Public and Expert Perceptions of Sea-level Change on the Severn Estuary

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This thesis is submitted to Cardiff University in partial fulfilment of the requirements for the degree of Doctor of Philosophy

October 2013

DECLARATION

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ACKNOWLEDGEMENTS

I would like to thank my supervisors, Nick, Lorraine and Rhoda for allowing me this opportunity and for their support throughout my PhD. I would also like to thank Cardiff University for funding the research through a President's Scholarship.

A huge thank you goes to all of the expert and public participants who generously gave their time to be part of this research. This thesis would not have been possible without such willing and insightful input.

I am very grateful to members of the Understanding Risk Group for their help and advice on everything from coding to computer melt downs, especially Christina Demski for her unending patience! Thanks also to Kate Walker-Springett for sharing her GIS expertise with me, Robert Sposato for his statistical insights, and Chris for being a voice of reason and source of much merriment throughout my final year.

The biggest thank you goes to Mum, Dad and James for 30 years of supporting a needy child and sister. Thanks Mum for inspiring me to study geography, and Dad for inspiring me to study psychology! Now I promise to get a proper job.

SUMMARY

As coastal communities become increasingly exposed to the risks posed by sea-level change, understanding their beliefs and responses becomes more important. While studies have identified differences in lay and expert understandings of climate change, little research has investigated how these groups understand sea-level change. This thesis uses a mental models approach to explore and compare expert and public perceptions of sea-level change on the Severn Estuary, a threatened coastal environment in the southwest of the United Kingdom.

A three-phase methodology is adopted. First, expert perceptions are investigated through semi-structured interviews, probability elicitations and cognitive mapping with experts in the field of sea-level change on the Severn Estuary (N=11). Second, public perceptions are investigated through mental models interviews that include a semi-structured discussion, a picture sorting task, and a cognitive mapping session (N=20). Third, perceptions raised during public interviews are explored by way of a wider survey of members of the public living around the Severn Estuary (N=359). These perceptions are then compared and contrasted. A grounded approach is utilised to explore themes emerging from expert and public qualitative interviews, while regression analyses explore the relationships between themes explored in the quantitative public survey.

Results show areas of public understanding consistent with expert understandings: most public respondents think that sea levels will rise, leading to increased flooding and property damage. However, the Severn Estuary public does not feel well informed about sea-level change, and there are a number of key differences between expert and public perceptions. For example, there is low public salience of some of the key drivers of sea-level change and its indirect impacts. Perceptions are influenced by many factors including information sources, the ways in which individuals think about the future, and the biases that they hold. Many findings are consistent with climate change research more generally. For example, respondents tend to express low concern about sea-level change in relation to other matters such as the economy; they feel detached from the issue, seeing it as something that will happen in the future to other people; and they perceive that neither the causes of nor responses to sea-level change are their responsibility.

From an applied perspective, the study fills a research gap in how the Severn Estuary public perceives sea-level change in their region, and provides insights into how it might best be communicated. From a methodological perspective, the study illustrates the utility of using mixed methods, interdisciplinary approaches for investigating public and expert perceptions of specific climate change risks.

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LIST OF ABBREVIATIONS

3CM	Conceptual content cognitive map
AC	*Ante Christum*, Latin for 'before Christ' (years)
ACC	Anthropogenic climate change
AR4	IPCC 4th Assessment Report (IPCC, 2007)
AR5	IPCC 5th Assessment Report (IPCC, 2013)
BP	Before present (years)
CBA	Cost benefit analysis
CDF	Cumulative distribution function
CLT	Construal Level Theory
CO_2	Carbon dioxide
EPP	Expert perceptions phase
IPCC	Intergovernmental Panel on Climate Change
M	Mean
m	Metres
Mdn	Median
NAO	North Atlantic Oscillation
PDF	Probability density function
PPP1	Public perceptions phase one
PPP2	Public perceptions phase two
RCP	Representative Concentration Pathway
SD	Standard deviation
SLC	Sea-level change
SLR	Sea-level rise
SPSS	Statistical Package for the Social Sciences
SRES	Special Report on Emissions Scenarios (IPCC, 2000)
STS	Science and Technology Studies

1 INTRODUCTION

'Appropriate and timely risk communication is critical for effective adaptation and disaster risk management' (IPCC, 2012, p. 15),

It has been known since the 19th Century that heat-absorbing gases in the atmosphere can influence the Earth's temperature (Arrhenius, 1896), and there is now overwhelming expert consensus that the world is warming because of the gases that humans emit (Anderegg, Prall, Harold, & Schneider, 2010; Cook et al., 2013; IPCC, 2013). This warming causes water in the oceans to expand and land-based ice to melt into it, leading to a rise in global mean sea level. In coastal regions sea-level rise (SLR) increases risks such as erosion, flooding and salt-water contamination. Ten percent of the world's population live in such regions[1] (McGranahan et al., 2007), and the number of people exposed to the risks associated with SLR is expected to grow (Nicholls et al., 2008). The impacts are expected to be significant; the 21st century alone may see the forced displacement of up to 187 million people (Nicholls et al., 2011b). One coastal region at risk is the Severn Estuary, in the southwest of the UK. With one of the largest tidal ranges in the world and habitats of great ecological significance (Severn Estuary Coastal Group and ATKINS, 2010d), this unique environment is the focus of this study. Many of the Estuary's[2] features are reminiscent of other low-lying vulnerable settings, thus the findings of this study may also be applicable to other regions.

As threatened communities such as those around the Severn become increasingly exposed to the risks posed by sea-level change (SLC), understanding their beliefs and responses will become ever more important in order to develop more constructive forms of communication. Knowledge of SLC and its related facets is important, for example in reducing deaths from its immediate impacts such as flooding (Jonkman & Kelman, 2005)[3], facilitating informed adaptation responses, and in encouraging engagement with its major cause, climate change (Lorenzoni, Nicholson-Cole, & Whitmarsh, 2007). Research shows that experts and lay publics often diverge in their conception and assessment of risks (Cox, Pidgeon, Lake, & Poortinga, 2005; Morgan, Fischhoff, Bostrom, & Atman, 2002), but while studies have identified differences in lay and expert understandings of climate change (e.g. Bostrom, Morgan, Fischhoff, & Read, 1994; Reynolds, Bostrom, Read, & Morgan, 2010), little research has investigated how these groups understand SLR. This thesis aims

[1] Coastal regions are in this case defined as areas beside the sea within ten metres elevation of sea level (McGranahan, Balk, & Anderson, 2007).
[2] 'The Estuary' refers to the Severn Estuary, and is used throughout the thesis for brevity.
[3] Whilst flood-related deaths have occurred on the Estuary (Bryant & Haslett, 2007), deaths from flooding are rare in the UK (Kovats, 2008) and it is more likely that impacts on the Estuary will be through other means such as damage to property and economic losses.

to fill this gap by using a mental models approach to explore and compare expert and public perceptions of SLC, with a view to the future design of risk communications on the Estuary. The mental models approach (Morgan et al., 2002) is chosen for its emphasis on public perceptions in developing risk communications, and for its structured methodology in eliciting these perceptions.

The mental models approach has traditionally focused on knowledge-based perceptions of risks. However, perceptions are determined by a great many factors in addition to a person's knowledge (Baumann & Sims, 1978; Kahan et al., 2012), and it is wrong to assume that if a person knows about a risk they will respond with adaptive coping strategies rather than with maladaptive ones (Smith, Horrocks, Harvey, & Hamilton, 2011). Indeed, a lack of knowledge is just one of many barriers to engaging with climate change (Lorenzoni et al., 2007). Therefore, as well as investigating public knowledge of SLC, this thesis also investigates other factors that might influence responses, including factors that may predispose an individual to make a given decision, and factors that may influence their perceived ability to cope.

Thesis structure

The purpose of this study is to investigate perceptions of SLC on the Severn Estuary in order to improve risk communications. To do this, it asks three core questions:

1. How do 'experts' perceive the risks of SLC on the Severn Estuary?
2. How does 'the public' perceive the risks of SLC on the Severn Estuary?
3. What implications do these perceptions have for risk communications on the Estuary?

The study uses a mixed-methods design, answering the above research questions by way of three empirical phases. The first is an Expert Perception Phase (EPP), which develops an expert model of the risks to later compare with public risk perceptions. The model is developed through a review of the literature and elite interviews with experts in the field of SLC on the Severn Estuary (N=11). The second phase, Public Perceptions Phase One (PPP1), explores public risk perceptions through qualitative mental models interviews with members of the public living around the estuary (N=20). The third, Public Perceptions Phase Two (PPP2), investigates the prevalence of these risk perceptions, and the relationships between factors, through an online quantitative survey of a larger sample of the Severn Estuary population (N=359). The empirical research structure is shown in Figure 1.

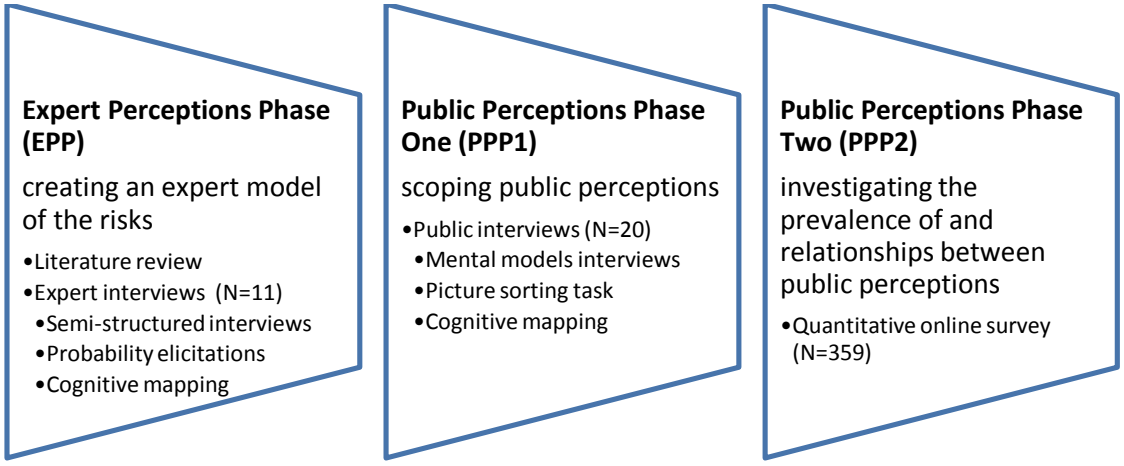


Figure 1: Empirical Research Phases

The thesis is structured as follows. Chapter 2 provides the rationale for the thesis and its structure, supported by a review of the literature regarding SLC, the Severn Estuary and risk perceptions. The methodology and results of the three empirical phases are organised into two main parts; the expert phase first, followed by the public phase. Chapters 3 and 4 present the methodology and results of the Expert Phase (EPP). Chapter 5 presents the methodology of both public phases (PPP1 and PPP2). The results of these public phases are discussed alongside each other in Chapters 6, 7 and 8, organised by themes. The thesis is concluded in Chapter 9, followed by references and appendices.

Chapter 2. Rationale and literature review provides the rationale for the thesis, supported by a review of the literature.

Chapter 3. Expert perceptions: Methods presents the methodology of the EPP, including its overarching rationale and limitations.

Chapter 4. Expert perceptions: Results presents and discusses the two main outputs of the EPP: an expert model of the risks of SLC on the Severn Estuary, and probability elicitations of future SLC. While Chapter 4 provides a summary of what the expert model contains, it is too long to contain within the main structure of the thesis. The notes to accompany the model are therefore appended (Appendix O).

Chapter 5. Public perceptions: Methods details the rationale behind the two public phases (PPP1 and PPP2) and discusses the methods and limitations of each.

Chapter 6. Public results: Orienting dispositions is the first of three chapters presenting and discussing the results of PPP1 and PPP2. This chapter discusses the factors that might predispose an individual to make risk appraisals.

Chapter 7. Public results: Risk appraisal is the second of three chapters discussing the results of PPP1 and PPP2. It addresses the factors that comprise a public risk appraisal of SLC: the appraisal of the threat, and the appraisal of ability to cope with the threat.

Chapter 8. Public results: responses and relationships firstly discusses public responses (both active and inactive) to SLC. It then presents and discusses the results of statistical regression analyses (PPP2) on factors influencing SLC risk perceptions.

Chapter 9. Conclusions completes the thesis with a discussion of the theoretical, methodological and applied implications of this research for the Severn Estuary and elsewhere, and with suggestions for future research. It includes recommendations for future communications on the Estuary, drawing on results from all three empirical phases.

Appendices A to N contain methodological details and data tables.

Appendix O contains notes to accompany the expert model developed during the EPP.

Important definitions

Public. While the existence of multiple 'publics' rather than a single homogenous 'public' is recognised, this thesis tends to use the term 'public' by way of convention and consistency with other public perception research (as per Whitmarsh & O'Neill, 2011). Throughout the discussion, 'public' refers to people living around the Severn Estuary, not the wider Welsh and English population; further research is needed to investigate whether the perceptions of Severn Estuary residents are representative of other groups.

Public perceptions of sea-level change. Public perceptions are defined as 'people's beliefs, attitudes, judgements and feelings, as well as the wider cultural values and social dispositions people adopt' (Pidgeon, Hood, Jones, Turner, & Gibson, 1992, p. 89). This thesis is interested in these factors with relation to sea-level change.

Public responses to sea-level change. Public responses are defined as reactions to sea-level change. They can be active, such as engaging with sea-level change by taking adaptive actions, or inactive such as denying or ignoring the issue.

Engagement with sea-level change. Engagement is defined as it is by Lorenzoni et al. (2007) to be a personal state of connection with the issue of sea-level change, including caring about it and being motivated to take adaptive and mitagative action.

2 RATIONALE & LITERATURE REVIEW

This chapter provides the rationale for the thesis and its structure, supported by a review of the relevant literature. It explains the reasoning behind the research and behind the methods chosen to answer the research questions, beginning with a discussion of the Severn Estuary and the reasons why it is important to understand public perceptions of SLC there. It then presents the mental models approach through which these perceptions are examined, before considering limitations of the approach, particularly its emphasis on the knowledge deficit model of risk perceptions. It then outlines non-knowledge factors that affect risk perceptions, such as sources of risk information, emotions and perceived coping capacity. The chapter concludes by presenting the aims and hypotheses that drive the research.

2.1 Sea-level change as a risk

Risk is a 'concept used to give meaning to things, forces, or circumstances that pose danger to people or to what they value' (Stern & Fineberg, 1996, p. 215). It is usually defined in terms of the likelihood of an undesired event occurring and the consequences of the occurrence (Brooks, 2003). Risk perception research is interested in the ways in which people think about risks. It can be defined as 'people's beliefs, attitudes, judgements and feelings, as well as the wider cultural values and social dispositions people adopt' (Pidgeon et al., 1992, p. 89). This thesis is interested in how people think about the risks posed by sea-level change. Despite the large amount of media and policy attention paid to terrorist attacks, economic downturns and other global risks, natural disasters still have the greatest potential for disruption (Dezenski, 2012). Sea-level rise has the potential to increase the incidence and severity of such disasters. But it is a 'critical and uncertain climate change risk' (Schaeffer, Hare, Rahmstorf, & Vermeer, 2012), and one of the least understood impacts of anthropogenic climate change (ACC) (Hansen & Sato, 2012).

To understand the risks posed by SLC, it is necessary to first understand climate change, a major driver of sea level fluctuations. The climate naturally varies according to the amount of radiation emitted from the sun and changes in the Earth's axis and orbit around the sun (Milankovitch Cycles)[4]. The Earth's climate also naturally varies according to atmospheric factors (e.g. changes in gas concentrations), oceanographic factors (e.g. changes in ocean currents) and terrestrial factors (e.g. volcanism, orogeny[5] and changes in albedo[6]) (Burroughs, 2007). As well as these natural variations, the Earth's average temperature is currently undergoing secular change due to human activities, principally the emission of greenhouse gases such as carbon dioxide and methane through burning fossil fuels like coal and gas (IPCC, 2007, 2013). As these greenhouse gases build up in the atmosphere, they decrease the amount of thermal radiation that can escape into space, and raise the temperature of the Earth's surface and atmosphere. Over the past decades, this process has caused global average surface temperatures to increase, especially since about 1950 (Solomon et al., 2007).

The rate and extent of future ACC is unknown. However, a mean warming of around 1.3^{o}C above pre-industrial levels is estimated from the combustion of fossil fuels by existing infrastructure alone between 2010 and 2060 (Davis, Caldeira, & Matthews, 2010), so warming can be expected to exceed this as world population and energy use increase. It is now recognised that global temperatures may rise by as much as 4^{o}C by 2100 (New, Liverman, & Anderson, 2009; New,

[4] Milakovitch cycles are orbital changes that drive ice age cycles: obliquity (Earth's axial tilt), precession (Earth's wobble on its axis) and eccentricity (shape of Earth's orbit around the sun).
[5] Orogeny is mountain building
[6] Reflectivity of the Earth's surface

Liverman, Schroder, & Anderson, 2011), and 'the uncertainty is not *whether* the world will experience climate change but *how* its impacts will be felt' (Foresight, 2011, p. 10). While impacts remain uncertain, the southwest of the UK is likely to be affected by ACC in a number of ways, including sea-level rise.

2.1.1 Terminology: sea-level rise and sea-level change

The term 'sea-level rise' is used to describe a rise in the average level of the sea at the coast. This thesis uses the term 'sea-level change' as well as sea-level rise, for three reasons. First, although it is considered extremely unlikely that sea-levels will fall on the Severn Estuary in the foreseeable future, it remains a possibility; and over very long timescales, a probability. Second, the term sea-level change was used in all public interviews to prevent leading participants and biasing responses. The third reason is related to the processes at work on the Severn Estuary. While sea-level rise immediately evokes connotations of gradually rising waters, sea-level change is open to interpretation as changes caused by more everyday factors such as tides and waves, and more dramatic changes in sea level due to storm surges and tsunamis.

2.1.2 The causes, rates and impacts of global sea-level change

The causes, rates and impacts of SLC are considered only briefly here on account of a fuller description constituting a large proportion of the expert model (Appendix O). Global sea levels have varied by hundreds of metres over geologic time due to land movements, and due to eustatic[7] changes as the amount of water held in the cryosphere[8] has waxed and waned. During the last glacial maximum around 20,000 years ago, average global sea level was about 130m *lower* than it is at present (Clark et al., 2009). During the Pliocene around three million years ago, when atmospheric CO_2 concentrations were about the same as today, the sea level is thought to have been 15 to 25m *higher* than present (Raymo, Grant, Horowitz, & Rau, 1996; 2011).

> *'Global sea-levels rose 17cm through the twentieth century, and are likely to rise more rapidly through the twenty-first century when a rise of more than 1m is possible' (Nicholls, 2011, p. 114).*

Sea-level measurements from tide gauges, satellites and proxy data show that global mean sea level rose during the 20th century and is continuing to do so (Gehrels et al., 2007; IPCC, 2013; Solomon et al., 2007). As the world continues to warm, mean global SLR is inevitable (Nicholls et al., 2011a)

[7] Eustatic changes are large scale (global or ocean-level) changes in sea-level.

