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The challenges of longitudinal surveys in the flood risk domain

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ABSTRACT

There has been much research regarding the perceptions, preferences, behaviour, and responses of people exposed to flooding and other natural hazards. Cross-sectional surveys have been the predominant method applied in such research. While cross-sectional data can provide a snapshot of a respondent's behaviour and perceptions, it cannot be assumed that the respondent's perceptions are constant over time. As a result, many important research questions relating to dynamic processes, such as changes in risk perceptions, adaptation behaviour, and resilience cannot be fully addressed by cross-sectional surveys. To overcome these shortcomings, there has been a call for developing longitudinal (or panel) datasets in research on natural hazards, vulnerabilities, and risks. However, experiences with implementing longitudinal surveys in the flood risk domain (FRD), which pose distinct methodological challenges, are largely lacking. The key problems are sample recruitment, attrition rate, and attrition bias. We present a review of the few existing longitudinal surveys in the FRD. In addition, we investigate the potential attrition bias and attrition rates in a panel dataset of flood-affected households in Germany. We find little potential for attrition bias to occur. High attrition rates across longitudinal survey waves are the larger concern. A high attrition rate rapidly depletes the longitudinal sample. To overcome high attrition, longitudinal data should be collected as part of a multisector partnership to allow for sufficient resources to implement sample retention strategies. If flood-specific panels are developed, different sample retention strategies should be applied and evaluated in future research to understand how much-needed longitudinal surveying techniques can be successfully applied to the study of individuals threatened by flooding.

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Attrition bias; longitudinal; flood risk; panel; attrition rate

1. Introduction

Given the continuously high human and economic losses caused by flooding, floods have been considered as the natural hazard with the largest effect on humanity (UNISDR 2011). Moreover, it is expected that flood impacts will increase due to the effects of climate change and socio-economic development (IPCC 2014). Therefore, many strategies have been developed to cope

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with and manage flooding through flood defences, risk prevention, preparedness, or aiding recovery (Hegger et al. 2014). Against this background, there has been a movement towards integrated flood risk management (Bubeck et al. 2016). Integrated flood risk management takes into account that flood defences can fail and addresses this residual risk through land use planning, building codes, risk communication stimulating risk-reducing behaviour, and risk transfer. Integrated flood risk management, thus, requires all relevant stakeholders to contribute to flood risk reduction in accordance with their capabilities. For example, Germany requires flood-prone property owners to take steps to limit flood damage according to their capability (Thieken et al. 2016b). Therefore, a large number of researchers have surveyed flood-prone households, especially in response to large flood events (Thieken et al. 2017). Such surveys have studied, for example, the employment and effectiveness of adaptation measures (Kreibich et al. 2005), risk perceptions (Botzen, Aerts, and van den Bergh 2009), intangible impacts (Hudson et al. 2017), and recovery (Bubeck and Thieken 2018). This demonstrates a wide range of potential research questions within the flood risk domain (FRD) due to the importance of understanding behaviour and effects at an individual level.

Reviews of the literature revealed that the majority of empirical studies employ a cross-sectional survey design (Bubeck, Botzen, and Aerts 2012; Kellens, Terpstra, and De Maeyer 2013). Although, cross-sectional surveys provide crucial insights, they are also limiting, as many research questions involve an important temporal element, such as preparedness behaviour or recovery. Surveys that capture the temporal dimension can answer questions that may otherwise be impossible to answer. For example, risk perceptions and psychological impacts are different in the months immediately after an event than before (Tversky and Kahneman 1973). Also, previous studies indicate that flood experiences strongly influence preparedness behaviour, which in turn considerably reduces flood impacts during subsequent events (Kreibich et al. 2017). Therefore, to better understand the dynamics of human behaviour in relation to flooding, there have been repeated calls for developing longitudinal, or panel, studies (Bubeck and Botzen 2013; Siegrist 2013, 2014). Furthermore, Aerts et al. (2018) called for the integration of human behaviour in flood risk modelling, which will require detailed records of behaviour over time and in response to flood events in order to deliver meaningful modelling results and, consequently, well-informed risk management decisions.

However, while panel datasets offer great research potential, there are potential problems associated with panel datasets within the FRD. Longitudinal studies of individuals threatened with random and unpredictable events are difficult to conduct (Weinstein 1989). The problems and difficulties include additional expense in terms of money and time and a longer time to produce policy-relevant results as compared to cross-sectional surveys (Bubeck and Botzen 2013). Additionally, if a panel study is designed to study responses to a flood, a flood may not occur during the study period. Moreover, the respondent dropout, or attrition, rate is a unique problem in panel datasets (Cheng and Trivedi 2015). Additionally, nonrandom attrition may lead to respondents dropping out of the sample in a systematic manner linked to the specific variables of interest. This may create an endogeneity problem that leads to inaccurate statistical findings, in addition to the smaller sample sizes (Cheng and Trivedi 2015). This problem is known as retention bias. There are many potential reasons for high attrition or low retention due to survey design or context (Lynn 2018), and there is a lack of experience with potential dropout rates and the potential for attrition bias within the FRD.

Therefore, the main research questions of this article are: What is the potential for attrition bias in flood risk panel datasets? What are the potential attrition rates? What are the lessons learnt from these surveys? The answers to these research questions can be used to better understand and develop other panel datasets in the FRD.

To answer these research questions, we undertook two approaches: the first was a literature review (LR) of the academic literature using longitudinal or panel data in the FRD. The LR revealed only seven different examples of longitudinal data being employed, revealing a significant research gap, as certain research questions can only be answered using longitudinal data and not the dominate cross-sectional approach.

