (Figure 3). Many more people thought that they lived in a very-low-risk zone than actually

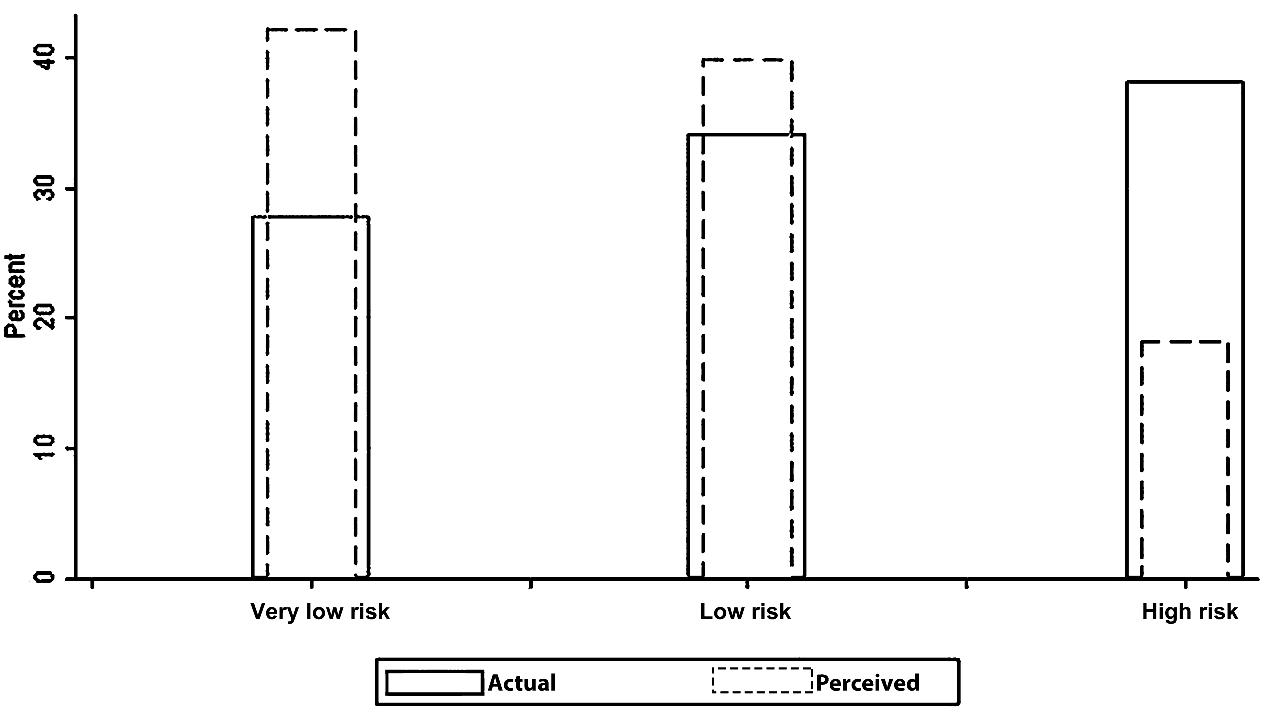

Figure 3 Comparing actual and perceived flood risk zones.

live there, meaning that those in low- and high-risk zones did not perceive their flood risk to be so high. Rather than ignorance of the flood risk, given their past experiences, the most likely explanation is that people are used to living with floods and perceive them to be less serious than risks that manifest less frequently. In fact, one household member commented, 'I do not suffer from floods. I just have my garden and cellar flooded every year'. It is possible that one reason for building cellars was to deal with low levels of floodwater, whereas now, the cost of including a cellar in a new house might be seen as too high. Perception plays an important role in adopting interior measures. The worse the perception is of the municipality's ability to implement flood risk reduction measures, and the worse the perception is of available exterior flood risk reduction measures, the more likely it is for a household to adopt interior measures.

Other studies present more nuanced results. Using four categories of risk zones – very low, low, medium, and high – Siegrist and Gutscher (2006) in Switzerland showed that, overall, respondents' risk perceptions corresponded with the experts' risk assessments. In breaking down the results by language (German or French) and geography (urban or mountain areas), patterns emerged of both overestimates and underestimates of flood risk. That supports the notion that factors correlating with perceived flood risk and flood risk reduction measures can be culturally contextual, with the difference in this case being Swiss French or Swiss German. Consequently, it is important to include as wide a range of variables as possible in any analysis.