[8] The cryosphere is the portion of the Earth's surface where water is frozen, including snow, ice and permafrost.

through thermal expansion (changes in water volume due to temperature change)[9], glacio-eustacy (changes in water volume due to additions from melting land-ice) and changes in atmospheric surface pressure and ocean circulation.

The IPCC's Fourth Assessment Report (AR4) estimated future SLR of between 18cm and 59cm by the end of the 21st Century (Solomon et al., 2007). While these estimates have been highly cited, other studies -some using semi-empirical models[10]- show that AR4 projections may have been much too low (e.g. Nicholls et al., 2011b; Rahmstorf, Foster, & Cazenave, 2012). For example, Nicholls et al. (2011b) suggest that if temperatures rise by around 4°C, sea levels could rise by between 0.5m and 2m by 2100. Indeed, the AR4 acknowledged that 'because understanding of some important effects driving sea level rise is too limited, [the report did not] assess the likelihood, nor provide a best estimate or an upper bound for sea-level rise' (IPCC, 2007, p. 45). Most notably, AR4 estimates did not include the full effects of changes in ice sheet flow due to a lack of understanding of ice sheet dynamics (IPCC, 2007).

Ice-sheet dynamics have been included in the latest IPCC report (AR5), together with an improved physical understanding of sea-level components and increased agreement between process models and observations. This has meant that the confidence in global mean sea-level projections has increased since the publication of AR4 (IPCC, 2013). Indeed, while the process-model based SLR estimates in the AR5 are lower than those produced by semi-empirical models, the AR5 does project higher SLR estimates than the AR4 (IPCC, 2013). These projections are for a likely global mean SLR[11] of between 0.26m (low RCP2.6 estimate[12]) and 0.98m (high RCP8.5 estimate) by the year 2100, relative to the 1986-2005 baseline. In all RCPs, thermal expansion is the largest contributor (accounting for 30-55% of SLR), followed by glaciers (15-35%)[13] (IPCC, 2013).

Estimates of future SLR tend to focus on the 21st century (e.g. IPCC, 2007, 2013), but studies that do look further ahead project very large rises indeed. For example, Lenton (2006) calculates that sea levels will still be rising at the end of this millennium, and that the combined effects of thermal expansion and the melt of the Greenland ice-sheet will cause up 11.4m SLR by the year 3000[14].

[9] Thermal expansion (or thermosteric SLC) occurs because as water gets warmer, the molecules spread out causing the volume of the water to increase.

[10] Semi-empirical models use historical and present relationships between temperatures and SLR to predict future SLR from projections of future warming. This is different to process models, which aim to mathematically represent the various processes that contribute to SLR. For a discussion, see Rahmstorf (2007) and Nicholls et al. (2011b).

[11] Estimates shown here are for the 5-95% range of model results.

[12] AR5 uses Representative Concentration Pathways (RCPs) instead of the Special Report on Emissions Scenarios (SRES) scenarios used in AR4. RCPs are identified by their approximate total radiative forcing in the year 2100 relative to 1750; 2.6 watts per square metre (W m-2) for RCP2.5, 4.5 W m-2 for RCP4.5, 8.5 W m-2 for RCP8.5 and so on.

[13] The Greenland ice sheet is expected to make a net positive contribution to SLR, while the Antarctic ice sheet is expected to make a net negative contribution (due to increased snowfall on the continent); changes in outflow from both ice sheets combined will likely make a contribution to SLR of between 0.03m and 0.20m by 2100 (IPCC, 2013).

[14] These figures exclude contributions from Antarctica, which could add many more metres.

The latest IPCC report also states that beyond 2100, it is virtually certain (99-100% probability) that SLR will continue for many centuries (IPCC, 2013). For the RCP2.6 scenario, SLR is not expected to exceed 1m above pre-industrial levels by 2300 (IPCC, 2013), but for higher CO_2 concentrations, the rise is expected to be substantially greater; potentially more than 3m by 2300 for RCP8.5 (IPCC, 2013). AR5 projects that over a millennium or more, sustained warming will lead to 'near-complete loss' of the Greenland ice sheet, leading to global mean SLR of up to 7m (IPCC, 2013, p. 20).

SLC is expected to have a number of physical and socio-economic impacts. Physical impacts include immediate impacts like flooding, submergence and saltwater intrusion into surface water, and lagged impacts such as changes in water tables and wetland loss. Socio-economic impacts range from inconvenience like not being able to get to work, displacement and property damage, through to injury and death. More information about the impacts of SLC and their inter-relationships, as well as the factors that affect vulnerability, are provided in the expert model notes (Appendix O).

2.2 The Severn Estuary, an environment threatened by sea-level change

The Severn Estuary is important for many reasons, not least because of its high ecological significance (Severn Estuary Coastal Group and ATKINS, 2010d) and being home to around one million people (Severn Estuary Partnership, 2011). It is also the site of major industry, transport and energy infrastructures, and may in future become a key source of renewable energy (DECC, 2010). The estuary's response to SLC is therefore critical for the environment, the people who live there, and the people who otherwise depend on it, now and in the future. This section outlines the estuary's physical and social characteristics that make it suitable for particular attention, before discussing SLC at this regional scale.

2.2.1 Physical environment of the Severn Estuary

An estuary is the lower section of a river where saline sea water is diluted with fresh water (Nordstrom, 2009). Estuaries are vitally important ecosystems, with habitats provided by a range of features such as sub-tidal mudflats, marshes, creeks and beaches. They are also inherently dynamic because they are constantly subject to changes in conditions due to tides, surges, runoff and sediment inputs. In one sense, these fluctuating inputs of water, nutrients and material have made estuaries resilient: estuarine organisms are highly tolerant to rapid changes in temperature and salinity (Nordstrom, 2009), and estuaries have generally maintained their attractiveness for wildlife despite extensive industrialisation and land claim (Elliott & McLusky, 2002). However, the

complex nature of estuaries may also mean that they are particularly vulnerable to ACC: they are likely to be affected through a number of pathways including SLR, altered river flows, shifts in storminess, and ecological changes.

Definitions of the geographical area covered by the Severn Estuary are broad. Gloucester is often used as the upper boundary -as it is in this thesis- because it is the limit of tidal influence; but the placement of the seaward edge is more variable due to the various ways in which estuary boundaries can be defined (Elliott & McLusky, 2002). For example, the Second Shoreline Management Plan (SMP2)[15] sites the boundary between Lavernock Point (south of Penarth) on the Welsh side and Anchor Head (north of Weston-Super-Mare) on the English side (Severn Estuary Coastal Group and ATKINS, 2010b), whilst the Severn Estuary Partnership boundary is further west, roughly between Llantwit Major on the Welsh side and Minehead on the English side (Severn Estuary Partnership, 2009); a delineation that includes part of the inner Bristol Channel. For this thesis, the westernmost boundary of the Severn Estuary is taken to be roughly between Hinkley Point (Somerset) and Barry (Vale of Glamorgan). This delineation includes the nuclear infrastructure at Hinkley, the location of a potential tidal barrage, and the vulnerable low-lying Bridgwater region. Hereafter, 'Severn Estuary' will refer to this coastline and a 10 mile zone around it (Figure 2). This zone is chosen because it includes much of the low-lying plains surrounding the Estuary, including important transport infrastructure and settlements, while not being so large as to be perceived as irrelevant to interviewees and survey respondents.

The Severn is Britain's second largest estuary with an area of 557km^2 (IMCORE, 2011). Its classic funnel shape, which is unique in Britain, is in part the cause of its famous tidal range: after Canada's Bay of Fundy, it has the second highest tides in the world, with an average mean tidal range of 6.5m at neaps and 12.3m on springs (Langston, Jonas, & Millward, 2010). Tidal range increases further up the estuary, and high spring tides reach as far as Tewkesbury in northern Gloucestershire when river flows are low (Environment Agency, 2006). The whole of the Estuary is dominated by tidal processes, but fluvial (river) influence becomes appreciable further up (ATKINS, 2009). The Estuary has one of the largest catchments in the UK, and the rivers that flow into it (particularly the Wye, Avon, Usk and Severn) supply a vast amount of sediment (Severn Estuary Coastal Group and ATKINS, 2010c). This sediment is highly mobile (Kirby, 2010), with an estimated 10 million tonnes of suspended sediment carried during spring tides (Environment Agency, 2006). Much of it is deposited as mudflats, which comprise 93% of the Estuary's 100km^2 intertidal area (Environment Agency, 2006).

[15] The SMP2 was developed by a partnership of the Environment Agency (EA), local authorities, conservation authorities and internal drainage boards around the estuary. It sets out recommended coastal management for the Severn Estuary over the next 100 years, split into 'epochs' of 20 years, 50 years and 100 years.

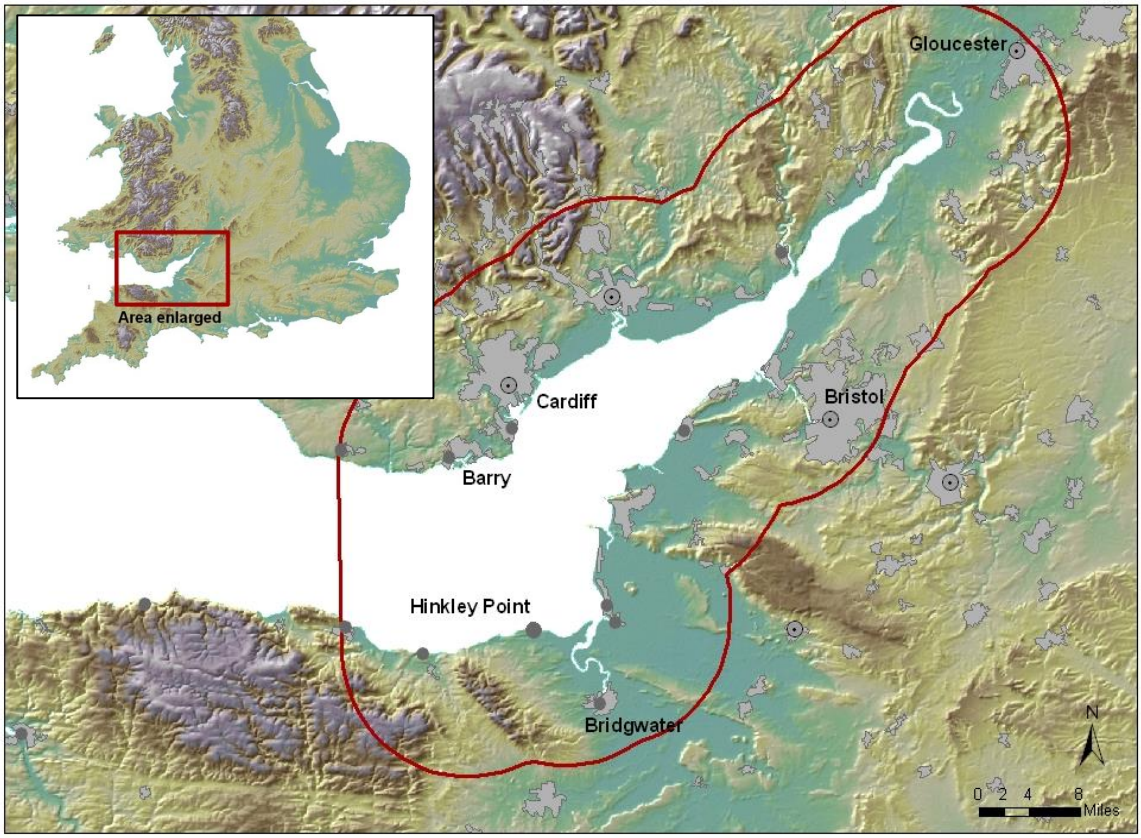


Figure 2: Map showing the location of the Severn Estuary in the UK, with ten mile zone included in analyses

The Severn Estuary's intertidal habitats are the first line of defence against coastal flooding. They also support considerable biodiversity, and the Estuary contains the largest aggregation of salt marsh habitat in the south and south-west (Severn Estuary Partnership, 2011). Such intertidal habitats are vulnerable to SLR, particularly through coastal squeeze, a process by which coastal environments are trapped between rising sea levels and fixed landward boundaries (Environment Agency, 2006). The importance of the Severn Estuary's ecology and its high conservation value have been recognised through a number of designations: the SMP2 study area includes seven Natura 2000 sites, over 50 Sites of Special Scientific Interest, four National Nature Reserves and one Area of Outstanding Natural Beauty (Severn Estuary Coastal Group and ATKINS, 2010c). The Estuary's international importance for wildlife was recognised in 1995 with its declaration as a Special Protection Area, and separately as a Ramsar site (an international wetlands designation). It was also made a Special Area of Conservation under the European Council Directive *92/43/EEC* on the Conservation of Natural Habitats and of Wild Flora and Fauna (European Parliament, 1992).

2.2.2 Socio-economic environment of the Severn Estuary

People have utilised estuaries since prehistoric times because of the flat land, safe harbours, river access and valuable resources that they provide, and many of the UK's largest cities including London, Cardiff and Glasgow were founded beside estuaries (HR Wallingford, 1997). The Severn Estuary is rich in archaeology and people have been living in the area since before the Estuary was formed around 8,000 years ago (Severn Estuary Coastal Group and ATKINS, 2010c). Human impact has been appreciable, particularly through the construction of flood embankments, industrialisation and the planting of *Spartina* (cordgrass) (Environment Agency, 2006). Perhaps the greatest impact has been from land reclamation, which dates back at least to early Roman times (Environment Agency, 2006).

Today, the Estuary has a mixture of urban and rural land uses, with the main settlements being Bristol, Gloucester, Newport and Cardiff. It is also home to significant industrial development including chemical processing plants, power stations and ports, which are supported by good transport links, cooling water, waste disposal and offshore aggregates for construction (IMCORE, 2011). The Estuary is also important for recreation and tourism (Knowles & Myatt-Bell, 2001), and may in future become a key source of renewable energy (DECC, 2010). The tidal floodplain throughout the Estuary is under pressure from future development. Key proposals in or adjacent to the SMP2 area include: development of wind farms; regeneration of ports and waterfronts including Portishead, Watchet and Weston; a major Bristol Port development; and a new gas fired power station at Uskmouth (Severn Estuary Coastal Group and ATKINS, 2010c).

Governance at the scale of the Severn Estuary is complex. While ACC and SLR do not adhere to administrative and political boundaries, the responsibility for reacting to these threats on the Estuary will be shared between a number of groups (Dodds, 2010): two Governments (Westminster and the Welsh Government), fourteen Local Authorities, two County Councils, a range of government agencies, and many landowners. A 'profusion of legislation and policy' exists, with direct and indirect implications for the Estuary's environmental management (Ballinger & Stojanovic, 2010, p. 144). This includes European directives, national and regional frameworks, and local action plans. Of particular note with regards to coastal management are the SMP2 (Severn Estuary Coastal Group and ATKINS, 2010e); the Severn Estuary Flood Risk Management Strategy (Environment Agency, 2011c), which is currently being updated; Catchment Flood Management Plans (Korontzi, 2009); the Coastal Habitat Management Plan (Environment Agency, 2006); and flood risk plans under the European Parliament's Floods Directive *2007/60/EC* (European Parliament, 2007). Devolutionary processes have greatly impacted the institutional framework for climate change risk management. For example Wales has its own environmental body, Cyfoeth Naturiol Cymru / Natural Resources Wales, and has developed its own National Strategy for Flood

and Coastal Erosion Risk Management (FCERM) (Welsh Government, 2011). See Appendix O for more information about Severn Estuary governance.

2.2.3 Sea-level change on the Severn Estuary

ACC is already occurring on the Severn Estuary, where winter temperatures have increased by between 1.4 and 2.2°C since 1961, and summer temperatures have increased by between 1.0 and 1.8°C during the same period (Hovey, 2010). ACC is likely to have both positive and negative impacts there. Positive impacts may include a boost to tourism as temperatures rise; and a lengthening of crop growing seasons leading to enhanced agricultural productivity (Defra, 2012). However, these benefits are likely to be outweighed by the negative impacts related to SLC.

Section 2.1.2 discussed rates of global SLC. Local SLC can vary considerably from the global mean, and SLC at the scale of the Severn Estuary is a function of a combination of factors acting on local to global scales, and on short and long timescales. These factors include global changes (particularly climatically driven global mean SLR); regional changes due to variations in ocean circulation, temperature, salinity and atmospheric surface pressure (Lowe et al., 2009; Milne, Gehrels, Hughes, & Tamisiea, 2009); and local changes due to storms, rainfall patterns, tidal amplitude variations and local land subsidence.

Records show that the mean sea level on the Estuary is gradually rising (Environment Agency, 2011b), and has been throughout the Holocene[16], with fluctuations superimposed onto this upward trend (Environment Agency, 2006). Estimated rates of historical SLR on the Severn Estuary are summarised in Table 1. The rates vary due to the dominance of different processes during different time periods (SLR was fastest when ice sheets melted at the beginning of the Holocene), and due to different methods for estimating SLR. For example, Allen (1991) measured the height difference between the shoreward and landward side of historic sea-defences for their pre-1945 estimates, and used geochemical methods for their post-1945 estimates. More recent work by Phillips and Crisp (2010) used tidal data from gauges in the Bristol Channel.

[16] The Holocene is the current interglacial period; the geological epoch that began around 11,700 years ago and continues today.

Period	Estimated SLR	Source
10,000BP – 7,000BP[17]	14mm/yr or 11mm/yr	Hawkings (1971) and Shennan (1983) respectively, cited by Environment Agency (2006)
Minimum average rate of SLR between the Later Roman period- Medieval Period (AC238-1327)[18]	0.40mm/yr	(Allen, 1991)
Minimum average rate of SLR between the Medieval and Modern periods (1327-1797)	0.79mm/yr	(Allen, 1991)
Minimum average rate of SLR during the Modern period (1797-1945)	1.49mm/yr	(Allen, 1991)
Minimum average rate of SLR during the period 1945-1990	4.65mm/yr[19]	(Allen, 1991)
1993-2007	2.4mm/yr	(Phillips & Crisp, 2010)

Table 1: Estimates of historical SLR on the Severn Estuary

It is not possible to precisely predict how sea levels will change in future on the Severn Estuary or anywhere else. Not least, the climate system is not perfectly understood or represented in climate models, has an element of intrinsic (unforced) variability, and will be forced by future unknown greenhouse gas emissions, which are themselves forced by unknown future economic conditions and value sets. However, there is consensus in the literature that sea levels on the Estuary will continue to rise in future, as shown in Table 2. The Table shows projections from a variety of sources including computer modelling (e.g. UK Climate Projections, 2012) and extrapolation from current trends (e.g. Phillips & Crisp, 2010).