The second approach was the construction of a dataset that follows individuals directly affected by the 2013 flood in Germany, mostly affecting the catchments of the rivers Danube and Elbe. This survey was developed to investigate the dynamic responses of the respondents related to their flood experiences over four years. The first wave of the survey was concerned with household flood effects, while the later survey waves were more concerned with psychological outcomes. This survey adds a new data point to the limited literature. Our LR and evaluation of attrition rates and bias provide important insights for developing the longitudinal datasets required by the FRD in the future.

The remainder of the article consists of a description of survey data classifications, a review of panel datasets, our developed dataset, results and discussion, and conclusion.

2. Classification of survey data

There is a range of different surveying methodologies employed within the FRD (see Table 1). These approaches can be split into three classifications: cross-sectional, repeated cross-sectional, and longitudinal/panel. While each survey classification has its niche, each also has associated positive and negative implications.

Cross-sectional surveys are the predominant survey approach, as they are relatively simple to produce, conduct, and tailor, while also being relatively resource friendly. However, this approach fails to capture temporal changes accurately, as respondents must reconstruct their experiences afterwards rather than contemporaneously with them. Therefore, cross-sectional studies do not allow for testing causal relationships or feedback effects (Siegrist 2013). Siegrist (2013) uses a hypothetical example to show how a cross-sectional study might indicate misleading inferences due to such feedback effects. Therefore, excluding the temporal dimension from the FRD research is inappropriate.

The repeated cross-sectional survey approach is similar but repeats the survey several times. While the same questions are asked and respondents are drawn from the same group, the same respondents are not always surveyed (Siegrist 2014). The result of this sampling approach is that each survey wave produces an independent (new respondents) or mixed (new and previous respondents) sample. This allows researchers to detect overall changes in aggregate trends, but not individual trajectories, such as in Kienzler et al. (2015). Furthermore, as the sample composition may change over time, it is possible that aggregate changes could also be driven by a changing survey population potentially creating misleading inferences.

Longitudinal studies differ in that they follow specific respondents over time, recording their individual responses to a consistent set of questions. This survey design allows for assessing changes over time at both the individual and aggregate level. Longitudinal surveys in the FRD consist of two main types. The first type involves panels that collect data from a wide range of individuals regardless of flood experiences. The second type follows specific flood-affected individuals in response to a known event.

The first type of FRD panel can employ commercially provided datasets or those developed by national scientific research bodies, if suitable questions are asked or the datasets can be linked to other datasets. For example, the 'Socio-Economic Panel' (SOEP) surveys in Germany, involving 200,000 respondents (Schupp et al. 2018) or the 'Understanding Society' panel involving 40,000 UK households (Knies 2018) both provide a nationally representative sample regarding a range of topics. These surveys could be connected with external datasets similar to the way a panel dataset conducted by the market research institute Forsa in Germany was (Osberghaus 2017). Generally, these surveys offer financial rewards to the respondents for taking part in the survey (Schoeni et al. 2013).

While these datasets can be useful, they are less well-suited for understanding the impacts of a particular flood. For example, consider the 'Understanding Society' panel. About 1/6 of

Table 1. A summary of applicable survey methods.

	Description	Temporal dimension present	Positive elements	Negative elements	Examples of suitable research topics	Examples of previous studies
Cross-sectional	A cross-sectional survey is a onetime survey of a selected survey population	No	Relatively simple to produce and conduct. Able to be rapidly updated and maintain internal consistency. Large and well developed literature to embed research in. Implications and policy-relevant suggestion can be produced quickly	Fails to capture temporal changes as they occur. Trends could be reconstructed but this tends to introduce measurement errors. Provides a onetime snapshot of the surveyed population which cannot confidently demonstrate causality without experimental techniques	Current risk perceptions Current adaptation preferences Adaptation intentions	Lo (2013) Demuth et al. (2015)
Repeated cross-sectional	Repeats a specific survey on the same sample population at least two times.	Yes (in aggregate)	Survey waves do not have to be connected at the level of individuals and as such are as resource intensive as cross-sectional surveys. Moreover, this eases privacy concerns regarding contact details. Survey waves can be pooled together allowing analysis via cross-sectional techniques. Additional respondents can be easily recruited to compensate for the loss in statistical power	Individual respondents are not followed. Therefore, temporal changes could be driven by changes in the sample. More expensive than cross-sectional surveys in total as multiple waves are conducted. Surveying and questionnaire methodology must be consist across waves for results to be sufficiently comparable	Identifying the impact of flood risk management policies on overall behaviour Overall changes in adaptation or risk perceptions after a flood As applicable to cross-sectional surveys	Kienzler et al. (2015)
Longitudinal or panel	Repeats a specific survey on the same pool of respondents, across at least two survey waves.	Yes (in aggregate and respondent level)	Individual respondents are followed so exact temporal trends are identified. Can establish and identify the presence of feedback loops or to establish causal relationships Reflects both cross-sectional and temporal aspects of the sample population	Most resource intensive survey style as respondents must be recruited, contact details securely stored; sample must be maintained over time. Respondents can lose interest over time if flooding becomes less important in their minds.	Identifying the impact of flood risk management policies on individual behaviour over time Individual trends on recovery from flooding Follow through on adaptation intentions and real behaviour. Changes in perceptions or adaptation after a flood.	See Table 2

(*continued*)

Table 1. Continued.

	Description	Temporal dimension present	Positive elements	Negative elements	Examples of suitable research topics	Examples of previous studies
				Temporal changes could be driven by changes in the sample (attrition bias). After recruitment, the study is restricted to the members of that sample. Results are not independent, therefore specialised techniques must be used	Questions applicable to cross-sectional surveys are also applicable	

households are threatened by flooding (Environment Agency 2009). This implies that 6700 of the responding households are flood-prone. This sample can be used to study risk perceptions or adaptive behaviour in general. However, in the case of responses to a specific flood, only a smaller sub-set of respondents will have been affected. The average level of flood protection in the UK is estimated to be against fluvial floods that are expected to occur every 75 to 230 years (Scussolini et al. 2016). This reduces the sample to an expected 29–89 observations, resulting in an insufficient sample to study responses to a specific flood.