Siegrist and Gutscher (2006) further revealed that many respondents did not know that flood risk maps exist for the community, implying that people judge flood risk based on experience and their knowledge of their community rather than on formalised calculations. That could be the same for the Becva River Basin. When referring to the high-, low-, and very-low- (called 'no') risk zones, some respondents might interpret the question qualitatively while others might refer to the formal definitions and to the flood risk maps. Nevertheless, even if the respondent is aware of the formal definition and of the maps, they might disagree with the official definitions or they might still respond from a personal rather than formal perspective.

Conclusions

This paper used the Becva River in the Czech Republic as a case study for household interviews examining which household measures were adopted to deal with river flood risk. The reasons for selecting these measures were also explored. Testing the hypotheses yielded:

H1: Households experiencing more floods and more flood damage tend to implement more flood risk reduction measures.

H1 is not confirmed. Trends over time emerged, but those trends could not be attributed due to experiencing specific floods or flooding over the long term.

H2: Higher perception of household flood risk leads to increased adoption of household flood risk reduction measures.

H2 is confirmed to a large degree, although further research could explore differences between awareness and perception.

H3: Socio-demographic and economic variables influencing adoption of household flood risk reduction measures are contextual.

H3 is mostly confirmed. The socio-demographic characteristics explored here appear to influence river flood risk reduction measures contextually, although a few financial factors corroborate with some literature from other locations, suggesting similarities across contexts. Context here, though, is focused on Europe with many of the studies finding that context matters.

The testing of these three hypotheses demonstrates the importance of cultural context, making it difficult to fully theorise or generalise how different influencing factors lead to different outcomes regarding specific household measures adopted or not adopted. Nonetheless, the results indicate that such theories should consider focusing more on risk perception than on hazard or disaster experience.

Households seem to be reticent to implement extensive measures, with further investigation required to explain the full reasoning behind the observed reluctance. Financial cost seemed to be a major limitation but that would tend to refer to immediate or short-term financial cost. An awareness campaign for residents, local authorities, and insurers could highlight the large costs incurred in disruption, repairing, and replacement if flood risk reduction measures are not implemented. In particular, residents might not be aware of the duration required for properly drying a property post-flood (including leaving doors and windows open) to avoid mould forming and to permit durable reconstruction, meaning that it is usually not feasible to live in a flooded house for months after the waters subside. Although subsidies for implementing household-level flood risk reduction measures are one possible approach, subsidies would not work for all households and all measures, with moving house illustrating how subsidies do not always work.

Further lessons are revealed by the regression analysis. The household's number of men and number of children, along with flood risk perception, were particularly important for determining measures selected and implemented. Conversely, elevating one's house was prominent in decreasing the likelihood of adopting other measures. These factors need to be explored further to be more certain of why they make such a difference. Such understanding would provide insights into the evaluation of household ability for, interest in, and responsibility for dealing with flood risk.

Another measure is improved communication among experts, municipalities, residents, and the private sector. Municipalities have data available on land use and flood risk zones, as well as the authority to change land use and urban development plans to try to reduce flood risk. If residents had more advice from experts – including from their insurance company – regarding flood risk reduction measures, then they might be willing to adopt them subject to financial constraints, saving themselves and their insurer the hassle of being flooded. Academics can assist by disseminating their knowledge to the public, municipalities, and insurance companies and involving them in research (e.g. Otto-Banaszak *et al.*, 2011).

Further data sets from other locations would assist in scaling up the local understanding achieved in this paper with regional and national perspectives for the Czech Republic. Similar studies in other countries would permit international comparisons to supplement existing literature that examines the role played by culture and cultural differences in household perceptions of flood risk and measures taken (e.g. Jaeger *et al.*, 1993; Thompson and Rayner, 1998; Begum *et al.*, 2007). These studies could then indicate which techniques, such as insurance or technical changes, might be transferable or not transferable to different locations in different contexts. With floods being a common problem across Europe and around the world, and with their characteristics changing rapidly due to climate change and development, continued research and application will be needed for dealing with flood risk at the household level and at larger governance scales (see also Etkin *et al.*, 2012; Haque *et al.*, 2012).

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