[17] BP = years Before Present

[18] AC = *Ante Christum*, Latin for 'before Christ'

[19] Some authors support these rates (e.g. French et al, 1994) while others suggest lower rates (e.g. Rossiter, 1972) or can find no evidence of accelerated SLR at all (e.g. Woodworth 1987, 1990)(Environment Agency, 2006).

<table>
<tr><th>Source</th><th>Projected SLR rate/level</th><th>For the period:</th></tr>
<tr><td>Environment Agency Severn Estuary Flood Risk Management Strategy (SEFRMS) (Environment Agency, 2011c).</td><td>The SEFRMS plans for SLR of approximately 1m and for an increase in river flows of up to 20%, using Defra guidelines (Defra, 2006), which at the time of the SEFRMS publication was still the formal Defra approved guidance for flood risk management planning.</td><td>2010-2110</td></tr>
<tr><td>Marine Climate Change Impacts Partnership (MCCIP, 2010).</td><td>21–68cm SLR projected in Cardiff under a medium greenhouse gas emission scenario.</td><td>1990 - 2095</td></tr>
<tr><td>Severn Estuary 2nd Shoreline Management Plan (Severn Estuary Coastal Group and ATKINS, 2010b)</td><td colspan="2">Current allowances for net SLR (mm/yr) in the South West and Wales, for draft management policies (after Defra 2006):
<table>
<tr><td>1990-2025</td><td>2025-2055</td><td>2055-2085</td><td>2085-2115</td></tr>
<tr><td>3.5</td><td>8.0</td><td>11.5</td><td>14.5</td></tr>
</table></td></tr>
<tr><td>UK Climate Projections (2012)</td><td>Central estimates for relative SLR at Cardiff:
High emissions scenario: 53.1 cm
Medium emissions scenario: 44.4 cm
Low emissions scenario: 37.3 cm</td><td>For 2095 (1980-1999 baseline)</td></tr>
<tr><td>Severn Estuary Coastal Habitat Management Plan (CHaMP)</td><td>The Severn Estuary CHaMP used Defra's recommended SLR allowance of 6mm/yr, pointing out that this 'probably represents a potential worst case' (Environment Agency, 2006).</td><td>Epochs of 20, 50 and 100 years.</td></tr>
<tr><td>Phillips and Crisp (2010)</td><td>Extrapolated from tide gauge data (1993-2007) from four locations in the region to suggest a 2050 MSL rise of 0.37m.</td><td>1993-2050</td></tr>
</table>

Table 2: Estimated future SLR on the Severn Estuary

The plume plots in Table 3 show more detailed estimates over time for Cardiff and Gloucester from UK Climate Projections 2009 (UKCP09). The UKCP09 projections are a suite of climate projections for the UK, providing climate information designed to help those planning climate change adaptation (UK Climate Projections, 2012). They use modelling, past observations, IPCC scenarios, and expert judgement together with the UK Met Office's supercomputers to provide probabilistic projections of future SLC.

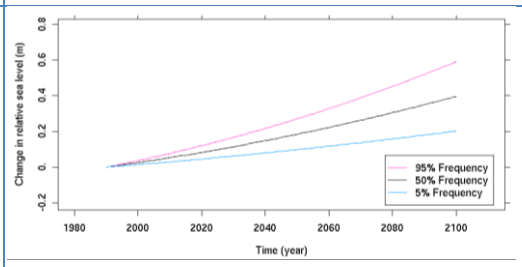
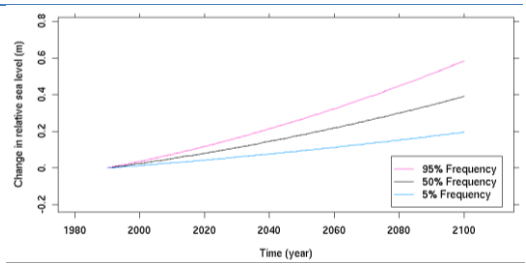
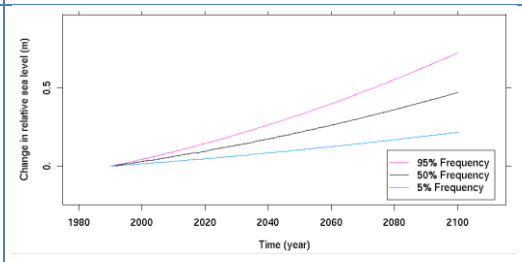
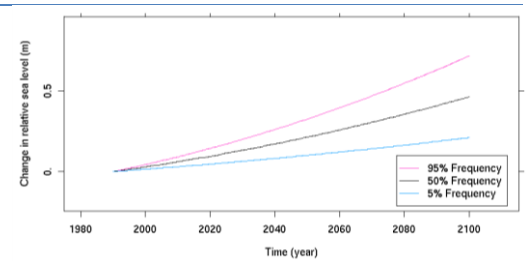
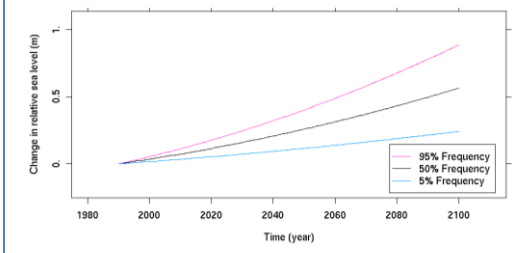
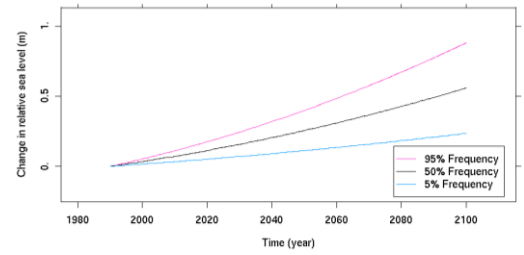
	Cardiff	Gloucester
Low emissions		
Medium emissions		
High emissions		

Table 3: UKCP09 Projections for future SLC on the Severn Estuary

The graphs show 5, 50 and 95th percentiles of relative SLR projections for Cardiff and Gloucester under low (IPCC SRES: B1), medium (IPCC SRES: A1B) and high emissions (IPCC SRES: A1FI) scenarios[20], relative to 1990 levels. Source: UKCP09 (UK Climate Projections, 2012)

Extremely high sea levels are usually the product of a combination of factors, such as a storm surge at a high tide. Mean SLR increases the likelihood of these extreme levels by raising the baseline level of the water; meaning a high tide or surge reaches higher than if the mean sea level was not rising. Extreme events have caused significant inundation to the area in the past (e.g. Horsburgh & Horritt, 2006), and will continue to do so in future, potentially reaching higher elevations due to raised mean sea levels. Future trends in some of these events, such as extreme tides, can be predicted with confidence. Others, such as the frequency and magnitude of storms, cannot, and there is currently debate over how these events may change in future (Christensen et al., 2007; Jenkins et al., 2009; UK Climate Projections, 2010; Woolf & Wolf, 2010). However, unless these events *decrease* in magnitude or frequency, the established SLR trend alone will mean that extreme

[20] These IPCC (AR4) scenarios can be summarised as follows. IPCC SRES: B1 = global population peaks mid-21st century then declines, clean and resource-efficient technologies are introduced. IPCC SRES: A1B = rapid economic growth, global population peaks mid-21st century then declines, a balance across all energy sources (fossil and non-fossil fuels). IPCC SRES: A1FI = rapid economic growth, global population peaks mid-21st century then declines, fossil fuel intensive (IPCC, 2000).

high waters will become more frequent in the coming decades. It is important to understand how people perceive these risks so that their perceptions can be taken into account when responding to them.

2.3 Understanding public perceptions of sea-level change on the Estuary

2.3.1 The role of public perceptions in risk management

Some commentators argue that risk perceptions should not be included in policy decisions. Their argument is based on the idea that public perceptions, which are not always based on scientific understanding, introduce bias and noise into the system, are prejudiced, and ultimately may lead to the loss of lives and resources (see Pidgeon & Beattie, 1998 for a review of these arguments). Others, including in coastal management arenas[21], have a more positive view of the role that public perceptions play. Fiorino (1990) suggests that there are at least three reasons why risk perceptions should be included in decision making. These are normative, substantive and instrumental:

- Normative: ignoring lay perspectives is incompatible with democratic ideals, and 'citizens are the best judge of their own interests' (Fiorino, 1990, p. 227).
- Substantive: lay risk judgments are as sound (or more so) than expert risk judgments (Fiorino, 1990). Non-experts can see problems that experts miss, and local knowledge can add an important layer to risk understandings. 'Far from being 'information poor' - groups of citizens actually have access to a range of cultural resources' (Irwin, Dale, & Smith, 1996, p. 49), possessing local knowledge that can valuably contribute to policy making and debate (Irwin, Simmons, & Walker, 1999).
- Instrumental: effective lay participation increases legitimacy, leads to better decision making, incorporates a broader range of values, and can reduce the probability of error (Fiorino, 1990).

One important instrumental role for public perceptions is to help shape future risk communications: without feedback from the target audience, scientists do not know how their well-intended communications are being received and understood by the public (Pidgeon & Fischhoff, 2011). This 'strategic listening' (Pidgeon & Fischhoff, 2011) is the purpose of the mental models approach (Morgan et al., 2002) adopted for this thesis (section 2.4.1). It aims to investigate

[21]Public participation is a key principle of Integrated Coastal Zone Management as set out in European Council Recommendation 2002/413/EC (European Parliament, 2002).

public perceptions so that future risk communications can be improved. But why communicate these risks?

2.3.2 The role of communicating sea-level change risks

Risk communication is the act of conveying information between people about levels of risk, the significance of risks or management decisions about risks (Renn & Levine, 1991citing Covello et al, 1986). The purposes of risk communication can include the following:

1. Ethical reasons for informing people of the risks that they may face: the 'right-to-know' function (Renn & Levine, 1991).
2. Allowing people to identify risks that are large enough to warrant some of their limited time and attention (Morgan et al., 2002).
3. Facilitation and motivation of deliberation and participation, for instance the facilitation of *informed* voting choices, or the 'buy-in' or opting out of risk amelioration measures such as coastal defence schemes (e.g. Evans, Milfont, & Lawrence, 2012; Ryan et al., 2012).

The purpose of this project is to facilitate effective communication of sea-level rise risks to enable lay people to engage with SLC and make informed decisions. Although some decisions about SLC risks are made centrally (for example decisions regarding coastal defence budgets), individuals must make their own decisions as to whether to install a flood board, move to higher ground, support local flood management plans and so on. The IPCC (2012) argues that such risk communication is a 'no-regrets' measure, meaning that it provides benefits under current climate, and also under a range of future climate change scenarios.

Research shows that a lack of communication can lead to low engagement and/or increased vulnerability. For instance, insufficient risk communications have been linked with poor perceptions of flood hazards in Norway (Krasovskaia, Gottschalk, Sælthun, & Berg, 2001); while in the UK, low awareness of climate change risks in coastal communities may be increasing vulnerability because people are less likely to take adaptive actions like retrofitting their homes or obtaining insurance (Fernandez-Bilbao, 2012). Communicating risks, however, is not a panacea. First, the public may have justified reasons for inaction; reasons that will hold whether they learn more about the risks or not. For instance, they may perceive the risk to be irrelevant for them (indeed, it might be), or may have a different value set to the one implied by the risk communications. Second, communication raises the possibility of introducing area-based stigma by drawing attention to risks (e.g. Gregory & Satterfield, 2002). Fischhoff (2001, p. 361) defines stigma as the 'principled refusal to engage in an act that would otherwise be acceptable'; i.e.

something that is stigmatised is 'just not done'. Stigma can lead to blight, whereby an area loses its appeal due to economic downturns, disinvestment and out-migration. It can be lessened by reducing the perceived risk (antithetical to the communication aim of raising awareness of it) or reducing the *social amplification* of stigma by educating the media and the government about the issue (Kunreuther & Slovic, 2001).

2.3.3 What we already know about public perceptions of sea-level change on the Severn Estuary

There has been little detailed research to date on public perceptions of SLC, and no published research to my knowledge has investigated SLC perceptions on the Severn Estuary in particular. So far, most relevant research has treated SLC as just one of the many aspects of climate change (e.g. Bostrom et al., 1994; Read, Bostrom, Morgan, Fischhoff, & Smuts, 1994; Reynolds et al., 2010), without investigating SLC in its own right. Studies that have particularly focussed on SLC have tended to rely heavily on survey approaches (Evans et al., 2012; Ryan et al., 2012). Few have used in-depth interviews (Harvatt, Petts, & Chilvers, 2011), and none to my knowledge has used a mental models approach. Indeed, as shown in section 2.6, much of what we know about SLC perceptions comes from our understanding of climate change perceptions more generally.

What we do know is that SLR is one of the more commonly discussed consequences of climate change among the public, media and policy makers (Rick, Boykoff, & Pielke Jr, 2011), and tends to be associated with negative affect[22], (Lorenzoni, Leiserowitz, De Franca Doria, Poortinga, & Pidgeon, 2006). The European public is more concerned about marine issues not directly related to climate change, for example pollution, over fishing and habitat destruction (CLAMER, 2011b), and research suggests that in general, the UK public has a low awareness of SLR (Fernandez-Bilbao, 2012)[23]. On the Severn Estuary, there is recognition amongst lay Estuary users (fishermen and wetlands visitors) that climate change is occurring (Gregory, 2012; Sterenfeld, 2012), and research indicates some acceptance of sea-level rise and the need for adaptation among stakeholders (Severn Estuary Coastal Group and ATKINS, 2010a). In unpublished survey results (N=100) from an undergraduate Earth Science project at Cardiff University (2012) 61% of local lay people thought that SLR was associated with climate change in the Severn Estuary region. However, apart from this research indicating a basic awareness of SLC, little is known about public perceptions of the issue. It is this gap in risk perception research that this thesis aims to fill.

[22] 'Affect' is the feeling that something is good or bad.

[23] However, Tol, Klein, and Nicholls (2009) suggest that compared to other European nations, knowledge of SLR and its consequences are widespread in the UK.

2.4 Addressing the gap: investigating public perceptions of sea-level change on the Severn Estuary

2.4.1 The mental models approach

This study uses a mental models approach to investigate public perceptions of SLC on the Severn Estuary. The mental models approach is based on the 'foundational assumption of behavioural decision theory that an individual's beliefs influence his or her decisions, which influence behaviours' (Austin & Fischhoff, 2011, p. 2). Its core premise is that for communications to be effective in changing behaviour, communicators must know what people already think of the issues, so that communications can be framed in ways that encourage people to integrate the new information into their beliefs rather than ignore or reinterpret it (Harris, Daniels, & Briner, 2002). The mental models approach to risk communication developed by Morgan et al. (2002) built on earlier work (e.g. Maharik & Fischhoff, 1993) to do this systematically, by finding out about the audience's mental models of a risk before communications are designed.

> *'Mental models are personal, internal representations of external reality that people use to interact with the world around them. They are constructed by individuals based on their unique life experiences, perceptions, and understandings of the world' (Jones, Ross, Lynam, Perez, & Leitch, 2011, p. 46).*

Mental models can be described as knowledge structures that people use to reason and make decisions. Such knowledge structures have been portrayed in a number of ways including schemas, scripts and frames (Breakwell, 2007, p. 94). The idea of schemata was first proposed by Immanuel Kant in the 1780s (Kant, 1996) and perhaps most famously developed by constructivist[24] psychologist Piaget to describe the ways in which children understand the world (Boyle, 1969). A variant on this general idea, the mental model was first suggested by psychologist Kenneth Craik, who proposed that people carry a small scale model of how the real world works in their head (Craik, 1943). While mental models are unique to individuals, research suggests that people who share common experiences and cultural backgrounds can share convergent mental models (Denzau & North, 1994). Experts are a prime example, with expert knowledge 'founded upon shared understandings of 'established' facts and theories' (Breakwell, 2007, p. 98). Mental models are important because 'the decisions that people make about a hazard will at least in part depend on what 'mental model' they have of it' (Breakwell, 2007, p. 93).

[24] Constructivism asserts than perceptions, memories and so on are actively built and assembled by the mind, rather than being passively acquired (Colman, 2009).

Mental models and learning

When faced with new information, we can ignore it, interpret it using our existing mental model, or (more rarely) change our model to accommodate it. We are undergoing cognitive change, or learning. Piaget suggested that schemas were created by a dual process of assimilation, by which new information is added to the schema; and accommodation, by which the schema changes to allow for this assimilation (Boyle, 1969). If new information is not assimilated into the model, but instead stored in relative isolation, it is less likely to influence thought and behaviour (Kearney & Kaplan, 1997). These cognitive changes can occur in a second or over many days and can be caused by intrinsic causes such as emotions, or extrinsic causes (Johnson-Laird, 2013) such as a new experience or an effective risk communications campaign.

Mental models and the construction of preferences

> *'decision making is a highly contingent form of information processing, sensitive to task complexity, time pressure, response mode, framing, reference points, and numerous other contextual factors' - (Slovic, 1995, p. 369)*

Sometimes when people are asked for their opinion, they do not already have one. Research shows that rather than answering 'don't know', individuals often form an opinion there and then (Schuman & Kalton, 1985), constructing what has been termed a 'pseudo-attitude' (Terpstra, Lindell, & Gutteling, 2009). The attitude is not necessarily unreal, but it has been quickly constructed. It may have been constructed based on other factors such as norms, analogies, values, or cues in the questions themselves (Slovic, 1995). Alternatively, it may draw on information in the individual's existing mental model, or from a model of issues that are perceived to be similar (Jones et al., 2011). For example, we might use a mental model of water flow to think about an electrical current (Jones et al., 2011). In the context of climate change, this often manifests in people drawing on their understanding of other environmental problems, particularly pollution and ozone depletion (Kempton, 1997).

The mental model that an individual uses when someone shouts "tsunami, run!" and the model that they use when someone says "I'd like you to think about the things that might make the Severn Estuary more or less vulnerable to SLC" are probably quite different. Of course they evoke different feelings, but they also allow for different levels of reflection: one must be very quick, while the other can be slower. Different decisions also *require* different degrees of deliberation: the decision of whether to sell your flood-prone house may require more deliberation than the decision of whether to run away from a large wave. The degree to which we think about things before we make a decision, and the means by which we make these decisions have been described in terms of bottom up and top-down information processing (van der Pligt, de Vries, Manstead, & van

Harreveld, 2000), and systems one and systems two processing (Kahneman, 2002). In top-down or systems one processing, thoughts are automatic and intuitive; the result of no conscious effort. In bottom up or systems two-processing, thoughts are deliberate and effortful. There is a gradation between the two, with attitude formation lying between these extremes of automatic processes and full cost-benefit-analyses (van der Pligt et al., 2000). van der Pligt et al. (2000) suggest that the type of processing that we use is different according to the attributes of the decisions being made. Processing is only completely automatic when the individual is confronted with very familiar, trivial and unimportant choices (van der Pligt et al., 2000); a situation unlikely to be the case with a complex subject such as SLC. Instead, an individual would rely more on bottom up processing, combining their beliefs to form an overall attitude judgement (van der Pligt et al., 2000). The degree of deliberation will depend on the *accessibility* of the 'mental contents', that is, the ease at which they come to mind (Kahneman, 2002), and is also likely to depend on the time available for deliberation.