Therefore, in order to study the long-term responses to a particular flood, specifically developed datasets are required. However, as floods are locally confined, the initial sample population is significantly smaller than for more generalised datasets, which makes it more difficult to recruit a panel. For instance, flood-affected individuals can hesitate when answering questions regarding a potentially traumatic event in its aftermath, or researchers may face a very limited potential survey population. While this problem is also applicable to cross-sectional surveys, its implications can be more substantial over several survey waves. An additional problem faced is the tendency of potential respondents to not actively think about (Tversky and Kahneman 1973) or to misunderstand flooding (King 2013) Such misunderstandings create problems in initially recruiting respondents before a flood due to its perceived unimportance. Therefore, datasets in the FRD may have to be developed in the aftermath of a flood event, when threat perceptions are highest. However, this potentially limits the sophistication of the collected data. Larger-scope panels, such as the SOEP, alleviate this pressure by being able to draw respondents from a wider geographical area as compared to the FRD.

3. Review of previously FRD longitudinal studies

To understand the context of current longitudinal datasets within the FRD, we provide a LR of these studies. The review approach was adapted from previous approaches in order to structure a LR (see the online Supporting information for more details). The review employed the following steps:

- The two search engines employed were the Web of Science and Google Scholar;
- The search was conducted over the period between 1 June 2018 and 31 July 2018, with a search taking place every two days;
- A series of keywords were employed to search within the topic field of both search engines (see Appendix 1), for papers published after 1 January 2000;
- The hits were then included in the final review sample if the following conditions were met:
    - The study was focused at the household or individual level;
    - The study was related to flooding;
    - The study included data collected from the same respondents at a minimum of two separate time points;
    - The study was published in an academic journal.

A detailed description of the search process is presented in Appendix 1 (Supporting information). The LR identified seven unique and suitable datasets, an overview of which is provided in Table 2. The dataset is referred to by the name of the author(s) in whose paper it was found. The dataset may have been used in other publications but the inclusion of those studies would not be appropriate as they would not offer unique data points. See, for example, Kaniasty and Norris (2008) and Norris et al. (2005)

The search protocol may appear strict due to its focus on flooding as compared to the wider set of natural hazards; however, this renders the results of the LR more comparable with the

developed dataset (see Section 4). Moreover, studies using national or regional panel data points (e.g. GDP) are excluded as they do not follow individuals over time.

The studies identified are divided into two groups: specially developed FRD panel datasets and those that adapted a pre-existing survey. Ginexi et al. (2000), Osberghaus (2017), Fay-Ramirez, Antrobus, and Piquero (2015), and Calvo et al. (2015) represent pre-existing datasets that were repurposed to investigate specific FRD related research questions. These studies are based on datasets that were not directly focused on flooding, but the researchers were able to re-contact the original respondents or to be connected to external datasets. Lin, Lee, and Lin (2017) represent a government-led and multistakeholder-driven panel dataset developed specifically to study the effects of a large scale flood event, while only Kaniasty and Norris (2008) and Fothergill (2003) represent academic studies that specially developed panel datasets in the FRD from scratch (similar to Section 4). Attrition rates per survey wave vary greatly across the studies, ranging from 6% to 70%. Table 2 also reveals that the majority of studies did not address attrition bias or the success of any sample retention strategy. This is likely due to most datasets being developed in an ad hoc fashion to focus on the FRD. This arguably prevented the development of a sophisticated sample retention strategy.

The LR identified a clear gap in the literature that uses panel data within the FRD at the individual level. This is because the LR identified only a few studies, while Kellens, Terpstra, and De Maeyer (2013), for instance, identified 57 cross-sectional studies on flood risk perceptions and communication alone.

4. A panel dataset in Germany

The LR revealed that experience with flood-specific longitudinal studies is lacking and that attrition rates and biases are hardly addressed. To address this research gap, we examine these aspects using a longitudinal survey of flood-affected households in Germany. This panel sought to follow individuals after a particular flood event to document their experiences, and thus, represents a flood-specific longitudinal survey, which is the most resource intensive and challenging survey type.

4.1. Survey

There are three survey waves of respondents that were directly affected by the flood event of May/June 2013 in Germany. The flood event was very severe in terms of its magnitude and spatial extent (Schröter et al. 2015). There was a monetary loss of between €6 and €8 billion affecting about 600,000 people (Thieken et al. 2016a).

In order to generate a sample, lists of affected streets were compiled, landline numbers were researched, and respondents were called. Only respondents who suffered property damage were interviewed. In each household, the person with the best knowledge about the flood was initially questioned. The surveys were conducted as computer-aided telephone interviews.

The first survey wave was conducted nine months after the flood, the second after 18 months, and the final wave after 45 months. At the end of each survey, the respondents were asked whether they were willing to be contacted again for the next survey wave. Only those who agreed could be contacted again. In total, there were 1652 responses, 710 responses, and 305 responses, respectively. The survey was delayed for nine months after the flood in order to allow time for flood-affected individuals to begin the recovery process and become aware of the flood's total impact.

The first survey wave focused on documenting the financial and physical flood effects and causes as well as the initial recovery from their experiences. The later survey waves focused more strongly on psychological and socio-economic factors. While efforts were made to survey

Table 2. A summary of the literature review and sample socio-economic panels.