Mental models and risk communication

> *'If people lack detailed knowledge of global climate change, how do they form their opinions on this issue?' (Kempton, 1997, p. 14).*

> *'It is all too easy for policy-makers and science-based institutions to communicate to stakeholders and publics and miss their targets because of an inadequate awareness of how those audiences are comprehending, interpreting or rejecting those communications.' - (Campbell, 2011, p. 4892).*

In the 1990s, the British government launched a communications campaign to raise awareness of climate change. Despite best intentions, it failed to significantly change the public's understanding of the issue, with 21% still believing climate change would destroy the ozone layer (Kempton, 1997). This was because 'the program was not designed to replace existing cultural models, which have a strong tendency to persist' (Kempton, 1997, p. 19). The mental models approach addresses this problem by making audiences' mental models key in the development of such communications. The approach developed by Morgan et al. (2002) follows five steps:

1. Create an expert model of the risks to enable a comparison of lay perceptions with a current 'best understanding'.
2. Conduct mental models interviews with members of the public. These open-ended interviews are designed to explore peoples' correct and incorrect beliefs about a risk, in their own words. Responses are analysed in terms of how they correspond with the expert model.
3. Conduct a questionnaire to estimate the prevalence of beliefs expressed in stage 2.
4. Draft risk communications using the results of steps 2 and 3.
5. Evaluate the communication, testing and refining it with members of the target audience.

This study follows steps 1-3 of this approach. Due to time constraints, it does not develop and test risk communications (steps 4 and 5), but does make recommendations for these (Chapter 9). Although the broad methodology has been followed closely, some modifications have been made. These include the addition of a probability elicitation phase during step one, a modified protocol for creating public cognitive maps, and an in-depth analysis of contextual factors such as emotions and worldviews (see section 2.5).

The mental models approach has been used to successfully explore climate change perceptions (Bostrom et al., 1994; Lowe & Lorenzoni, 2007) as well as perceptions of other risks such as electromagnetic fields (Cox et al., 2005), HIV/AIDS (Morgan et al., 2002) and chemical risks (Cox et al., 2003). Studies have shown that mental models approaches improve participants' understanding when measured soon after communication materials are studied by the audience (Morgan et al., 2002). It is however difficult to assess the outcomes of mental models communications (Austin & Fischhoff, 2011), particularly if there is a long time-lag between communications and decisions, or between decisions and outcomes.

2.4.2 Limitations and criticisms of the mental models approach

Some critics have argued that people do not reason with mental models (or solely with mental models) but use other means of reasoning (O'Brien, Braine, & Yang, 1994; Oberauer, 2006). However, the mental models theory has been shown to provide a good fit for data sets representing reasoning processes (Oberauer, 2006), and provides a coherent conceptual framework for eliciting public opinions. Having said this, some limitations and criticisms of the mental models approach remain. These are: researcher influence, an assumption of an expert model of 'truth', and an emphasis on the knowledge deficit model of risk perceptions. These are now discussed.

Researcher influence

The researcher is not a passive arbiter in any stage of the research process; instead, each stage is a co-construction between the researcher and the researched. First, the influence diagram used to summarise the expert model inevitably bears some imprint of the researchers who produce it (Lowe & Lorenzoni, 2007). Second, a person's mental model is not extracted from their head and laid neatly on the page, and the ways in which models are elicited, recorded and analysed can all bias research outcomes. In this thesis, reflexive accounts of each stage (sections 3.4 and 5.2.3) help to recognise such issues.

An expert model of truth?

> *'Science does not monopolise social rationality' (Stirling, 2011, p. 305).*
>
> *'Science informs, not defines' (Wynne, 2011, p. 305)*

The terms 'misunderstandings' (Cox et al., 2003), 'misinterpretations' (Cox et al., 2005) 'misconceptions' (Morgan et al., 2002), 'misperceptions' (Austin & Fischhoff, 2011; Lata & Nunn, 2011) and 'incorrect beliefs' (Morgan et al., 2002; Read et al., 1994; Reynolds et al., 2010) are common in mental models literature. Such terms imply that the expert model is correct or true, while the public model is not; and this is not necessarily the case. Science and Technology Studies (STS) show us that science is not rational, instrumental and self-contained, but is instead socially constructed; 'essentially and irredeemably human', affected by social, political and cultural values (Edge, 1995, p. 5). What then, is scientific truth? Kuhn stated that there is not one truth; amongst scientists, experts or members of the public (Kuhn, 1962). We cannot know truth when theories cannot be proved to be true but can only be falsified (Popper, 1963).

So while experts may have formal, scientific understanding, they are not the arbiters of truth. Indeed, local and lay knowledges 'may well represent a more robust and well-tested body of advice, information, and practical assistance than any new or externally generated piece of technical evidence' (Irwin et al., 1996, p. 55). Therefore, throughout the reading of this thesis, it should be remembered that public views are being compared with expert views by way of a 'tool' for exploring differences in risk perceptions. This does not imply that lay views are wrong; simply that they are different. For this reason, the thesis tends to use the term 'differences' or 'EP differences'[25] rather than 'incorrect beliefs' or 'misconceptions'. Where these latter terms are used, they are done so for brevity and consistency with mental models literature, and should not be taken to mean that such beliefs are inferior to the expert model.

A knowledge deficit?

The mental models approach to risk communication focuses on finding out what information the public requires (Morgan et al., 2002). It therefore tends to focus on knowledge aspects of risk perception. Indeed, knowledge has been shown to be a 'key determinant of behavioural intentions' towards climate change action (Bord, O'Connor, & Fisher, 2000), and lack of knowledge has been cited as a barrier towards personal engagement (Lorenzoni et al., 2007). However, a common criticism of the mental models approach is that it rests *too heavily* on the **knowledge deficit model** of risk understanding and communication. This model essentially says that the public knows too

[25] EP differences is used as an abbreviation for 'Expert/Public differences', to mean the differences between the expert model of SLC and lay perceptions of SLC.

little in order to act appropriately; misconceptions lead to inappropriate responses, and thus the public needs to be educated in order to respond appropriately (Kempton, 1997).

Critics of the knowledge deficit model point out that perceptions are determined by a great many factors in addition to a person's knowledge of a risk (Baumann & Sims, 1978; Kahan et al., 2012). This idea is not new; Kates (1971) suggested that residents of hazardous areas have a 'hazard perception threshold', below which no action is taken; thresholds that are unique to individuals and vary according to factors such as the individual's personality and previous experience (Kates, 1971, p. 441). Indeed, the definition of risk perception provided by Pidgeon et al. (1992, p. 89) includes 'people's beliefs, attitudes, judgements and feelings, as well as the wider cultural values and social dispositions people adopt'. Information is interpreted in relation to such prior beliefs and cultural values (Kahan, Jenkins-Smith, & Braman, 2011), and so 'communicators must attend to the cultural meaning as well as the scientific content of information' (Kahan et al., 2011, p. 23). Pidgeon and Fischhoff (2011) stress that communications should therefore respect audiences' values and feelings, not only listening to the 'facts' that people know, but to other contextual factors as well. Accordingly this thesis adopts an interpretive approach to risk perceptions, which seeks to both retain a focus upon knowledge (Sturgis & Allum, 2004), alongside an investigation of feelings, concerns and other factors.

2.5 An interpretive approach to risk perceptions

During the last few decades, a number of frameworks have developed to explore risk perceptions. The **psychometric paradigm** (e.g. Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978) was developed in the 1970s to use psychometric scaling methods to quantify and rate qualitative characteristics of risk perceptions such as control, dread and knowledge. Soon after, Douglas and Wildavsky's (1983) **Cultural Theory** of risk paved the way for the inclusion of more social and cultural factors in risk perception, such as blame. These factors are now recognised as essential: after all, we do not exist in a vacuum, and are influenced by a plethora of social networks and norms. A more recent suggested extension to cultural theory is the **cultural cognition of risk**, which draws on both cultural theory and the psychometric paradigm to describe how people form perceptions of risk that are coherent with their self-defining values (Kahan, Slovic, Braman, & Gastil, 2006). In this framework, the psychometric paradigm 'furnishes an account of the *individual level mechanisms* [such as heuristics[26]] through which cultural values shape risk perceptions' (Kahan et al., 2011, p. 2). The **Social amplification of risk** framework also attempts to unify the psychometric and cultural theories of risk (Pidgeon & Beattie, 1998) by linking 'systematically the

[26] Heuristics are cognitive aids or mental shortcuts, used to form judgments and make decisions.

technical assessment[27] of risk with psychological, sociological, and cultural perspectives of risk perception and risk-related behaviour' (Kasperson et al., 1988, p. 177). It examines how more 'objective' risk characteristics such as number of deaths can be *amplified* or *dampened* through social and psychological processes and interactions between actors. Finally, a later development in risk research has seen an 'increased awareness of and interest in more interpretative qualities of risk perceptions as grounded in context' (Pidgeon, Simmons, & Henwood, 2006, p. 96). This **interpretative approach** places a greater emphasis on qualitative methods, which are better able to 'capture the complexity of risk perceptions in specific hazard locations' (Pidgeon et al., 2006, p. 103). As such, interpretative approaches might incorporate such concepts as place identity (e.g. Bickerstaff, Simmons, & Pidgeon, 2006b) and biography (e.g. Parkhill, Pidgeon, Henwood, Simmons, & Venables, 2010).

As discussed above, mental models studies have traditionally focussed on knowledge rather than on these contextual factors (Bostrom et al., 1994; Morgan et al., 2002; Read et al., 1994). However, some mental model studies have begun to investigate such contextual factors in addition to knowledge. Cox et al. (2003) used a grounded theory[28] approach for their analysis of chemical users' interview transcripts, which raised issues of concern, experience and personal barriers to using protective measures. Their 'expanded mental models approach' allowed the research team to capture more of the 'considerable complexities and contextual richness in user representations and understandings' (Cox et al., 2003, p. 322). In a later study, Cox et al. (2005) also investigate contextual factors, discussing concern, affect and acceptability in their mental models studies of public perceptions of electromagnetic fields. This thesis also adopts such an interpretative approach to investigate contextual factors, in parallel with the more traditional knowledge-based mental models approach developed by Morgan et al. (2002).

Like in Cox et al's (2003) study, the interpretative approach used here is facilitated by a grounded analysis of the mental models data. Such an analysis was not however the initial aim of the study. It was during EPP transcription that it was decided that contextual factors should be investigated, due to themes such as optimism emerging from the data. These factors are discussed under three main headings: orienting dispositions, risk appraisals and responses, drawing on a variety of frameworks (particularly Bubeck, Botzen, & Aerts, 2012; Dake, 1991; Grothmann & Reusswig, 2006; Rogers, 1975). First, **orienting dispositions** include an individual's sources of information and personality characteristics, which may influence their appraisal of a risk. Second, this **risk appraisal** can be conceptualised as having two components: an appraisal of the threat itself ('threat appraisal'), and an appraisal of the individual's ability to cope with the threat ('coping appraisal').

[27] The technical assessment of risk focuses on the probability of events and the magnitude of consequences (Kasperson et al., 1988).
[28] In grounded theory, the theory is generated by the data, approaching the research without any strong prior theory (Henwood & Pidgeon, 1992).

Third, their **responses** to a risk may be active (such as installing a flood board or buying home insurance) or inactive (such as avoiding the issue).

Although themes are broadly categorised into these three categories, in reality they interact and do not stand alone. For example, while the psychological distancing[29] of risks could be described as an orienting disposition whereby individuals who think about a risk as psychologically distant may be less likely to engage with possible solutions (Lorenzoni & Pidgeon, 2006), it could also be described as a non-active response, 'a manifestation of a personal denial about direct effects' (Lorenzoni & Pidgeon, 2006, p. 82). Scepticism and uncertainty, which are also here categorised as personality variables (orienting dispositions), could equally be described as inactive responses, for example where individuals fall into a maladaptive 'uncertainty trap', claiming that they "don't yet know enough to act" (Moser, 2007, p. 67).

The next section expands upon each of the factors discussed in the thesis, drawing on relevant risk perception literature. To reiterate, these factors emerged from a thematic analyses of public and expert interviews, so the following review does not attempt to cover all aspects that may influence risk perceptions. Instead it provides a theoretical background for the data analyses. As discussed in section 2.3.3, literature on public perceptions of SLC is sparse. Therefore, the following review draws on literature from both SLC perceptions in particular and climate change perceptions more generally.

2.6 Factors included in the analysis of public perceptions

2.6.1 Orienting dispositions

Orienting dispositions are those factors that may 'predispose' an individual to make particular choices and decisions. They include sources of information, personality variables[30] and demographic factors such as age and gender. Each is discussed here.

Sources of information

Formal education

British school children are introduced to a range of scientific disciplines, and the ways in which teachers present scientific information has been suggested to affect confidence in science as a

[29] Psychological distance describes the perceived remoteness of things. Something is psychologically distant if it is far into the future or past, in a distant place, refers to experiences of others, or is unlikely (Liberman & Trope, 2008).

[30] Personality can be defined as 'the sum total of the behavioural and mental characteristics that are distinctive of an individual' (Colman, 2009, p. 565).

whole (Oulton, Dillon, & Grace, 2004). However, a higher level of education does not necessarily mean higher scientific literacy (Hargreaves, Lewis, & Speers, 2003). This may be because our time exposed to science at school is small compared to our time exposed to science elsewhere (Falk & Dierking, 2010)[31] such as through media, friends, museums and walks in the park. It is therefore important to consider how such other information sources may influence risk perceptions, as discussed below.

Media

People receive information about climate change and SLC through a variety of media, including television, newspapers and online sources. TV is among the most common sources of scientific information in the UK (Hargreaves et al., 2003), and is also one of the most trusted: TV (particularly the BBC) is rated as more trusted than newspapers or the internet in Europe (CLAMER, 2011a) and the UK (Hargreaves et al., 2003). Some research shows that although people tend to say they distrust media *per se*, they tend to trust the media that they do use (Hargreaves et al., 2003). However, they do not passively absorb and blindly trust whatever they read (e.g. Butler & Pidgeon, 2009). While media tend to focus on flooding and SLC generally rather than in relation to specific areas of the UK (Harvatt et al., 2011), journalists in prominent UK newspapers do tend to accurately portray SLR projections (Rick et al., 2011).

Science

A whole body of research has developed to investigate the character and situation of knowledge amongst experts and lay publics, and it is recognised that 'the public understanding of science represents an *interactive* process between lay people and technical experts rather than a narrowly didactic or one-way transmission of information packages' (Wynne, 1991, p. 114). For example, studies show that members of the public often see science as an inaccessible 'other' possessing 'unique powers' (Bickerstaff, Lorenzoni, Pidgeon, Poortinga, & Simmons, 2008; Bickerstaff, Simmons, & Pidgeon, 2006a; Michael, 1992). In Michael's account, the public address science as 'an abstract entity or principle' (p313) and differentiate themselves from it, being 'not mentally equipped to comprehend science' (Michael, 1992, p. 318). But the public also challenge expert authority, for example by undermining theoretical knowledge by common sense (McKechnie, 1996). Research shows that despite this complex relationship, scientists tend to be among the most highly trusted sources of information (CLAMER, 2011b; Ding, Maibach, Zhao, Roser-Renouf, & Leiserowitz, 2011; Hargreaves et al., 2003; Whitmarsh, Kean, Peacock, Russell, & Haste, 2005). However, in 2012, one third (34%) of UK respondents disagreed with the statement that 'climate

[31] This paper refers to work carried out in the USA. However, their calculations are broadly in line with the contact UK school pupils also receive.

scientists can be trusted to tell us the truth about climate change' (Shuckburgh, Robison, & Pidgeon, 2012).

Experience: direct and vicarious

> *"Who are you going to believe? Me or your own eyes?" – Chico Marx in 1933 film 'Duck Soup'*

We live in a culture where 'seeing is believing' is an 'axiom of common sense' (Irwin et al., 1999, p. 1315). Weber (2010) suggests that learning about climate change from personal (direct) experience is difficult because observations are spaced in time and memory of past events can be faulty. However, research indicates that experiences of *specific* local risks such as flooding are influential in determining perceptions of these risks (Baumann & Sims, 1978; Harvatt et al., 2011; Siegrist & Gutscher, 2006; Spence, Poortinga, Butler, & Pidgeon, 2011; Wagner, 2007). Personal observation is the most trusted source of information on the causes of flooding (Whitmarsh, 2008), and mental models of flash flooding risks have been shown to be founded on personal experience, consisting largely of observations (Wagner, 2007). Visibility is key and 'the more visible an influencing factor, the better it is understood' (Wagner, 2007, p. 679).

Local knowledge is important in the public understanding of global environmental issues as well as local ones (Bulkeley, 2000). However, the experience of local flood risks on the perception of more global risks such as climate change are more mixed: for instance Whitmarsh (2008) found that flood victims' understanding of and responses to climate change differs very little from those of other people; while Spence et al. (2011) found that people reporting experience of flooding tend to express more concern over climate change. Similarly, in qualitative interviews with residents in four UK locations, Zsamboky, Fernández-Bilbao, Smith, Knight, and Allan (2011) found that there were higher levels of awareness of climate change by residents of areas in which flooding had occurred.

The link between direct experience and risk perception has been explained by way of the availability heuristic and the Precaution Adoption Process Model. The availability heuristic (Tversky & Kahneman, 1973), postulates that people make judgements about the probability of events by how easily they think of examples. Here, experience is relevant because if an individual has experienced a risk they are likely to think it is more probable, because they think of examples more readily. The Precaution Adoption Process Model asserts that health-protective behaviours are enacted after an individual has progressed through a series of stages, from being 'unaware' of the risk, through 'uninvolved', 'undecided', 'decided to act' (or not), 'acting' and 'maintaining action' (Weinstein, Sandman, & Blalock, 2008). In this model, personal experience of a hazard is likely to determine progress between stage two (unengaged) and stage three (undecided) (Weinstein et al., 2008).

Individuals can also gain experience vicariously, for example through learning from informal sources of information such as friends, family and the community. 'In the absence of personal familiarity people might draw on second hand experience' (Marx et al., 2007, p. 54); and such vicarious experience has been shown to affect climate change risk perceptions, at least in the short term (Lowe et al., 2006). Research shows that the amount of information gained through such sources can vary across age groups; while 32% of 18-24 year olds get information about marine climate change issues from friends and family, only 14% of individuals aged 65+ get information from these sources (CLAMER, 2011a).

Personality variables

Concern

In a recent survey of the Welsh public, 36% of respondents were very concerned about climate change, 48% were fairly concerned, 9% were not very concerned and 7% were not at all concerned (Capstick, Pidgeon, & Whitehead, 2013). In relation to SLC in particular, 70% of European respondents report being concerned about SLR (CLAMER, 2011a), with such concerns ranking high compared to other marine climate change issues (CLAMER, 2011b). In the USA, 70% of survey respondents said they would be bothered a great deal if sea levels rose 20 feet, flooding coastal areas (Hamilton, 2008)[32].

Despite widespread self-reported concern about climate change issues among European and USA publics, climate change ranks low *relative to other concerns*, and is a psychologically distant risk (Lorenzoni & Pidgeon, 2006; Pidgeon, 2012; Wolf & Moser, 2011). It particularly receives low priority compared to day-to-day issues like personal economic security (Lorenzoni et al., 2007; Zsamboky et al., 2011). Concern about climate change decreased between 2006 and 2010 (Pidgeon, 2012), a decline that could be attributed to a number of factors. First, there may be a 'finite pool of worry' (Weber, 2006), where we can only worry about so many things at once; if a new concern enters our consciousness, others may be perceived as less of a worry. Second, concern may decline as a result of individuals getting fatigued or simply bored with climate change (Kerr, 2009). Third, individuals may be ambivalent, holding coexisting opposing attitudes, opinions or feelings[33]. Indeed, qualitative studies of survey responses show that 'just because an individual explains they do not personally worry about global warming does not mean that they think there is nothing to worry about" (Carolan, 2010, p. 316). Such ambivalence can be due to avoiding the issue, holding fluid or unstable attitudes, changes in opinion over time, and the wording or interpretation of

[32] Note that the framing of SLR as causing flooding in coastal areas is likely to have inflated this response.

[33] This is the dictionary definition of ambivalence; *not* its common usage as meaning indifference.

questions (Carolan, 2010). Distrust and politicisation of the issue may also be factors (Pidgeon, 2012).

Uncertainty and Scepticism

'Nobody likes uncertainty' (Sandman & Lanard, 2011), which is unsurprising, particularly in the context of SLC where uncertainty means not knowing whether to buy a house on the floodplain or invest in a ten-metre high flood defence. Public uncertainty about climate change is a complex issue and has been found to relate to many factors including emotions, perceived levels of knowledge and knowledge sufficiency, risk judgment variables (Powell, Dunwoody, Griffin, & Neuwirth, 2007), and values (Kahan et al., 2011). Kahan et al. (2011) for instance found that egalitarians tended to perceive higher consensus on climate change. This is in part through a mechanism of biased assimilation, whereby individuals perceive information consistent with their own attitude as more convincing, thus assimilating this evidence in a biased manner (Corner, Whitmarsh, & Xenias, 2012; Kahan et al., 2011). It has recently been suggested that genuine uncertainty amongst the public about one aspect of climate change risk can spread to generate uncertainty about other aspects, in what has been termed 'uncertainty transfer' (Spence, Poortinga, & Pidgeon, 2012).

There is growing recognition that climate change uncertainties need to be communicated; for example the IPCC states that risk communications are improved by the explicit characterisation of uncertainty (IPCC, 2012), and the Environment Agency recognises that it needs to communicate uncertainties so that people can make more informed decisions (Defra & Environment Agency, 2011). Indeed, although some scientists believe that the public cannot understand uncertainty (Frewer et al., 2003), research shows that the public understand uncertainties regarding climate change (Darier & Schüle, 1999). Furthermore, Fischhoff (2011, p. 703) suggests that framing climate science as uncertain shows 'the fateful gambles that we face. From that perspective, greater uncertainty can mean greater reason to act'. Communicating uncertainty may also increase trust in communications, and may make public expectations of scientists and risk assessors more realistic in the long-run (Johnson & Slovic, 1995).

While uncertainty 'refers to a lower subjective sense of conviction or validity', scepticism refers to strongly held disbeliefs in climate change (Poortinga, Spence, Whitmarsh, Capstick, & Pidgeon, 2011, p. 1016). Research shows that although climate change scepticism about trends and attribution is not currently widespread in Britain, scepticism about impacts and the belief that climate change as an issue has been exaggerated, is more prevalent (Poortinga et al., 2011; Shuckburgh et al., 2012; Whitmarsh, 2011). Research suggests that scepticism is largely determined by environmental and political values rather than education or knowledge (Poortinga et al., 2011; Whitmarsh, 2011). Both uncertainty and scepticism about climate change are thought to act as barriers towards engagement with the issue (Lorenzoni et al., 2007): if people think risks do not or

might not exist, they are less likely to respond to them. Indeed, in a number of US states, doubt in SLR is impacting on adaptation measures, as residents cite peer reviewed papers showing lower rises and sceptic view points (Peach, 2012).

Values and worldviews

Cultural theorists such as Mary Douglas and Aaron Wildavsky (e.g. 1983) stress the importance of values and worldviews in risk perceptions. Values can be defined as concepts or beliefs that pertain to desirable end states or behaviours, transcend specific situations, guide behaviour, and are ordered by relative importance (Schwartz, 1992). While values focus on general overarching life goals, worldviews focus on more specific aspects (de Groot & Thøgersen, 2013). Worldviews are 'general social, cultural and political attitudes towards the world' (Leiserowitz, 2006, citing Dake), which 'provide powerful cultural lenses, magnifying one danger, obscuring another threat, selecting others for minimal attention or even disregard' (Dake, 1992, p. 33).

Both values and worldviews have been found to affect a range of climate change perceptions from scepticism (Poortinga et al., 2011) and policy preferences (Leiserowitz, 2006) to perceptions of scientific consensus (Kahan et al., 2011). For example, Whitmarsh (2011) found that values and politics are a much larger predictor of climate change beliefs than education and knowledge. Bellamy and Hulme (2011) found that egalitarian values were associated with heightened perceptions of the risks posed by abrupt climate change, while other research suggests that people who hold the worldview that the environment is resilient may find environmental risks more acceptable because they believe that nature can take whatever is thrown at it (Tansey & O'Riordan, 1999).

Future thinking

Studies have shown that people find it difficult to envision the future, particularly on timescales of 50 years or more (Lorenzoni & Hulme, 2009), or even as little as 15-20 years, after which peoples' imaginings of the future 'go dark' (Tonn, Hemrick, & Conrad, 2006, p. 810). People think about time in different ways (Moser, Stauffacher, Krütli, & Scholz, 2011). Some, for example, are optimistic, while fewer are pessimistic (Carver, Scheier, & Segerstrom, 2010). Some think about the past in order to consider the future, while others think about all the possible things that *could* happen regardless of what has happened in the past (van Asselt, van't Klooster, van Notten, & Smits, 2010). Van Asselt et al (2010) identified two 'temporal repertoires' to describe how experts think about the future: historic determinism, where the future is conceptualised as being determined by the past and present; and futuristic difference, where the relationship between the past, present and future is looser, and discontinuity is key. They suggest that despite foresight practice being more aligned with the futuristic difference repertoire, there is a strong tendency to resort to historic determinism.

Psychological distance

Psychological distance describes the perceived remoteness of things. Something is psychologically distant if it is far into the future or past, in a distant place, refers to experiences of others, or is unlikely (Liberman & Trope, 2008). Construal Level Theory (CLT) posits that psychological distance is related to the extent to which people's thinking is abstracted or concrete. In CLT, predicting far into the future requires a higher level of construal than predicting close events (Trope & Liberman, 2010), and distant events are more likely to be represented by a few abstract features rather than by complex, contextualised ones (Trope & Liberman, 2003). Psychological distance has a number of implications. When thinking about something requires a high level of construal (i.e. when it is psychologically distant), it is perceived to be less likely (Pahl, 2010). *Lower* levels of psychological distance in relation to climate change are associated with *higher* levels of concern (Spence et al., 2012).

Studies show that the UK public associates climate change with impacts that are distant in both time and space (Shuckburgh et al., 2012; Spence et al., 2012). Psychological distance has also been found to apply to SLC: Evans et al. (2012) found that New Zealanders perceive greater seriousness of sea-level rise for the world than for New Zealand, and a greater threat for New Zealand than for themselves. However, as with many other factors that influence perceptions, the situation is more nuanced than this. Spence et al. (2012, p. 970) found that the UK public 'really perceives climate change as global, being both distant and local in nature'. Likewise, a recent Wales-specific survey report showed that the Welsh public perceive the impacts of climate change to be close to home and relevant to the here and now, while also expressing high levels of concern for developing countries and the natural world (Capstick et al., 2013).

Emotions

> *'we cannot assume that an intelligent person can understand the meaning of and properly act upon even the simplest of numbers such as amounts of money or numbers of lives at risk, not to mention more esoteric measures or statistics pertaining to risk, unless these numbers are infused with affect' - (Slovic, Finucane, Peters, & MacGregor, 2004).*

The way that somebody feels about a risk is an important aspect of their perception of that risk. We are after all emotional beings and rely on the 'feelings' we get about risks every day, as basic as judging whether someone on the street is going to cause us harm. Researchers in both sociology and psychology have investigated how the ways in which someone *feels* about a risk affects their perceptions of it. Cultural theorists have drawn on such influences as Immanuel Kant's aesthetic judgments, which inspired Lash's (2000) 'risk cultures', defined by aesthetic notions of taste rather

than by cognitive judgment. Lash describes these notions as affective, embodied and habitual, based on feelings such as pleasure, fear, shock and joy (Lash, 2000). To Lash, risk perceptions take place through imagination and sensation rather than judgments determined by physics and maths that have an 'objective reality' (Lash, 2000, p. 52).

Social psychologists have been influenced by a variety of work in their analyses of risk, including influential research on heuristics (e.g. Tversky & Kahneman, 1974). Slovic and colleagues particularly endorse the importance of the affect heuristic –the feeling that something is good or bad- in rational reasoning about a risk, for example in its impact on probability assessments and in risk/benefit judgements (Slovic et al., 2004; Slovic, Finucane, Peters, & MacGregor, 2007). Often, this 'affect heuristic' is reliable, and studies show that analytic reasoning can be ineffective unless guided by emotion and affect (Phillips, 1984). Our emotions about a risk are often guided by previous experiences of it, and research indicates that people who have not experienced a flood underestimate the negative feelings associated with such an event (Siegrist & Gutscher, 2008). Such emotions can influence adaptive behaviours, at least for a time after a flood has occurred (Terpstra, 2011).

Slovic et al. (2004, p. 311) recommend that risk communications should be infused with emotion, particularly where 'lack of experience may otherwise leave us too "coldly rational"'. Roeser (2012) supports this stance, suggesting that emotions are necessary for reflection and understanding the moral implications of climate change, leading to increased motivation. Having said this, emotion can be a de-motivator as well as motivator (Moser, 2007). For example, while some studies indicate that fear is an effective way of motivating behaviour change (Hine & Gifford, 1991), others indicate that fear tactics are ineffective in motivating personal engagement with climate change (O'Neill & Nicholson-Cole, 2009). Moser (2007) suggests that appeals to emotion are only effective when people feel personally vulnerable, have supportive and enabling conditions to act, and believe that they and their response can effectively solve the problem.

Demographics

Socio-demographic factors such as gender and age have been found to influence the interpretation of risk. Research indicates for example that women tend to be more concerned than men about climate change (Shuckburgh et al., 2012), marine climate change issues (CLAMER, 2011a) and SLR (Hamilton, 2008); and some studies suggest that women have greater scientific knowledge of climate change than men do, despite underestimating this knowledge in self-report measures (McCright, 2010). However, the effects of gender on climate change perceptions are contested. Firstly, it appears that when climate change is framed as a global rather than a local issue, a gender effect may not exist (Davidson & Freudenburg, 1996). Secondly, research suggests that gender

effects that do exist may not be due to demographic characteristics *per se,* but due to other features of the men and women recruited for risk perception research (Flynn, Slovic, & Mertz, 1994).

Some research finds that older people are less concerned about or perceive a lower threat from climate change (Kellstedt, Zahran, & Vedlitz, 2008; Whitmarsh, 2008) and SLR (Hamilton, 2008) than young people; a relationship suggested to reflect the assumption that climate change is a future risk (Whitmarsh, 2008). Zsamboky et al. (2011) found a 'not in my lifetime' mentality due to the great proportion of elderly people living in coastal towns. This finding was supported by Fernandez-Bilbao (2012), who found that older participants were particularly dismissive of climate change, believing it would not happen in their lifetimes. However, other research indicates that concern about climate change *per se* and marine climate change issues in particular is lowest among younger people[34] (CLAMER, 2011a; Shuckburgh et al., 2012). This discrepancy might in part be explained by recent research that indicates the relationship between age and concern about SLC is not a linear one, with middle-aged people showing the highest levels of concern. This was found in a recent survey of the Welsh public, which showed that it is the oldest and youngest groups who are least concerned about climate change (Capstick et al., 2013).

2.6.2 Risk appraisal

Threat appraisal: knowledge

In self-report measures, 41% of UK survey respondents know a fair amount or a lot about climate change (Shuckburgh et al., 2012). However, a number of key misconceptions are often cited. For example, the belief that ozone layer depletion causes climate change has been found in a number of studies (Bord et al., 2000; Bostrom et al., 1994; Tobler, Visschers, & Siegrist, 2012). Recycling is consistently cited as a key mitigation measure (e.g. Lowe et al., 2006; Read et al., 1994), a perception also at odds with expert consensus[35]. Regarding specific knowledge aspects, studies show that public knowledge of consequences tends to focus on immediate physical impacts, such as flooding, rather than more indirect impacts such as social disruption (Capstick et al., 2013; Lorenzoni et al., 2006).

With regard to SLC, 43% of European respondents feel informed about SLR (CLAMER, 2011a), and research both in Europe (CLAMER, 2011a) and the USA (Akerlof, 2012) shows that the majority of respondents think that sea levels will rise in future. Some specific aspects of SLC are generally understood, for example ice-melt is a highly salient image associated with climate change

[34] Shuckburgh et al. (2012) found that young people in the UK (16-24 year olds) express less concern than older people (35-64) about climate change. CLAMER (2011a) found that older people expressed more concern than younger people, especially those in the 55-64 age bracket compared to 18-34 year olds.

[35] Although recycling reduces the energy used to make new products, therefore mitigating climate change and SLR, this effect is small compared to mitigation approaches such as using renewable technologies and greener transport.

(Lorenzoni et al., 2006). However, a number of misconceptions have been cited, notably regarding the causes of SLC. For example, just 16% of survey respondents in Ann Arundel County (Maryland, USA) correctly stated that about half of observed SLR in the region is due to subsidence (Akerlof, 2012), and studies show a low awareness of the importance of thermal expansion (Read et al., 1994; Reynolds et al., 2010; Tobler et al., 2012).

Knowing about the causes of SLC may be particularly important, with knowledge of the causes of global warming shown to be a 'key determinant of behavioural intentions to address global warming' (Bord et al., 2000, p. 205). It is suggested that this is because 'intent to behave responsibly requires actual knowledge of global warming causes. Believing something bad is happening need not coexist with knowing what to do about it' (Bord et al., 2000, pp. 206-207) and 'responsible decision making requires at least some minimal knowledge of cause and effect' (Bord et al., 2000, p. 216). Indeed, survey results from Switzerland showed that of all their knowledge subscales, it was knowledge about climate change and its *causes* that were most strongly related to concern (Tobler et al., 2012). Furthermore, Lorenzoni et al. (2007) found that a lack of basic knowledge about the causes of climate change, including as a result of perceived lack of locally-relevant information, was acting as a barrier to engagement.

Coping appraisal

Responsibility

Studies show that individuals contextualise risks within broader perspectives such as blame (Cox et al., 2005), and climate change risks tend to be viewed in a framework of global equalities and fairness (Wolf & Moser, 2011), demography, health and consumption (Darier & Schüle, 1999). Studies show that individuals locate the responsibility for causing and mitigating climate change with others, including individuals, governments, industry, other countries and businesses (Lorenzoni et al., 2007), blaming climate change on factors such as corporations' profit motivated cultures (Darier & Schüle, 1999). The responsibility for climate change action particularly tends to be ascribed to powerful external actors such as government and businesses. This has been found in the UK (Pidgeon, 2012; Poortinga, Pidgeon, & Lorenzoni, 2006; Spence, Venables, Pidgeon, Poortinga, & Demski, 2010b), Wales (Capstick et al., 2013) and in Australia (Ryan et al., 2012). The transferral of responsibility has also been shown to exist in the context of groundwater flooding (Kreibich, Thieken, Grunenberg, Ullrich, & Sommer, 2009) and SLR (Harvatt et al., 2011). The perceived responsibility for SLC adaptation and mitigation is important because if people do not feel personally responsible for the causes of and responses to SLC, they are less likely to engage in adaptive behaviour (Kellens, Terpstra, & De Maeyer, 2013).

Efficacy

Self efficacy is a person's perceived ability to take action and make a difference. Previous research has also shown that taking individual action against climate change is perceived as difficult (Capstick et al., 2013; Spence et al., 2010b). This lack of perceived self efficacy is important because it can be a barrier to engaging with climate change (Lorenzoni et al., 2007); 'unless they feel they can produce the results they want, there is little incentive for people to take action' (Breakwell, 2007, p. 54). The 'locus of control' construct, which describes this locating of control with one's self or with others, emerged in the 1970s and 80s (Breakwell, 2007). In a related field, one early study found that individuals who believe that the locus of control lies with an external power (i.e. have a lack self efficacy) 'confront a tornado in a manner that is consistent with their attitudes [...]; they await the fated onslaught, watchful but passive' (Sims & Baumann, 1972, p. 1391).

Trust

Trust is a complex issue involving a number of facets including confidence, reliability, honesty, consistency, objectivity, fairness and accuracy (Renn & Levine, 1991). Low levels of trust in the agencies perceived to be responsible for flood protection and information dissemination have been found amongst community groups in research reported by Fernandez-Bilbao (2012) in the UK. Similarly, moderate to low levels of trust were placed in councils to protect Wellington city, New Zealand, from future SLR (Evans et al., 2012).

Poortinga and Pidgeon (2003) have put forward the idea of 'critical trust' whereby members of the public do not uncritically accept agencies' decisions, but instead view them with an amount of scepticism. Indeed, a 'healthy' amount of distrust in government agencies can be a good thing. Studies show for example that trust in public flood defences is negatively related to flood preparedness and mitigation (Kellens et al., 2013). However, distrust in the agencies responsible for *communicating* SLC can be problematic, not least because 'when people lack knowledge about a hazard, their risk judgments are based on the degree to which they trust the responsible risk managers' (Kellens et al., 2013, p. 42).

2.6.3 Responses

Active responses

The ways in which individuals, governments and stakeholders may actively respond to SLC on the Severn Estuary include mitigation and adaptation responses. So far in the UK, the main focus in tackling climate change has been mitigation, i.e. attempting to reduce greenhouse gas emissions (Adaptation Sub-Committee of the Committee on Climate Change, 2010), which can include personal measures such as driving less and eating less meat. However, a commitment to SLC

(Nicholls & Lowe, 2004) means that adaptation is also necessary. Adaptation can be defined as 'the planned or unplanned, reactive or anticipatory, successful or unsuccessful response of a system to a change in its environment' (Tol et al., 2009), and on a personal level can include moving away from flood risk areas, purchasing home insurance or installing flood boards. This study focuses on peoples' perceptions of SLC rather that their active responses to it; thus while PPP1 respondents' comments regarding active responses are considered in section 8.2, such responses are not discussed at length.