Authors	Geographical region	Years	N (wave 1)	Sampling technique	General panel vs. flood-specific	Topic	Number of survey waves after initial survey	Attrition rate overall	(Average) Attrition rate per wave	Attrition bias	Discussion of sample retention within the FRD
Studies identified by the LR											
Osberghaus (2017)	Germany	2012–2014	7480	The data is drawn from the Omninet Panel conducted by Forsa (market research institute) and is on the whole composed of about 10,000 representative German households. The survey is conducted online or via their TV. However, the panel loses sharpness tracking indviduals.	Flood topics included but not primary focus of dataset which was more related to climate change and energy consumption	The respondents are asked a range of questions based on a set of themes which include climate change and weather events, housing, and insurance coverage, among others	1	45%	45%	Not discussed	Follows the same methods as the Onminet Panel overall, but not specially discussed in relation to the FRD.
Fay-Ramirez, Antrobus, and Piquero (2015)	Queensland, Australia	2010–2011	2361	The researchers used data from a pre-existing longitudinal study on social wellbeing. The authors retained contact details from the previous survey wave and contacted a random sample of the previous respondents.	Pre-existing panel survey, which included general questions on natural disasters	To study the individual perceptions of collective efficacy changed after the 2010/2011 floods in Queensland Australia	1	40%	40%	Limited through random sampling of respondents to be contacted	Not strongly discussed. The authors make a statement that less funding was available. The relevant apart of the panel was developed ad hoc.
Kaniasty and Norris (2008)	Mexico	2000–2002	658	The dataset consists of two subsamples drawn from different survey sites. For one site the sample was randomly selected out of the eligible population (due to population size and geographical spread). The second subsample sampled the entire community. The survey data was collected via Face-to-face interviews	Flood-specific survey	The survey had two main research objects. The first was to study the social consequences of the 1999 Mexican floods a, while the second was to study the extent to which the social impacts were influenced by societal context	3	16%	6%	Potential from gender imbalance, but minor	Not strongly discussed other than in relation to attrition bias.

(*continued*)

Table 2. Continued.

Authors	Geographical region	Years	N (wave 1)	Sampling technique	General panel vs. flood-specific	Topic	Number of survey waves after initial survey	Attrition rate overall	(Average) Attrition rate per wave	Attrition bias	Discussion of sample retention within the FRD
				conducted with local interviewers. Survey was split into two sessions. Socio-demographic questions were asked first, and then the physiological interview was conducted the following day.							
Fothergill (2003)	North Dakota, USA	1997–2000	60	The author used two approaches to generate the sample: generation via referral snowballing and responses to an advertisement in a local newspaper. The interviewers were conducted face-to-face in a range convenient of locations.	Flood-specific	The interaction between social stigma and the likelihood of a woman accepting post-flood disaster assistance	1	70%	70%	Not discussed	Not strongly discussed
Ginexi et al. (2000)	Iowa, USA	1992–1993	2401	The survey was conducted by telephone, where each respondent was called up to 7 times in order to establish a connection. The original respondents were randomly selected from eligible population via telephone numbers.	Pre-existing cross-sectional survey related to mental health and service use	The authors which to perform a systematic evaluation of the disaster's subjective impacts	1	27%	27%	Discussed but determined to not present a large implication	Not strongly discussed as the 'panel aspect' was developed ad hoc.
Calvo et al. (2015)	New Orleans, USA	2004–2009	1019	The original sample was constrained to low income parents who were full-time students at two New Orleans community colleges. Moreover, in order to be eligible for the study, participants had to be between the ages of 18	Pre-existing study (Opening Doors study) studying college retention.	To study the wellbeing impacts of flooding and the rate at which wellbeing recovered.	2	50%	30%	Not strongly discussed, only mentioned was that data was not missing at random	Not strongly discussed

(*continued*)

Table 2. Continued.

Authors	Geographical region	Years	N (wave 1)	Sampling technique	General panel vs. flood-specific	Topic	Number of survey waves after initial survey	Attrition rate overall	(Average) Attrition rate per wave	Attrition bias	Discussion of sample retention within the FRD
				and 34; be parents of at least one dependent child under the age of 19; have a household income under 200 % of the federal poverty level; and have a high school diploma or equivalent.							
Lin, Lee, and Lin (2017)	Taiwan	2010–2015	1754	Not described, referenced document is no longer publicly available as of 04.09.2018.	Flood-specific	Social Impact and Recovery from Typhoon Morakot	3	44% (32% between 2010 and 2012)	24%	Not discussed	Sample retentions strategy was not strongly discussed other than attempts to maintain a fixed interview per respondent. This implies that multiple contact details not connected to residence were collected.
Study presented in the current manuscript											
Developed panel dataset	Germany	2013–2017	1652	See Section 4.1.	Flood specific	See Section 4.1	2	85%	60%	Not strongly present (see Table 3)	Within each survey wave respondents were asked to provide suitable contact details for the next survey wave. Multiple attempts at phone calling the respondents.
Examples of panel data studies											
Tillmann et al. (2016)	Switzerland	1999–2015	n_1=7800 n_2=3700 n_3=6100	The survey of Swiss households drew a random sample of private households on the basis of the Swiss telephone directory. The	n.a.	The objectives of the study are to provide a database for social reporting on stability and changes in living arrangements and wellbeing.	n_1=15 n_2=10 n_3=2	n_1=80% n_2=74% n_3=27%	12%	Not discussed	n.a

(*continued*)

Table 2. Continued.

Authors	Geographical region	Years	N (wave 1)	Sampling technique	General panel vs. flood-specific	Topic	Number of survey waves after initial survey	Attrition rate overall	(Average) Attrition rate per wave	Attrition bias	Discussion of sample retention within the FRD
				survey was conducted via telephone.		Additionally, the survey wishes to promote social science research					
de Vos (2009)	Netherlands	2007–2017	7000	The survey is conducted via online questionnaires every month. Each survey is expected to take about 15 to 30 minutes, after which respondents are paid. The panel is based on a probability sample of households drawn from the population register by Statistics Netherlands. Households that could not otherwise participate are provided with a computer and Internet connection.	n.a.	The central survey seeks to measure change in people's lives, their reaction to life events and the effects of societal changes and policy measures	9		12%	Not discussed	n.a
Xie et al. (2017)	China	2010–2014	33,600	The survey employs Probability-Proportional-to-Size Sampling (PPS) with implicit stratification to draw a representative sample of China. Moreover, the surveys work closely with local officials. Face-to-face interview, telephone if not interviewer was available.	n.a.	The study focuses on both the economic and noneconomic wellbeing of the Chinese people residents	2	21%	12%	Not discussed	n.a
Jenkins and van Kerm (2017)	23 European countries	2008–2011	8900	The survey approach differed per country but was standardised following the approach required survey.	n.a.	The European Union Statistics on Income and Living Conditions aims to collect timely and comparable longitudinal	3	35%	13%	Not discussed	n.a

(*continued*)

Table 2. Continued.