Inactive responses

Optimism

> *'overly positive self-evaluations, exaggerated perceptions of control or mastery, and an unrealistic optimism are characteristic of normal human thought' (Taylor & Brown, 1988, p. 193).*

People employ a number of cognitive strategies to avoid accepting unpleasant futures (Smith et al., 2011), including denial and unrealistic optimism (Hamilton & Kasser, 2009). Optimism is a common trait (Carver et al., 2010) describing the expectation of success, of good prevailing over evil (Mautner, 1996). People have been found to be unrealistically optimistic about their future life events, believing they are less likely to experience negative events, and more likely to experience positive events than other people are (Weinstein, 1980). Dunning, Heath, and Suls (2004) suggest people hold these optimistic biases because a) they lack crucial information when comparing themselves with others, and b) they ignore valuable information that they have or could find. Optimism has been linked to higher levels of engagement coping and lower levels of avoidance (Carver et al., 2010; Taylor & Gollwitzer, 1995), better health, mood and achievement (Peterson, 2000). It has even been suggested as a prerequisite for our survival as a species (Varki, 2009). But research suggests that optimism and positive illusions may also reduce peoples' capacity for realistic and accurate decision making (Dunning et al., 2004; Taylor & Gollwitzer, 1995), and optimistic beliefs have been cited as potential barriers towards public engagement with climate change (Lorenzoni et al., 2007).

Avoidance

An 'active silencing of risk', whereby people actively take measures to avoid confronting an issue, has been noted in relation to environmental risks such as living with nuclear facilities (Bickerstaff & Simmons, 2009). The reasons for such avoidance may be explained in the context of cognitive dissonance: 'Individuals may use strategies of denial to assuage their guilt in the knowledge that their actions adversely affect the climate, and to justify inaction in response to the uncomfortable

implications of climate change mitigation for high consuming lifestyles' (Lorenzoni et al., 2007, p. 453). The theory of cognitive dissonance states that if a person knows various things that are inconsistent with each other, (s)he will make them more consistent, for example through changing his or her beliefs to be consistent with his or her actions (Festinger, 1962). Thus, if (s)he knows that mitigating climate change means driving less, but will not drive less, (s)he may begin to deny that climate change is a real problem or avoid the issue altogether.

External facilitators and barriers, reappraisals and feedbacks

It should be noted that it is more than a person's risk perceptions that determine their actions. There are a number of other barriers (and facilitators) to engaging with climate change such as a lack of (or provision of) enabling initiatives (Lorenzoni et al., 2007). Zsamboky et al. (2011) list a number of institutional barriers to public action at the coast, including spending cuts and a lack of flexibility with funding (e.g. for coastal defences). These external facilitators and barriers are not considered in detail in this thesis, but are touched upon in section 7.3.1 with regard to the externalisation of responsibility for mitigation and adaptation actions.

2.7 Researcher epistemology and reflexivity

Now that the framework for the thesis has been set, a few notes on epistemology[36] and reflexivity[37] are necessary to situate the study. A fundamental epistemological issue present in all research is that the researcher inevitably contributes his/her own constructions to the interpretation of data (Henwood & Pidgeon, 1992), from selecting the domains of knowledge that are deemed important for the research (Sturgis & Allum, 2004) to interpreting what is meant by a comment made during an interview. This reflexivity should be acknowledged and documented, as it is in this thesis in a reflexive account of each empirical stage. However, I should elucidate my positioning in relation to the research before any such discussions commence. How I approach the research questions is influenced by, among other things: the newspapers that I read (predominantly the Guardian and online media), the leisure activities I engage in (some being water based), where I live (beside the Severn Estuary), the company that I keep (currently a number of sociologists and psychologists!), and my educational background and disciplinary grounding (BA Geography and MSc Science of Natural Hazards).

[36] Epistemology is 'the branch of philosophy that inquires into the nature and the possibility of knowledge' (White, 1996, p. 174), including its acquisition and character.
[37] Reflexivity refers to the ways in which research activity shapes the object of inquiry and vice versa; the 'researcher and researched are characterised as interdependent in the social process of research' (Henwood & Pidgeon, 1992, p. 106).

Although my epistemology has been grounded in geography, this study is truly multi-disciplinary, situated within Psychology and Earth Sciences Departments, aiming to draw together the physical processes of SLC and human responses to it. Influences from other disciplines such as sociology and STS have also been important to situate themes, inform methodology, and aid the interpretation of results. It could be argued that such an approach is not only desirable for climate change research, it is necessary. Climate change and SLC cannot be studied from a human or physical position alone; the nature of the issues means that they are inextricably related. However, interdisciplinary research is challenging and researchers can face many institutional, personal and practical obstacles in conducting, disseminating and following-up their work (Foulds, Macrorie, Franz, & Wang, 2013). Indeed, finding a balance between disciplines has been difficult, but an interdisciplinary approach has also meant that I have been introduced to a wealth of literature that I may not have otherwise come across; a literature that has provided a multi-disciplinary context for findings.

Thirty years of climate change perception and communication research (Wolf & Moser, 2011) have drawn upon many disciplines. Research to date can be broadly categorised into survey studies and more qualitative approaches such as interviews. This is a mixed-methods study, utilising both qualitative approaches (EPP interviews and PPP1 interviews) and quantitative approaches (EPP probability elicitations and PPP2 surveys). Adopting a mixed-methods approach such as this can add 'considerable value' to climate change attitude research by combining evidence from different methodologies (Pidgeon, 2012, p. 86). While quantitative surveys cast a wide net and can investigate statistical relationships, they often belie underlying nuances and ambivalences[38] (Carolan, 2010), and rarely provide much insight into the contexts of public knowledge (Sturgis & Allum, 2004). In this thesis, qualitative data both inform survey content and provide such context. Indeed, the PPP1 and PPP2 data work in tandem, often allowing for the triangulation[39] of findings, 'giving a more complete picture than any one approach alone' (Pidgeon, 2010, p. 12). The adoption of such an approach has facilitated a more holistic consideration of the study's research aims and hypotheses, which are outlined below.

[38] This refers to the dictionary definition of ambivalence as the coexistence of opposing attitudes, opinions or feelings, *not* its common usage as meaning indifference.

[39] Triangulation is a method to 'map out, or explain more fully, the richness and complexity of human behaviour by studying it from more than one standpoint' (Cohen, Manion, & Morrison, 2000, p. 112).

2.8 Research aims and hypotheses

2.8.1 Research aims

As discussed in 2.3.2, the purpose of this study is not to convince people to take a particular action, but to improve communications that provide Severn Estuary residents with the information they need to make their own informed decisions about how to respond to SLC. The outputs of the study should therefore provide an understanding of public perceptions of SLC on the Severn Estuary, and practical recommendations for future communications based upon these findings. The study realises these aims by answering the following research questions:

1. How do 'experts' perceive the risks of SLC on the Severn Estuary? (Chapter 4)
    a. What do experts perceive the risks of SLC on the Severn Estuary to be?
    b. How much SLC do experts expect on the Severn Estuary?
    c. What factors influence expert perceptions of future SLC on the Severn Estuary?
2. How does 'the public' perceive the risks of SLC on the Severn Estuary? (Chapters 6, 7, 8)
    a. Is SLC a salient issue for the public?
    b. What does the public know about SLC on the Severn Estuary?
    c. How much SLC does the public expect on the Severn Estuary?
    d. What factors in addition to knowledge affect public perceptions of SLC on the Severn Estuary?
3. What are the implications of these perceptions for risk communications? (Chapter 9)
    a. What information about SLC should be communicated with the public?
    b. How might SLC best be communicated with the public?

2.8.2 Hypotheses

Communications should be grounded in the findings of this research rather than in prior assumptions of what the public need to know (Morgan et al., 2002). Furthermore, the thesis is exploratory on account of no published research having studied public perceptions of SLC on the Severn Estuary. However, SLC perception research in other regions (Hamilton, 2008; Harvatt et al., 2011) and research on climate change perceptions more generally (e.g. Lorenzoni & Pidgeon, 2006; Pidgeon, 2012; Wolf & Moser, 2011) inform some tentative hypotheses, which are outlined below. A more detailed set of hypotheses, developed from EPP and PPP1 analyses to inform the content of the PPP2 survey, are provided in Appendix J and section 8.5.

Expert perceptions of SLC on the Severn Estuary

It is hypothesised that SLC on the Severn Estuary will be an issue of great complexity, fraught with uncertainties as it is elsewhere (Hansen & Sato, 2012; Woodworth, Church, Aarup, & Wilson, 2010). Although it will not be possible to precisely predict how much sea levels will rise in future, there will be consensus amongst experts that mean sea level on the Estuary will rise, as it is expected to globally (IPCC, 2007, 2013) and locally (e.g. MCCIP, 2010; Phillips & Crisp, 2010; UK Climate Projections, 2012).

Public perceptions of SLC on the Severn Estuary

Research yields mixed results as to the UK public's awareness of SLR (Fernandez-Bilbao, 2012; Tol et al., 2009) so a tentative hypothesis is that there will be some understanding of SLC and its processes, and that most respondents will think that sea-levels will rise in future, as found by CLAMER (2011a) and Akerlof (2012). However, there will be some key 'misconceptions', as noted in previous research (Akerlof, 2012; Read et al., 1994; Reynolds et al., 2010; Tobler et al., 2012). In addition to knowledge, other factors such as emotions and previous experiences will also influence public perceptions (Bubeck et al., 2012; Hamilton, 2008; Harvatt et al., 2011). Like climate change, SLC will be of low concern relative to other issues, and will be a psychologically distant risk (Lorenzoni & Pidgeon, 2006; Pidgeon, 2012; Wolf & Moser, 2011).

3 EXPERT PERCEPTIONS: METHODS

This chapter details the methodology for the first empirical stage of the research: the Expert Perceptions Phase (EPP). This Phase was designed to develop an expert model of the risks of SLC on the Severn Estuary. It involved a literature review and interviews (N=11) with experts in the field of SLC on the Severn Estuary. The chapter first details the overarching rationale for the EPP, before discussing the methodology used for each part of the interview, data analyses methods, and the limitations of each approach. It concludes with a reflexive account of the phase.

3.1 Introduction and overarching rationale

Face-to-face interviews were carried out during the summer of 2011 with eleven experts from academic, consultancy and governmental roles who had expertise in sea-level processes, impacts and adaptation responses on the Severn Estuary. These interviews accompanied a literature review, which together facilitated the creation of an expert model of the risks. This was a mixed methods phase, with each interview session including a semi-structured interview, the creation of a cognitive map and a subjective probability elicitation of future SLR. The interview and cognitive map facilitated the creation of a 'meta-influence diagram', while the probability elicitation produced Estuary-specific estimates of future SLC. Table 4 shows how each part aimed to answer the research questions.

Research Question	**Data**	**Data collection methods**	**Data analysis methods**
What do experts perceive the risks of SLC on the Severn Estuary to be?	Scoping of issues and details of specific processes, impacts and measures. Identification of key experts in the field for interview	Literature review	Assimilation into a meta-diagram of the risks
	Scoping of issues and details of specific processes, impacts and measures.	Semi-structured interview during elite interview sessions with experts in the field of SLC on the Severn Estuary	Thematic analysis facilitating assimilation into a meta-diagram of the risks
	Relationships between risk factors/themes	Cognitive mapping task	Assimilation into a meta-diagram of the risks
How much SLC do experts expect on the Severn Estuary?	Estimates of SLC in 2050, 2100 and 2200	Subjective probability elicitation during elite interview sessions	Conversion of cumulative distributions into box plots and line graphs.
What factors influence expert perceptions of future SLC on the Severn Estuary?	Thoughts articulated during probability elicitations	Audio recordings of subjective probability elicitation	Thematic analysis

Table 4: Research summary, EPP

A literature review was necessary in order to scope the potential topics for interview, to identify experts to approach for interview, and to cover areas not covered during interview sessions. The main literature review was carried out during autumn 2010 and spring 2011, and updated at regular

intervals until November 2012. There are four reasons why expert interviews were necessary to accompany the literature review in creating the expert model. These are:

1. **Topics can be missed during a literature review** and the literature does not always represent nuances and the wide range of opinions held by experts. Interviews tend to give a more 'diverse and heterogeneous picture of a subject than written reports' (Hansson & Bryngelsson, 2009, p. 2274). This can be particularly important in a case such as this, which requires specific knowledge of the Severn Estuary.
2. **Expert judgements are a useful tool while research is ongoing.** While expert judgement is not a substitute for definitive scientific research, it can 'provide useful insights for policy makers and research planners while research to produce more definitive results is ongoing' (Morgan, Pitelka, & Shevliakova, 2001, p. 280).
3. **Expert judgements can provide an up-to-date snapshot of current expert understanding**. Science evolves, and views change. Speaking with experts draws on their most up-to-date views rather than consulting literature that may no longer be fully endorsed.
4. **All methods use expert judgements in some form.** There are three ways of estimating the likely occurrence of future SLC: looking at past records, using computer models to simulate future conditions, and using expert judgement (Arnell, Tompkins, & Adger, 2005). The first assumes that the events in question have occurred in the past, and the conditions were the same then as they will be in future; and the second method relies upon the underlying assumptions of the models (Arnell et al., 2005). Both of these methods require, to some extent, the judgements of experts; even models use expert judgements, either explicitly or implicitly (Arnell et al., 2005; Dessai & Hulme, 2004). The third method, used here, elicits expert judgement directly.

3.2 Expert perceptions phase: data collection methodology

3.2.1 Sampling strategy

With increasing calls for public participation in decision making, there has been a tendency to dissolve the boundary between experts and the public (Collins & Evans, 2002). However, it is necessary to delineate the groups in order to create a model of expert perceptions. There is 'no agreed definition of what constitutes an 'expert'' (Lowe & Lorenzoni, 2007), and expertise can be described using a variety of criteria. An expert can be defined by the way in which they approach a problem (O'Hagan et al., 2006), how they work with the topic (e.g. through interacting with it or contributing to it) or through their lived experience of it (Collins & Evans, 2002). Alternatively, an

expert can be anyone whose knowledge we want to elicit (Garthwaite, Kadane, & O'Hagan, 2005). For this study, interviewees were selected on the basis of their ability to best answer my interview questions (c.f Rice, 2010). As per Morgan and Keith (1995), no attempt was made to select a statistically representative sample of experts, because the main purpose of this part of the study was to scope all the possible risks and explore different opinions and views.

Cooke and Goddens (2004, cited in Lowe & Lorenzoni, 2007) recommend that experts be selected on their reputation including their experience, publications, background and perspectives. Other factors to consider include balance of views, interest and availability (Arnell et al., 2005). For this study, experts from academic, consultancy and governmental roles who had expertise in sea-level processes, impacts and adaptation responses on the Severn Estuary were identified through a literature review, attending events and conferences, and through recommendation. They were initially contacted via email, outlining the objectives and general format of the interview. A snowball sampling procedure was also used, whereby each expert interviewed was asked to suggest others. Hansson and Bryngelsson (2009) point out that the initial sample plays a major role in the outcome of a snowball sampling procedure, but the proportion of contacts made through this method was small compared with my initial sample so this should not pose a great problem. Some bias was however introduced at the sampling stage due to experts' availability, with two of the 13 experts approached not available for interview. Such non-response can introduce error, a function of the number of non-respondents and the degree to which these non-respondents differ from respondents (Goldstein, 2002). To reduce this error, work by the two non-participating experts was included in the model via the literature review despite no interviews taking place.

Participating experts' areas of expertise, genders and number of years of experience are listed in Table 5. As shown, the sample included experts from a range of backgrounds. They together covered each main theme in the expert model, including physical processes, vulnerability factors, social and physical impacts (specific areas of expertise are not shown in Table 5 in order to uphold confidentiality). Although some experts are not leading experts in SLC *per se*, all work on topics related to some aspect of SLR on the Severn Estuary or are involved in related decision making processes.

Expert (pseudonym)	Expertise	Gender	Experience in field (years)
Bob	Academic	Male	5-10
Sandra	Government	Female	<5
Andrew	Academic	Male	>20
Claire	Academic	Female	5-10
Roxy	Consultant	Female	11-20
Harry	Academic	Male	11-20
Matt	County Council	Male	>20
James	Environment Agency	Male	5-10
Daisy	Government	Female	<5
Frank	Academic & advisor to various organisations such as local authorities and the Department of Energy and Climate Change (DECC)	Male	>20
Jack	Academic	Male	>20

Table 5: Expertise of experts interviewed, EPP

Ethical considerations

Ethical approval was obtained from the Cardiff School of Psychology Ethics Committee for each of the three empirical phases of research, including the expert interview phase. The data collection process entailed strict confidentiality in accordance with The British Psychological Society's 'Code of Human Research Ethics' (2010) but was not entirely anonymous due to the nature of the research (the need to transcribe and possibly follow up on interviews). Written consent was obtained from participants prior to the interview commencing, and interviewees were made aware that they could withdraw from the interview at any stage. Opportunities were made available for participants to ask any questions they had. Each was given a full debrief, and informed that they had the right to access the information they gave up until the point it had been anonymised. Participants were also made aware that they had the right to ask for the information they gave to be destroyed/deleted up until the point that the data was anonymised, and were informed of the procedures for contacting the investigator should any concerns have arisen. Letters of invitation, consent forms and debrief sheets are provided in Appendix A. Once data collection was complete, data was anonymised and aliases were used for transcription, coding and analysis.

3.2.2 Interview methodology: introduction

Expert interviews have been used in a plethora of studies, from nuclear radiation (Wynne, 1996) to unemployment (Stephens, 2007). This study used face to face interviews, which remain the 'gold standard' for such interviews (Granger Morgan and Henrion 1990, cited in Kriegler, Hall, Held, Dawson, & Schellnhuber, 2009). Face to face interviews allow a strong rapport to be built between interviewer and interviewee and facilitate a continual 're-moulding' of the interviewer-interviewee interaction through 'visual cues and small utterances' (Stephens, 2007). Also, the probability

elicitation and cognitive mapping methods utilised in this study would have been very difficult over the phone or via email.

The interviews took around two hours, and were carried out either in my office or in the expert's own place of work. The interview protocol, covering the three stages of the interview, can be found in Appendix B. Each session began with an introduction to the project, the objectives of the interview and an outline of what the expert could expect. Participants were then asked a few introductory questions about their job title, description of their expertise and for how long they had worked in the field before the three main interview sections commenced. These were: a semi-structured interview, a cognitive mapping task and a probability elicitation.

3.2.3 Semi-structured interview

Rationale

The first part of the session was a semi-structured interview. An interview can be described as a conversation with a purpose (Kahn & Cannell, 1958 cited in Fowler & Mangione, 1990). The purpose of this semi-structured interview was to elicit experts' opinions in a way that was meaningful to them. The objective was to scope the risks of SLC on the Severn Estuary, and to find out as much about these risks as possible. The value in using semi-structured interviews rather than a structured protocol is that it allows new themes to emerge; themes that may not have been encountered during the literature review.

Methods

The direction of the interview was largely determined by the expert's answers and discussion, though key topics (issues facing the Severn Estuary, SLC processes and impacts) were raised if the expert did not mention them. Additional topics were followed up if the expert mentioned them. These topics included adaptation and mitigation, public understanding, and uncertainty. Additionally, protocols were tailored towards each respondent's area of expertise. So while all main topics were present on all protocols, topics pertaining to the experts' area of expertise were in bold to ensure they were followed up. In some cases, specific topics were added, for example Harry was asked about relationships between the North Atlantic Oscillation and sea level on the Severn Estuary. The protocol ensured that all necessary topics were discussed, while the semi-structured format encouraged maximum input from the expert, allowing them to introduce new topics and focus on those that they thought were important. In practice, all of the main tropics were covered to some extent during each interview.

Limitations

A limitation of semi-structured interviews is that, as with any interview, topics may be missed if the expert does not think of them and if they are not covered with the 'key questions' on the protocol. However, the creation of a cognitive map later in the session was an additional prompt for such ideas.

3.2.4 Cognitive map creation

Rationale

Participants were asked to create a cognitive map to summarise their thoughts about SLC on the Severn Estuary. This stage further explored expert perceptions (particularly relationships between themes), and also acted as a prompt for further thought and discussion. Topics often arose during this stage that had not come up during the semi-structured interview.

It has been argued that mental models can be represented by means of a 'cognitive map' or 'influence diagram' drawn onto paper: a mind map representing knowledge in a manner representative of how the knowledge is used (Kearney & Kaplan, 1997). An influence diagram is a directed network of linked concepts. It is a snapshot of all the factors that a person thinks influence something, including the decisions that might shape the processes. The result should be a 'visual display that expresses a participant's unique knowledge structure' (Kearney & Kaplan, 1997). Such maps can occur at many levels of abstraction. For example I might have a detailed representation of the items in my office and some of the offices in my building, but only a vague representation of some of the buildings on my street. Hereafter, maps created by individual experts are referred to as 'cognitive maps' to avoid confusion with the 'meta-influence diagram' that was created to summarise expert understanding (see 3.3).

Mental models and their corresponding cognitive maps vary among individuals. They may vary by the number of items known, the ways in which items are linked together, and the level of ownership -the degree to which a person knows how to *use* a term rather than just knowing it (Kearney & Kaplan, 1997). Even people who share the same level of expertise can be expected to have different cognitive maps due to different experiences and training (Otto-Banaszak, Matczak, Wesseler, & Wechsung, 2011). Any method of measuring a person's cognitive maps should allow for the expression of these differences (Kearney & Kaplan, 1997).

Methods

The concept of cognitive maps was explained to the participant, and the objectives outlined. Experts were shown an example of a ready-made cognitive map about what influences whether I get sunburnt, with a description of how the map might be constructed. They were then asked to

draw a similar diagram for SLC on the Severn Estuary. Throughout the process they were asked to talk about what they were writing and drawing so that I could understand what each part meant and the rationale behind the map structure. Example cognitive maps are shown in Figure 3 and Figure 4.

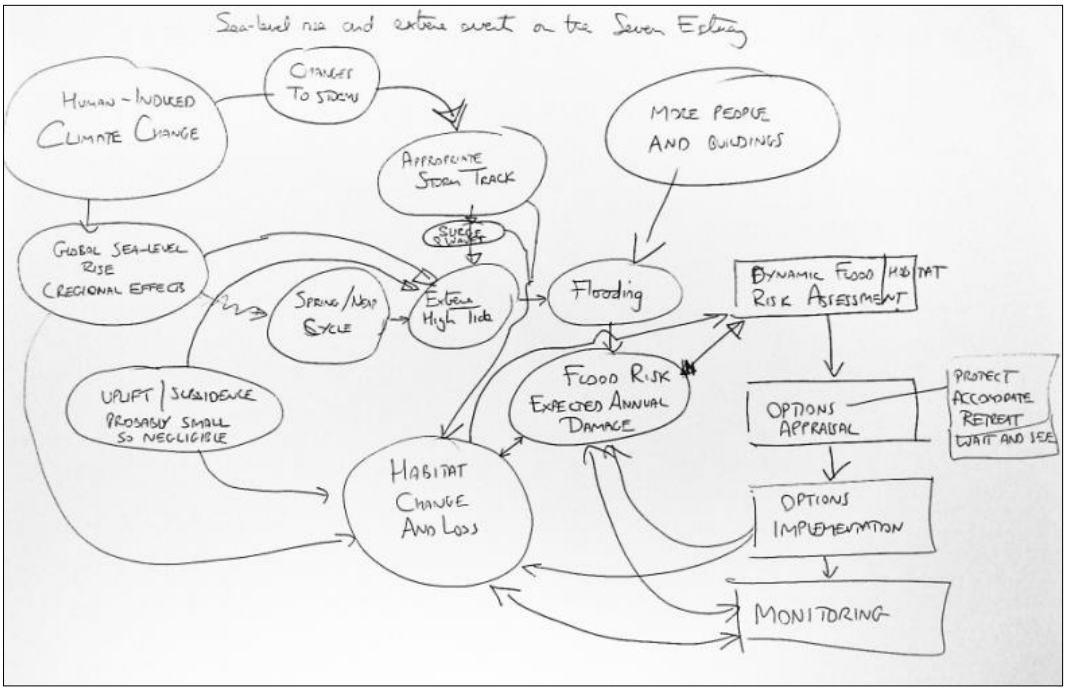


Figure 3: Example of a cognitive map (by Jack, academic)

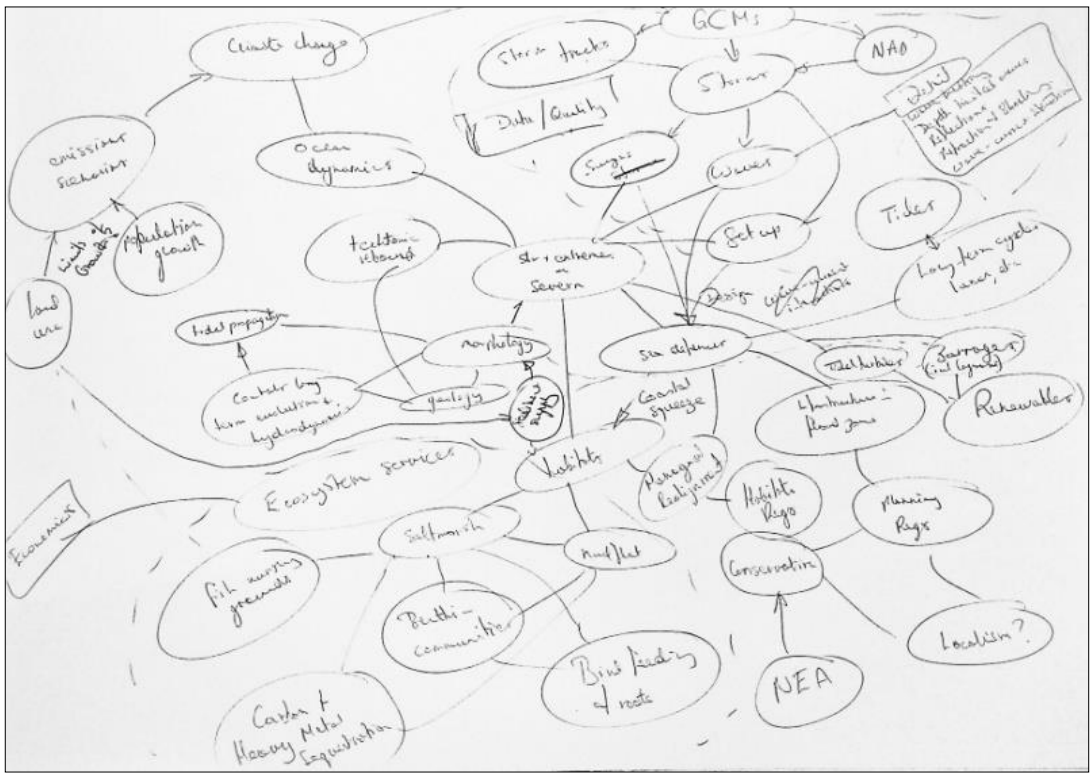


Figure 4: Example of a cognitive map (by Frank, academic and advisor)

Limitations

As with the other stages of the interview session, the cognitive map cannot hope to cover every thought about SLC in an expert's mind. However, in the two hours available, the combination of the semi-structured interview and the cognitive map creation produced a wealth of valuable information for creating a meta-diagram of the risks.

3.2.5 Subjective probability elicitation

Rationale

The scale of impacts on the Severn Estuary will depend on the rate and magnitude of future SLR, which will be forced by both global and local factors acting over short and long timescales. Many of these factors are uncertain. However, policy decisions will still need to be made in order to plan adaptation measures; and without assessments of the scale, magnitude and likelihood of future SLC, policy makers will make their own assumptions about the likelihood of different outcomes (Mastrandrea & Schneider, 2004). Probability is the best known and most widely used formalism for numerically quantifying such uncertainty (Morgan & Henrion, 1990).

There are a number of ways to elicit probability estimates from experts. These include questionnaires that simply ask the respondent to estimate the likelihood that certain events will happen (e.g. Arnell et al., 2005), Delphi methods (e.g. O'Neill, Osborn, Hulme, Lorenzoni, & Watkinson, 2008), and subjective probability elicitations. Watson and Buede (1987) state that questionnaires are the elicitation technique of last resort because experts cannot discuss the meaning of questions with the researcher, and the researcher cannot tailor subsequent questions to experts' answers. The Delphi method is a process whereby experts are asked for their opinions, these opinions are summarised, and shown to the experts again to allow for revisions of their earlier answers, eventually leading to a convergence towards a 'correct' answer. This was not used here because it was these very uncertainties and differences that were being studied.

Instead, each expert participated in three subjective probability elicitations: one for 2050, one for 2100 and one for 2200. Subjective probability elicitation is an established methodology (Spetzler & Stael Von Holstein, 1975). It is a process by which a person's personal probabilistic ideas are converted into a number between zero and one (Jenkinson, 2005), and allows a quantification of an individual's personal judgement of uncertainty based on their synthesis of knowledge, thoughts and published literature (Zickfeld et al., 2007). A probability elicitation was included in the EPP for a number of reasons. These are:

- To provide local probability estimates. Relative SLC occurs at different rates in different locations, so local projections are necessary to allow for effective local adaptation planning.

However, local estimates made using modelling techniques can be problematic due to downscaling factors and spatial variability.

- To facilitate a discussion of multiple viewpoints. Research shows that experts can hold vastly different views about the same topic (Arnell et al., 2005; Nordhaus, 1994; Vaughan & Spouge, 2002; Zickfeld et al., 2007; Zickfeld, Morgan, Frame, & Keith, 2010), but such diversity is not always represented in consensus reviews such as IPCC reports.
- To elicit a distribution of estimates of future SLC rather than point estimates such as means and medians, which do not represent the full range of possibilities. 'So far, much of the focus in assessments of climate change and its impacts has been on central tendencies' (Kunreuther et al., 2013, p. 447). Elicitating probability distributions discourages simplification, embracing the 'intrinsically plural, conditional nature of knowledge' called for by Stirling (2010).
- To further explore the uncertainties involved in estimating SLC. Acknowledging such uncertainties is important for public and planners alike. 'The establishment of consensus by the IPCC is no longer as critical to governments as a full exploration of uncertainty' (Oppenheimer, O'Neill, Webster, & Agrawala, 2007).
- To investigate the contexts in which estimates are made, including assumptions, alternative scenarios, and barriers to elicitation.
- To elicit estimates for 2200 as well as the more usual time periods of 2050 and 2100. Few authors consider projections further into the future than 2100 (but see Lenton et al., 2006; Winkelmann, Levermann, Martin, & Frieler, 2012), when it is clear that beyond 2100 the magnitude of climate change and the resulting impacts are 'likely to be very large indeed' (Houghton, 2009), and management decisions made now have consequences beyond 2100 (Lenton et al., 2006).

Methods

There are a number of ways in which probability judgments can be encoded (elicited and recorded) during subjective probability elicitations. Popular methods include direct estimation where the expert is asked to state their response, responses on a scale, the use of probability wheels[40], and the use of bets. Each has their own advantages and disadvantages. Some are more intuitive for the participant depending on their background, while others yield more analysable data. It has also been documented that respondents' responses can be made more or less extreme by the choice of response mode. 'It is an open question as to whether one response mode gets closer to the true

[40] Probability wheels are devices for visually representing probabilities. The arms of the wheel can be moved to represent larger or smaller slices of the wheel (like a pie chart), and a spinning pointer is anchored in the centre of the wheel. The proportion [X] of the wheel that represents the probability is varied until the probability that the pointer will end up on [X] is the same probability that the elicited value (e.g. sea-level rise) will be [Y] (Morgan & Henrion, 1990).

opinion, or indeed whether opinion actually varies with response mode' (Wallsten & Budescu, 1983, after Fischoff, Slovic and Lichtenstein 1980).

Two elicitation encoding methods were piloted with colleagues (N=3) to test user friendliness and the utility of results. These were: 1) a box plot drawn directly onto a scale whose outer bounds were first stated by the experts, and 2) a cumulative density function (CDF) method whereby participants stated the probability of various sea level magnitudes and their responses were marked on graph paper to produce a CDF. Common problems with boxplot-style methods are centring and spacing effects, where people preferentially use the centre of the scale and space their responses over the scale aesthetically, as reported by Renooij (2001). The CDF method, on the other hand does not require participants to be able to see the results as they articulate them, which reduces anchoring biases[41]. The CDF method was chosen for this reason and for the richer data that it provided. The interview protocol was adapted from the Stanford / SRI Assessment Protocol (Spetzler & Stael Von Holstein, 1975) and from Watson and Buede (1987). It ran as follows:

1. Motivation

   Rapport was developed between the interviewer and the participant during the semi-structured interview, and the objectives of the elicitation were made clear. Participants were made aware of common heuristics and biases such as anchoring, overconfidence[42] and herding[43] in order that such biases might be reduced.

2. Structuring

   The conditions of the probability elicitation were specified so that each estimate was as 'accurate' as possible. However, elicitations were unconstrained: the only conditions specified in this study were that the judgements should be for SLC in 2050, 2100 or 2200 on the Severn Estuary relative to 2011 levels. Two experts responded by doing multiple elicitations for different scenarios.

3. Conditioning

   The participant was asked to talk about the information, scenarios and anchors they were using, and assumptions they were making. Participants were free to refer to trusted sources throughout the elicitation. Having said this, some experts did not do so because such sources were unavailable or because they chose to use what they remembered from the literature. Throughout the elicitation, participants were asked questions such as "how might extreme values come about?" and "is there no way at all that SLC could be more/less than that?" to increase the robustness of estimates.

[41] Anchoring is where an initial estimate is used as an anchor on which to base subsequent estimates, biasing judgments towards the initial anchor (Tversky & Kahneman, 1974).

[42] Overconfidence is common both in expert and non-expert judgements and can result in probability distributions that are too narrow.

[43] Herding occurs when other peoples' opinions are incorporated into our own. It can cause problems if the 'herd' is led down the wrong path.

4. Encoding

   Although the probability elicitations were mainly directed in terms of percentage probability (e.g. a 95% chance of SLC being greater than *X*) or as a decimal (e.g. a probability of 0.95 that SLC will be greater than *X*), judgements were not constrained in this way and participants were encouraged to think of probability however they were most comfortable. For example, Matt described small probabilities as fractions[44]. A probability wheel was available for the experts to use if they wished, but most did not utilise it. The encoding process was as follows:

   - First, the participant was asked to think about what the extreme values might be and give the absolute upper and lower bounds (the range) of possible SLC, however small their probabilities. This reduced the possibility of anchoring on a mean or central estimate (Morgan et al., 2001) and counteracted central bias (the tendency to choose data points around the middle of the distribution). I marked the maximum and minimum sea-level values onto a piece of graph paper and drew a scale between them to create the x-axis.
   - Next, the participant was asked to assign cumulative probabilities to sea-level values within that range. Each response was marked onto the graph (marked with an 'X' on the example in Figure 5), the y-axis of which had been prepared prior to the interview. This process was repeated until around eight points were spread out on the distribution. Any inconsistencies were checked and corrected if necessary.
   - A rough line (marked with an A in Figure 5) was drawn between the points to form a cumulative distribution function.
   - Sea-level values corresponding to the median and the 50% and 90% confidence intervals were then read from the graph (example marked with a B in Figure 5), and the distribution adjusted if necessary until the respondent was satisfied that it summarised their own probability assessment. Elicitations carried out with Bob, Sandra, Andrew, Claire and Harry did not include checking all confidence intervals during the interview session but were confirmed with the experts via email correspondence afterwards.
   - Finally, the participant was asked "If I had £1000 and would give it to you if you made exactly the right estimate of SLC by [year], what would your absolute best estimate be?" in order to obtain a 'best estimate'.

5. Verification

   Throughout the elicitation, estimates were checked to ensure the participant actually believed their distribution. For example, if the probability of more than 50cm sea-level rise was 0.7, the probability of it being less than 50cm was checked to be 0.3.

[44] Some research shows that talking about likelihood as a frequency (e.g. 10 in 100) versus talking about it as a probability (e.g. 10%) affects judgement of risk (Slovic, Monahan, & MacGregor, 2000), so this should be borne in mind.