Authors	Geographical region	Years	N (wave 1)	Sampling technique	General panel vs. flood-specific	Topic	Number of survey waves after initial survey	Attrition rate overall	(Average) Attrition rate per wave	Attrition bias	Discussion of sample retention within the FRD
						multidimensional data on income, poverty, social exclusion and living conditions					
Behr, Bellgardt, and Rendtel (2005)	11 European countries	1994–1998	9400	The survey approach differed per country but was standardised following the approach required for the European Community Household Panel survey (i.e. SOEP in Germany).	n.a.	These interviews cover a wide range of topics concerning living conditions. They include detailed income information, financial situation in a wider sense, working life, housing situation, social relations, health and biographical information of the interviewed.	4	20%	5%	Not discussed	n.a
Wilkins (2017)	Australia	2001–2015	14,000	The reference population for the HILDA Survey was all members of private dwellings in Australia following broadly the rules adopted by the Australian Bureau of Statistics. Households were selected using a multistaged approach to ensure representativeness. The surveys were mainly conducted via face-to-face interviews, however, a small amount were conducted via telephone.	n.a.	Household, Income and Labour Dynamics	14	46%	4%	Not discussed	n.a

the same respondents from a household, if this was not possible another member of the household could also answer. However, as a switch in respondents poses problems when analysing psychological factors, the panel presented in this article only comprises respondents who could be identified as moving through the waves. Respondent congruence over time was determined by comparing the respondent's sex as well as a plausible change in age between survey waves. As a consequence, 175 cases were removed from the initial sample.

4.2. Investigation into attrition bias

Attrition bias occurs when respondents do not drop out of the survey at random, but rather there are independent variables related to this process. In itself this is not so problematic, if the variables linked to the attrition of respondents are not connected with the dependent variable, or variable of interest. Therefore, in order to judge if attrition bias is present, we collected the variables that are deemed important within the FRD to stratify the respondents, as the variables that alter attrition probabilities are context-dependent (Watson and Wooden 2009). SI.2 in the online Supporting Information describes the variable selection process for Table 3.

Table 3 presents the regressions used to establish relations regarding the likelihood of attrition. A sample without the potential for attrition bias would find these variables to be insignificant or unimportant. Model 1 in Table 3 presents a logit model of the probability of a respondent moving from Waves 1 to 2, while Model 2 investigates the probability of a respondent being present in all three survey waves. Under both models, independent variables are set to their values in Wave 1.

Table 3. Logit regression model of the probability of a respondent moving to the next survey wave.

	Model 1		Model 2	
	Coefficients	Marginal effects	Coefficients	Marginal effects
Bavaria vs. Saxony-Anhalt	0.12	0.117	0.071	0.0707
	(0.23)	(0.234)	(0.298)	(0.298)
Saxony vs. Saxony-Anhalt	−0.24	−0.242	−0.25	−0.246
	(0.19)	(0.190)	(0.25)	(0.252)
Thuringia vs. Saxony-Anhalt	0.047	0.0465	−0.097	−0.0967
	(0.24)	(0.236)	(0.32)	(0.319)
Other Länder vs. Saxony-Anhalt	−0.12	−0.115	−0.0063	−0.00630
	(0.35)	(0.353)	(0.47)	(0.468)
Female	0.1	0.0997	0.33*	0.326*
	(0.15)	(0.145)	(0.19)	(0.194)
Knew of flood risk potential	0.21	0.206	0.37	0.366
	(0.25)	(0.249)	(0.33)	(0.332)
Age	0.12***	0.122***	0.26***	0.257***
	(0.047)	(0.0468)	(0.087)	(0.0865)
Age squared	−0.00089**	−0.000892**	−0.002***	−0.00202***
	(0.00041)	(0.000408)	(0.00072)	(0.000716)
Household size	−0.073	−0.0725	−0.11	−0.105
	(0.077)	(0.0767)	(0.093)	(0.0934)
Dependency ratio	−0.091	−0.0908	−0.087	−0.0867
	(0.25)	(0.247)	(0.33)	(0.331)
Suffered high damage	0.28*	0.280*	0.34*	0.340*
	(0.15)	(0.149)	(0.19)	(0.192)
Experienced flooding before 2013	0.17	0.170	0.16	0.155
	(0.24)	(0.240)	(0.33)	(0.332)
Constant	−4.5***	−4.536***	−9.6***	−9.614***
	(1.4)	(1.422)	(2.7)	(2.690)
Observations	856	856	856	856

Notes: Robust standard errors in parentheses, paramater estimates outside.
***$p < .01$,
**$p < .05$,
*$p < 0.1$.

Table 3 shows that only three variables have a significant correlation with attrition probabilities: *age*, *age squared*, and *suffered high damage*. The age variables indicate a nonlinear relationship, whereby as age increases there is a tendency for participation to increase, although at a decreasing rate. On the other hand, suffering worse flood damage reduced the likelihood of attrition. There was only a small potential for attrition bias in the developed panel overall. Attrition bias can occur through the variables *age* and *damage suffered*, but their effect depends on their overall importance for a given research question. In essence, if either age or flood damage suffered is expected to have a large effect regarding a given research question, then the tendency of the sample to focus on these individuals could be problematic.

4.3. Investigation into retention bias

A high attrition rate leads to retention bias when the number of observations becomes too small to be meaningful. The attrition rate is defined as the fall in observations between survey waves due to respondents not responding in later survey campaigns. There was an attrition rate of about 60% for both Waves 2 and 3 (Table 4). This rapid decrease in respondents is problematic, as a 60% attrition rate limits the number of survey waves. For example, a fourth wave is likely to be unviable, as the expected number of respondents would be 90–120 respondents before accounting for incomplete responses. A larger initial sample may alleviate rather than eliminate this problem.

Our attrition rate can be connected to either the survey methodology or the questions asked. This is because we specifically follow known victims of the 2013 flood in Germany. The attrition rate can also imply a lower willingness to take part in a survey studying this event as its importance and memory fades. Additionally, it has been noted that survey response rates, in general, have been declining, leading to higher panel attrition rates (Couper 2012). This can be seen from our survey, which had a low initial response rate, high willingness to be contacted for the next survey wave but low willingness to take part in that survey wave (see Table 4). Understanding of the reason behind this trend is limited, as cost and effort data are often not consistently available (Couper 2012). However, part of the low initial response rate could be due to the strict inclusion criteria. There was a total noneligibility rate amounting to 63%, as many households stated that they had not been financially affected by the 2013 flood whose impact we sought to study. Nonflood-specific panels can limit the low response rate problem due to the larger geographical area from which they can draw respondents as compared to flood-specific panels.

Table 4. Panel response rates in the raw sample (Panel A) and the responses adjusted for incongruence of respondents (Panel B), and data subsets used in the qualitative and quantitative analysis of factors correlated with a respondent leaving the sample (Panel C).

	Panel A: raw sample			Panel B: adjusted	
	Number of observations	Percentage who agreed to be contacted again	Attrition rate	Number of observations	Attrition rate
Survey Wave 1	1 652	80%		1477	
Survey Wave 2	710	92%	57%	535	64%
Survey Wave 3	305	91%	58%	227	58%
Panel C: sample subset					
	Dependent variable		*Data values*	*Logit model output*	
Model 1	Binary variable taking the value of 1 if the respondent moved from the Waves 1 to 2, and 0 otherwise		Initial values in Wave 1	Probability of moving from Waves 1 to 2	
Model 2	Binary variable taking the value of 1 if the respondent was present in all three Waves, and 0 otherwise		Initial values in Wave 1	Probability of a respondent in Wave 1 being present in Waves 2 and 3.	

5. Results and discussion

5.1. Attrition bias

Overall, attrition bias was limited in the studies identified in the LR, as those which discussed attrition bias did not present robust evidence in favour of attrition bias. Therefore, it is unlikely that the identified studies were negatively affected by attrition bias. Our result helps to strengthen the conclusion that attrition bias is not likely to be present in FRD panel datasets that seek to follow respondents after a known flood event. However, the analysis of attrition bias should be better documented in future FRD panels.

5.2. Retention bias

5.2.1. Experiences from the FRD

The survey in Section 4 displayed an average per wave attrition rate of 60%. The mean attrition rate of the studies in Table 2 was 38%, with a standard deviation of 21%. This rate includes the study by Kaniasty and Norris (2008), which may be an outlying result. Excluding their study increases the mean attrition rate to 42% with a standard deviation of 17%. Section 4's attrition rate of 60% lies within about one standard deviation of the mean of the LR studies, indicating a high (but not excessively so) attrition rate. The fact that our survey shows such a high attrition rate can be linked to the challenges associated with developing a flood-specific panel, compared with using a pre-existing panel. Fothergill (2003) reports an even higher attrition rate of 70%. More research in a larger number of cases is needed to understand the reasons for this high attrition rate. In addition, there is a need to develop and evaluate mechanisms or strategies that limit sample attrition so that reliable and cost-effective retention strategies can be employed in future panel datasets.

There are also different patterns across the identified datasets. The studies using pre-existing datasets display an average per survey attrition rate of 36% per survey wave. On the other hand, specially developed surveys display an average per survey attrition rate of 40% per survey wave. Excluding Kaniasty and Norris (2008) increases the attrition rate to about 50%. While it is difficult to generalise from only a few studies, it appears that the datasets generated by using pre-existing surveys had a lower average attrition rate. However, overall flood-specific panel datasets face difficulties in both recruiting and maintaining a sample regardless of panel design.

Furthermore, the average attrition rate within the FRD may be higher than in other study areas. Consider the following SOEP datasets included in Table 2. Tillmann et al. (2016) present the Swiss Household Panel Study, with an average attrition rate of 12% per survey wave. de Vos (2009) presents a 12% attrition rate for the Longitudinal Internet Studies for the Social sciences. Xie et al. (2017) present the China Family Panel Studies, which has an average attrition rate of 12%. Jenkins and van Kerm (2017) report attrition rates from the EU-SILC panel, produced by aggregating information from 23 European countries. The median attrition rate per survey wave between 2008 and 2011 was 13% (with a range of 3–23%). Behr, Bellgardt, and Rendtel (2005) report attrition rates from eleven European countries for the European Community Household Panel between 1994 and 1998. The average per survey wave attrition rate was 5%. Finally, the Household, Income and Labour Dynamics in Australia Survey is identified as having an average per wave attrition rate (for the original sample) of about 4% (Wilkins 2017). The average per wave attrition rate across these studies is 11%, about one-third the average rate in the FRD. The comparison of the studies from the FRD and the socio-economic studies further highlights the difficultly of maintaining FRD panel datasets from a primarily academic starting point. The panels with lower retention rates have financed specific retention strategies and incentives, which the more ad hoc FRD panel datasets have not been able to focus upon. Moreover, as noted in Section 2, these supported panels also have a wider population from which to draw

respondents, easing sample recruitment concerns in addition be being potentially better resourced than panels developed purely within the academic sphere.

5.2.2. Experiences from the medical literature

Since there is a limited amount of literature to draw from within in the FRD, lessons can also be drawn from outside the FRD. For this purpose, we draw upon the medical literature, as this field employs a large number of panel data studies in order to study such topics as illness progression and the success of medical interventions. In this context, there have been many studies investigating the success of various sample retention mechanisms. Abshire et al. (2017) interviewed researchers whose teams were able to achieve a high retention rate to identify the best practices regarding sample retention. Abshire et al. (2017) find that these studies often employed a specialised respondent retention team. A dedicated team allowed for respondent-tailored retention strategies, which is also recommended by Lynn (2018). Additionally, in the studies investigated by Abshire et al., detailed contact details for the participant and at least one additional contact person were kept. Within the FRD, the inability to re-contract respondents was noted as a problem for the panel presented in Lin, Lee, and Lin (2017). This Taiwanese study found that 69% of households had moved at least once which greatly increased surveying costs. Additionally, this level of effort may only be possible for panels that have sufficient levels of governmental or multisector support to cover this expense, as was the case for the SOEP.

Moreover, participants in the medical studies were actively engaged with in ways that were not only related to the study, for example celebrating public holiday. However, regular contact such as this may be more successful in the medical context than with regard to the FRD because the individuals in a medical study are more active beneficiaries of the research conducted. This tangible benefit may not be as clear in the case of a respondent's flood-related experiences, unless these benefits are clearly explained. Explaining the benefits must also be treated with care to avoid priming respondents towards certain responses through increased wishful thinking or other behaviour. Therefore, the survey may best be orchestrated in concert with wider flood risk education campaigns in order to increase the overall willingness to take part. However, the effectiveness of this strategy should also have its success evaluated as part of the panel's design and research focus.

An additional concern that occurs in the medial literature, as noted by Compadre et al. (2018), is that different groups in society pose different challenges when attempting to recruit and maintain respondents. For instance, a cancer research project found that many African–American participants had conflicting views about genetics research (McDonald et al. 2012). McDonald et al. (2012) found that African–American participants considered the potential benefit to themselves and their wider community as positive participation outcomes while harbouring concerns about exploitation and the researchers' motivations. These problems should be considered as part of the study design, although this may be difficult to assess if the reasons for nonparticipation are not recorded. Therefore, these reasons should be elicited and recorded to address them explicitly during recruitment. In relation to the FRD, these reasons could be the belief that nothing can be done to limit flooding or that it is somebody else's responsibility. Recording the reasons given for nonresponse can highlight if there are potential communities that are particularly difficult to engage with and why. These insights can be used to further design inclusive flood risk management policies. Moreover, this knowledge can identify which designs tailored survey features for a target group, allowing researchers to optimise sample recruitment and retention (Lynn 2018). Optimising sample recruitment and retention are important in the FRD, given the potentially limited population from which FRD panels can recruit respondents.

Finally, previous studies have found a positive correlation between size of a financial incentive offer for study participation and the incentive's success (Abshire et al. 2017). Respondents also

positively respond to nonfinancial strategies, such as facilitating data collection and emphasizing other potential benefits of participating in the study (Abshire et al. 2017). However, it is not clear which retention strategies are the most effective. Moreover, Abshire et al. (2017) note that most of the high retention studies identified were funded with large governmental grants that were able to finance a specific retention team and generous retention incentives. This is similar to the case with the study by Lin, Lee, and Lin (2017) included in the LR. In addition, certain retention strategies are likely to have culturally specific considerations (Sankaré et al. 2015; Spruill 2010). The questions of appropriate methods for and frequency of contact attempts is an important area for further exploration and may uncover variations in acceptability depending on the population. Likewise, the ethics of financial incentives have been widely discussed and remain an important ethical consideration – whether it is suitable to 'commercialise' responses to sensitive topics. Research practices and policies must ensure cultural sensitivity and the protection of subjects while facilitating longitudinal research (Abshire et al. 2017).

5.3. Implications for future research in the FRD

One of the main implications of this article's results for the FRD is the need for the further development and refinement of panel datasets within the FRD. This is clear because the LR identified fewer than ten such datasets, indicating a possible overreliance on cross-sectional studies that can produce misleading results regarding changes in perceptions and motivations of flood-affected residents.

In order to be able to design panel datasets, further experience within the FRD is required to understand the possibly unique context of the FRD. The LR indicates that the attrition rate of FRD panel datasets is potentially much higher (about three times higher) than in other areas of research. A possible reason for this may be that larger socio-economic panels have much larger budgets to dedicate towards sample retention (as identified in Subsection 5.2.2) Therefore, there should be an on-going focus on understanding sample attrition and effective retention mechanisms in the FRD. Improving the overall understanding of sample retention requires sufficient documentation of attrition rates, retention strategies, and sample design criteria. Our LR shows that this currently not the case. Improved record keeping in this area would allow different experiences to be compared in order to identify the best practice for the FRD in particular. For example, a study with a high attrition rate because fewer resources are available in later survey waves generates different lessons than a study surveying an area with high rates of post-flood migration.

Moreover, there should be a strong focus on developing retention mechanisms and designing them in such a way that they can be robustly evaluated. Therefore, future FRD panel studies should have a clear and well-developed sample recruitment and retention strategy from the start of the project. A comprehensive well-designed strategy for recruiting respondents is required to generate a sufficient initial sample given the potential difficulty in establishing a set of respondents and the declining willingness to take part in surveys (Couper 2012). For this reason, it is important that future studies attempt to build and maintain trust between the initial survey participants and researchers. Individualized or participant-centred communication or retention strategies could help to overcome high attrition rates (Kaye et al. 2012). Examples of such activities could be direct community involvement, context and culturally sensitive research methodologies, and regular and continuing communication with respondents. None of these strategies were consistently reported across the studies in Table 2. There is also a need for also recording the reasons for the initial sample recruitment or failure to take part in the survey.

These co-creative and collaborative approaches are important due to the low level of willingness to take part in a longitudinal study. For instance, the comments provided by participants in the cross-sectional study of Poussin, Botzen, and Aerts (2013) highlight concerns that the

researchers would use this data to allow insurance companies to increase their premiums or questioning of the ethical basis of the survey, similar to the study by McDonald et al. (2012).

Additionally, if datasets are developed to follow the responses to a particular flood event, it is unrealistic to expect continued participation as the memory of the flood event fades, in line with availability heuristics. These features further indicate the challenges of developing an initial sample to act as the base of the panel before accounting for the willingness of those contacted to take part in the survey. This is in addition to the high average attrition rates generating a further lifespan limit on the dataset. Therefore, in addition to collaborative or participatory research approaches there are additional steps that could limit retention bias in a longitudinal study. One method could be to include only respondents that agree from the beginning to take part in a multiwave survey of a known length. An additional mechanism to reduce the attrition rate could be face-to-face interviews. Face-to-face interviews offer the greatest chance for producing the highest participation rates, although at the highest surveying cost (Lynn 2018). Finally, the rationale for nonparticipation should be recorded, which will enable the research team to develop suitable mechanisms or strategies to reduce the likelihood of nonparticipation in their particular context.

The final implication of this article's results relates to the observation that the ideal panel dataset would contain observations from before and after a flood event. This would allow the flood to act as an 'exogenous' event and allow researchers to identify changes in behaviour as well as temporal impacts. However, such datasets may not be feasible as academic projects given the relatively short timeframes research projects operate under compared to the frequency of flooding. Therefore, projects aiming to develop such a comprehensive study may face additional funding hurdles as there is a chance that no tangible results could be produced during the project's lifetime. For example, panel datasets seeking to follow trajectories after a flood cannot predict and mobilise resources in a sufficient timespan to include pre-flood and post-flood sections. Similarly, panel datasets that survey flood-prone areas provide a pre-flood sample, but the sample may not be flooded at all, or may not be sufficiently flooded to study post-flood changes or the consequences of a specific flood.

A possible solution would be to conduct the survey in concert with a larger multisector partnership of organisations and researchers. A governmentally supported multisector organisation could be able act in the wake of a flood event to locate those who need assistance and provide the required relief such that trust and positive associations with the organisation can be developed. Longitudinal data collection can then be initiated as part of this effort (similar to Lin et al.). However, such an approach should account for potential ethical concerns or ways in which the participating respondents may produce a biased sample. Such a survey framework could allow for sufficient resources to be provided for a large initial sample in addition to resources being available to generate an effective sample retention team. A governmental base for funding may be more sustainable than an academic funding basis because the governmental funding cycle runs across the entire financial year while academic funding cycles are narrower, and results may not be able to be produced in a reasonable timeframe. The current temporal horizons are not suitable for funding the construction of panel datasets that follow flood-affected individuals over time. These datasets must currently be constructed on an ad hoc basis in order to maximise willingness to take part and sample size. While it is possible to construct longitudinal datasets through academic sources, there are associated limitations. For example, Osberghaus (2017) employed a panel designed to study climate change and energy-related topics rather than flooding per se. Therefore, they surveyed topics which can be funded in advance (e.g. pre-existing risk perceptions) and could be better integrated into pre-existing panel datasets (such as SOEP), while other topics only become viable after following respondents in the aftermath of a flood (e.g. length and trajectory of intangible flood impacts) which requires a collaborative effort for such a sample to be developed in a limited time window.

6. Conclusion

There is great interest in developing strategies under the umbrella of integrated flood risk management to cope with growing flood risk. However, cross-sectional survey data is over-relied upon to guide integrated flood risk management. Cross-sectional surveys are useful, but they are unable to fully capture the important dynamic relationships found in the FRD. Studying these dynamics requires panel datasets.

Due to the difficulties in establishing panel datasets for studying behavioural responses to unpredictable events, there are few current examples of panel datasets. We present one such panel dataset that follows those affected by the 2013 flood in Germany over four years. The survey captures the respondents' flood impacts and how they respond to and recover from their experiences. Studying these dynamics requires a fairly stable sample of respondents. This is because if certain types of respondents are more likely than others to drop out of the survey, this can lead to the presence of attrition bias or retention bias if large numbers of respondents leave the sample.

We studied the potential for attrition and retention bias to occur within our panel dataset and the wider context of the limited FRD panel datasets. Overall, retention bias is problematic, as the developed panel had an average attrition rate of 60% per survey wave, while the mean attrition rate per wave identified by the LR was about 40%. This average attrition rate in the FRD is about three times larger than other commonly used SOEP datasets, which can be linked to the specific challenge associated with developing flood-specific datasets or how their ad hoc nature prevents the development of a suitably designed and resourced sample retention strategy. This high attrition rate could also stem from the need for such surveys to follow flood-affected individuals over time, which means as memory of the flood fades so does the willingness to take part in the survey. As for attrition bias, both the LR and our sample tended to display only a minor potential for attrition bias to occur. Therefore, future FRD panel datasets must overcome the potentially high attrition rates.

In order to overcome this attrition problem, we recommend that, for the design of panel datasets that seek to follow flood-affected individuals over time, longitudinal data should be collected as part of a multisector partnership which acts in concert with the flood risk management authority and in cooperation with the local community. Moreover, such a partnership should focus on providing and promoting the nonmonetary incentives and benefits that participants can receive from participation in order to ease ethical concerns regarding the surveying of potentially traumatic events. Finally, in addition to better documentation and evaluation of all the different approaches undertaken to develop panel datasets, the reasons for nonparticipation should be recorded to help understand how surveying techniques should be adapted to be more inclusive.

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