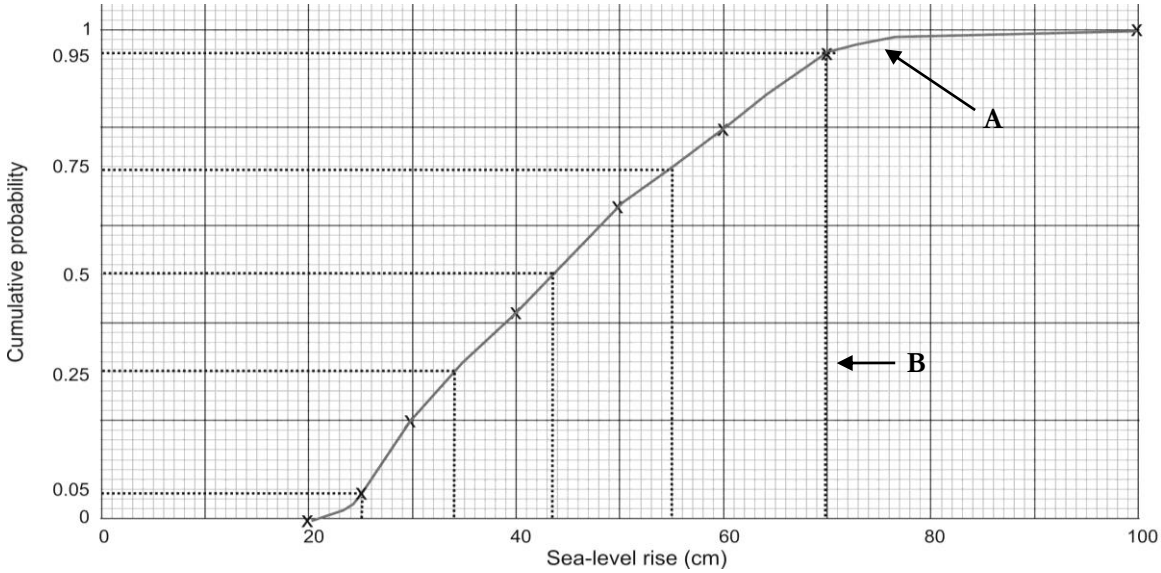


Figure 5: Example of points on an elicited subjective probability distribution

The points [X] are elicited from the expert, before a rough line (A) is drawn between the points. Sea-levels corresponding to confidence intervals (B) are then read off and checked with the expert.

The probability elicitation method used here differs from previous SLC elicitations (Bamber & Aspinall, 2013; Titus & Narayanan, 1996). First, experts were not constrained in their elicitations and were free to make estimates as large or small as they felt appropriate. This is in contrast to elicitations of SLC projections by Titus and Narayanan (1996), where experts were consulted regarding the probabilities of each separate parameter in their SLR model, and results were aggregated, thus constraining projections by model parameters. Second, previous studies have not been systematically analysed in terms of the wider context in which they were made to take into account the factors that may have influenced the experts' judgements. In this study, experts were encouraged to talk through their thoughts as they worked through the elicitations, and the elicitations were audio recorded, transcribed and thematically coded. This allowed for an exploration of how judgements were constructed, and facilitated an increased understanding of expert motivations, assumptions and barriers.

Limitations

There are three main limitations of the probability elicitations carried out for this study. Firstly, the small sample size means conclusions are tentative, leaving research questions regarding the probably judgements of other experts. Because the problem is very specific (SLR *on the Severn Estuary*) the expert base is relatively small, which may cause some skewing by anomalous perspectives (Arnell et al., 2005). Second, it should be noted that each expert's judgement depends on what they retrieve from memory (or their chosen source) at that particular time, and possibly on the order in which the information is integrated into a unified opinion (Wallsten & Budescu,

1983). Each elicitation is therefore a snap-shot of personal opinion at the time the interview was carried out and will change in light of new information.

Third, elicitation is a 'far from perfect process' and while 'probability is perfect [...] we can't elicit it perfectly' (O'Hagan & Oakley, 2004, p. 239). Furthermore, evaluating the success of a subjective elicitation is difficult. Garthwaite et al (2005, p. 694) suggest that 'a "true" distribution would be the result of a method that leads the expert to view the problem from as complete and unbiased a perspective as possible through appropriate use of cognitive tools' and that a successful elicitation will faithfully represent the person's opinion. This was verified to some extent at the end of each elicitation by checking data points with experts and asking whether they were happy with the CDF. Of course, we cannot know which experts were most accurate in their probability elicitations because SLC in 2050, 2100 or 2200 hasn't happened yet. So unlike frequentist probabilities such as tossing a coin, or predictions that are easily tested after the event such as weather forecasts (Murphy & Winkler, 1974), elicitations of SLC for 2050, 2100 and 2200 cannot be calibrated (yet).

3.3 Expert perceptions phase: analysis methodology

Transcription

Around 140,000 words were transcribed during the expert interview phase. Transcription is a pivotal part of qualitative research (Oliver, Serovich, & Mason, 2005) and although it took some time, it was not regarded as a chore to be endured! Transcribing my own material had a number of advantages, namely:

1. The transcription process facilitated 'intense familiarity' with the data, and thus aided the 'methodological and theoretical thinking essential to interpretation' (Lapadat, 2000, p. 204).
2. Transcription can powerfully affect the way in which participants' opinions are understood and what conclusions are drawn (Oliver et al., 2005). In this research, transcription formed the first stage of the analysis, allowing me to get to know the data and make notes on themes as they arose. These themes then formed much of the coding structure, shown in Table 7.
3. I was less likely to make content errors than outside transcribers, as I was present in all of the interviews and was able to contextualise what was said.
4. I was already familiar with the subject matter so understood terminology.

Transcription can be regarded as the first stage of data reduction (Lapadat, 2000); it is not possible to include every nuance, gesture and sigh and so a transcription style must be decided upon. At two ends of the spectrum, interviews can be transcribed in a naturalistic (or verbatim) way, where each utterance is captured in as much detail as possible; or in a denaturalistic way, where grammar

is corrected, interview noise (e.g. stutters and pauses) is removed and accents are standardised (Oliver et al., 2005). I chose an approach somewhere in the middle. Because the purpose of my expert interviews was to create an expert model of the risks, I was interested primarily in information content. The key criteria were therefore that the transcript was readable (i.e. not contain notations that need to be explained) and was a true representation of that the expert said. It was unnecessary to report on each stutter and pause, especially considering the time investment necessary for naturalistic transcription (Halcomb & Davidson, 2006). Furthermore, naturalised transcription can be seen as disrespectful –even unethical- if participants would have written words differently or used different grammar to their spoken words (Oliver et al., 2005; Poland, 2001). Finally, verbatim quotes can be difficult to read, and their impact can be made stronger by some careful editing of the transcript, without changing the meaning of what has been said (Poland, 2001). Having said this, it was important to take into account when an expert expressed uncertainty, so some verbatim features (such as umms and aaahs) were included where contextually relevant. The following protocol was adapted from the literature (McLellan, MacQueen, & Neidig, 2003; O'Connell & Kowal, 1999; Poland, 2001) and was used for both expert and public interviews:

Item	**Protocol**
Long pause	**[pause]**
Short pause	**…**
Interruptions and broken speech	Only when contextually relevant (e.g., not where it is a stutter or stammer) **Wor-**
Inaudible speech	**[Inaudible segment]/[unclear]**
Talking over each other	**[overlapping]**
Uncertain text	It was **[uncertain? Unclear?]** what was said
Garbled words	**XXX XXXX** indicating approximate number of words
Emphasis	**CAPITAL LETTERS**
Sensitive information	**##sensitive information##**
Mispronunciations, grammatical errors, slang etc	Transcribed as the individual says them.
Dialectical pronunciations and enunciated reductions (e.g. 'wanna' and 'sorta')	Transcribed where they are meaningful, e.g. where they are deemed important to the context or might indicate uncertainty. Elsewhere they are standardised.
Filler words (e.g. um, yeah, whoa)	Transcribed where they are meaningful, for example where they are deemed important to the context or might indicate uncertainty. Elsewhere they are ignored.
Word or phrase repetitions	Transcribed where meaningful, for example where they are deemed important to the context or might indicate uncertainty. Elsewhere they are ignored.
Paralinguistic features (vocal phenomena such as laughing and sighing)	Not transcribed unless judged contextually important, where they will be written **[laughing]** for solo person, **[laughs]** for group, **[cough]** etc.
Extralinguistic features e.g. gestures	Not transcribed
Prosodic features (e.g. pitch, duration and loudness)	Not transcribed
Talking about irrelevant information (e.g. the weather today)	Not transcribed. Short comment summarising what is said **[talking about the weather]**

Table 6: Transcription protocol for EPP and PPP1 interviews

'The process of transforming speech into specific words is not without challenges' (McLellan et al., 2003) and an element of subjectivity comes into play when deciding where and when punctuation is required in order to not change the meaning or emphasis of a respondent. Some minor editing has been used to abbreviate quotes in this thesis. This editing largely consists of the removal of obvious repetitions and minor utterances from the interviewer. [...] indicates where larger sections of text have been omitted for clarity or where a topic was returned to after talking about something else.

Thematic analysis

Once interviews were transcribed, the next stage of the research was to 'code' the transcripts to allow an analysis of the themes and concepts within them. Coding describes the process of assigning sections of material (in this case transcript text) to these themes. Thematic analysis is a method of content analysis where the categories in the coding scheme capture the dominant themes within the transcript (Franzosi, 2004). 'Through its theoretical freedom, thematic analysis provides a flexible and useful research tool' (Braun & Clarke, 2006, p. 78). I used both structured (or deductive) coding to code responses on pre-defined themes like 'flooding' (c.f. Hansson & Bryngelsson, 2009) and a grounded exploratory (or inductive) approach whereby themes that emerged from the data were assigned new codes (c.f. Moser et al., 2011). These included codes like 'future' that were used when respondents talked about things that may affect how they think about the future. Some of these codes were then assigned sub-codes to allow for a more detailed categorisation: for instance 'future' consisted of sub-codes 'care' and 'uncertainty'. The framework therefore evolved from a set of pre-defined themes into a more complex set of codes. The final coding framework is shown in Table 7.

NVivo (a computer-assisted qualitative analysis program) was used to aid the coding, sorting and organisation of data. Once the data was coded, the codes were printed out and scrutinised to draw together themes to construct an expert model of the risks. Emergent codes were then scrutinised to explore issues such as the ways in which experts think about the future and what methods they use to make projections of future SLC. Cross-calibration and corroboration of the data with other researchers was not possible because I alone carried out all of the interviews, all of the transcribing and all of the analysis. However, this did mean that some interview error was minimised and meant the interviewing process was highly standardised between interviewees.

Table 7: Coding framework for EPP thematic analysis

Codes and sub-codes	Example	Coding frequency
Processes	It's quite a lot of work just to figure out what's happening now – Jack	10
Climate change (general)	Volcanoes yeah [pause], methane burps - Bob	14
Extreme events	One person's extreme event is not somebody else's - Andrew	48
Rainfall events	In 1981, there had been very little rain – Claire climate change suggests that we're going to see changes in rainfall patterns - Daisy	10
Storms & surges	I think the jury is out on storms – Andrew	104
Tides	You get the morphology essentially controlling the tidal propagation - Frank	27
Tsunamis	There's a couple of people who think it [1607] might have been a tsunami, but there's just so much written evidence that it was a storm – Claire	9
Other risks (i.e. not SLR or extreme events)	I think other things are a greater risk to food security than having to realign the coast slightly. Or climate change. Like foot and mouth, or some other- a crop disease - Roxy	39
Severn Estuary characteristics and vulnerability	You could raise sea levels by ten metres at low tide, and it still wouldn't be that significant - James	42
SLR	[with SLR] an event that was before a 1 in 100 year event, has become more likely - Jack	5
SLR – evidence & historical	When we analysed the extreme sea levels, there was a downward trend, and an upward trend of the minimum extreme sea levels – Harry	12
SLR – processes & rates	If the temperature increases, you will get increased [NAO] indices in the North Atlantic. With quite high probability. And that will mean higher extreme sea levels - Harry	94
Impacts	It's only a problem to us because we live right on the coast - Harry	12
Primary impacts	your potential climate change impacts are much more than they would be maybe on an open coast - Roxy	13
Biochemical cycling	I think we know very little about how sediments are moving through the estuary in ways that are important to biogeochemical cycling – Bob	10
Changes in tidal amplitudes	My judgment would be a decline in tidal range. Or no change – Jack	3
Flooding	[the Severn] is at risk from all these different sorts of flooding - Roxy	3
Coastal & generic	We really did have overtopping in Burnham. It's happened fairly recently - Andrew	75
Fluvial & surface	the length of time that many of the outfalls that we've got along the coast can actually discharge at will be reduced - James	55
Morphological change	centennial time scales before we see any impact on coastal habitats because of sediment loading - Bob	56

Continued…

Table 7 continued

Codes and sub-codes	Example	Coding frequency
Pollution	in a warmer, wetter world, Britain can expect to experience more frequent, big storm events, which will mobilise sediment, potentially pollutants, and all other kinds of stuff from catchments – Bob	19
Secondary impacts	there's another dimension here of course. More people and buildings - Jack	21
Economic, infrastructure & resources	it can't always be the public purse that has to step up and deal with these situations - Roxy	68
Environmental	one risk of course is that we might get species that we don't want - Daisy	31
Other	what are the impacts of food prices, what are the impacts of people moving - Sandra	6
Social (including homes)	most of our towns' populations are located around the coast - Sandra	58
Adaptation & Mitigation	there are some areas of managed retreat, land owners are unhappy, which you can understand- Matt	89
Understanding	I don't think people really understand what is going to happen - Bob	4
Expert's background	my interests are really understanding and managing long term coastal change - Jack	48
Future research	I think we need more research into what has actually taken place here - Andrew	10
Public understanding and communication	You've got to be very careful that we don't frighten people - Andrew	63
Science, epistemology & heuristics	I'm not sure if you can be the judge of whether I'm overconfident here - Jack	174
Timescales	People's values in 100 years, what are they going to be? – Jack	21
Uncertainty & risk – general	[re future sediment erosion and accretion] we just don't know; we just don't know - Bob	70
Probability Elicitation Themes		
Control & Comfort	I'm hoping that it would be less than [30cm SLR], because- actually that is quite a bit of water - Daisy	19
Future	I really can't think that far ahead - Claire	13
Care	If it goes over 2m, I'm not going to be here, what do I care? - Daisy	8
Uncertainty - probability elicitation	We've got no idea. And I'm willing to say "I have no idea". I have no perception at all - Andrew	60
Best/point estimates	point estimate is naughty, really - Frank	20
Methods of estimating probabilities	This is all what I can recall and what we noted from other peoples' work - Andrew	94
Sources	we talk about 1m over the SMPs, which is 100 years - Daisy	38
Severe negative impacts	if it's more than 2m here, that's really really devastating in other parts of the world - Daisy	18
Traits	I'm very optimistic - Claire	18

Table 7: Coding framework for EPP thematic analysis

Cognitive map analysis

The experts' individual cognitive maps were used mainly for a further scoping and discussion of SLC risks on the Severn Estuary. The analysis of transcripts from this stage brought many more issues to light and clarified where and how items were connected in experts' own mental models. The cognitive maps themselves were also studied to ensure all of the topics that were included in the diagrams were considered for the meta-influence diagram. Diagrams were also very useful for assigning topics to themes and for seeing how experts linked themes and topics.

Meta-influence diagrams are necessarily oversimplifications (Wood, Bostrom, Bridges, & Linkov, 2012), and it is not possible to include everything that might possibly influence a risk. Subjectivity is implicit in diagram construction, from which experts are selected and agree to participate, through to the choice of which items go in which section. Like the climate change diagram created by Lowe and Lorenzoni (2007, p. 134), my meta-diagram will bear 'some imprint of the research team who produced it'. However, also like Lowe and Lorenzoni (2007), I have been conscious of minimising the influence of my own views during the interview and map-creation process. One limitation cited by Ozesmi and Ozesmi (2004, citing Kosko 1992) is that if individual maps are aggregated to form one map, 'the interviewees' knowledge, ignorance and biases are all encoded in the maps'. However, I wanted to include such differences and disagreements in my model so this is not a limitation in this instance.

Creating the meta-influence diagram

> *'The expert model is a composite of expert knowledge and beliefs, and is not one assumed to exist in the head of any one expert. It may include contradictory beliefs and uncertainties […] and miss variables that researchers have not studied.' (Austin & Fischhoff, 2011).*

The aim of the meta-influence diagram is to summarise current expert understanding of the risks of SLC on the Severn Estuary. The influence diagram is a core part of the mental models methodology (Morgan et al., 2002), and provides a way of comparing public and expert perceptions. Sometimes, a simple diagram can tie the elements together, but sometimes 'the reality is just complicated, and the diagram reflects that' (Environment Agency, 2011a, p.44). The map was intended to represent qualitative rather than quantitative relationships between nodes. Such qualitative relationships 'capture the sort of information that can be conveyed in non-technical communications, as well as being relatively uncontroversial scientifically' (Maharik & Fischhoff, 1993, p. 246).

Influence diagrams were developed in the 1970s as a way to summarise information about uncertain decisions (Miller, Merkhofer, Howard, Matheson, & Rice, 1976). They have been utilised

by a number of agencies including the Environment Agency (e.g. Environment Agency, 2011a) and the World Economic Forum (World Economic Forum, 2011), for many uses including expert understanding of climate change (Lowe & Lorenzoni, 2007) and chemical risks (Cox et al., 2003). They have a common structure consisting of nodes and influences, which are often categorised into sections for ease of interpretation. Influence diagrams often include two types of node: rectangles to denote decisions, and ovals to denote uncertain circumstances (Morgan et al., 2002). As the majority of nodes in this diagram are processes rather than decisions, for the sake of clarity this delineation was not used.

'There is no simple recipe for converting the scientific information on a risk into an influence diagram' (Morgan et al., 2002, p. 42). Indeed, I found it a far from easy task (see section 3.4). Strategies suggested by Morgan et al (2002) include the assembly method whereby factors are listed and related, the use of physical laws, scenarios, and templates. The methodology used here was based on the assembly method. After coding the interview transcripts, the relevant information was entered into an Excel spreadsheet, using the initial code structure as a starting point, and further iteratively sub-categorised them. These eventually became the basis of a hierarchy. This hierarchy was then worked through with pen and paper, a white board and post-it notes to develop a map structure. This research phase was an iterative process and took around three months. A number of different computer programs and various formats were trialled before a coherent structure was achieved and refined. CMap Tools (2013) software was chosen due to its flexibility, availability of various shapes and arrows, and hierarchical functions. Because SLC on the Severn Estuary is a complex set of interrelated issues, separate diagrams were created for each theme, which were then organised to feed into each other.

Probability elicitation analysis

Probability elicitation analyses consisted of converting CDFs into box plots (c.f. Morgan & Keith, 1995; Morgan et al., 2001) and line graphs showing estimates over time, so that experts' elicitations could be compared and contrasted. Box plots show the range of judged possible values, the 5th and 95th percentiles, the interval spanned by the 50% confidence interval, the median and the 'best estimate'. Line graphs show low, medium and high estimates of SLC for the three time periods. The raw data is provided in Appendix C.

Some authors combine separate expert judgements to provide one refined expert judgement (e.g. Titus & Narayanan, 1996; Vaughan & Spouge, 2002). This was not done in this study for two reasons. Firstly, it was the range of views and projections that I was interested in. Second, as eloquently summed up by Keith (1996, p. 139), 'the fraction of experts who hold a given view is not proportional to the probability of that view being correct'. Subjective probability is by definition personal, and an aggregated probability distribution may not represent anyone's opinion at all.

3.4 Reflexive account of the expert perceptions phase

Interview sessions

The interviews were very productive, and fulfilled their objective of providing the information necessary to create a detailed expert model of the risks. If I had more time, I would have liked to have interviewed more experts to obtain more probability elicitations for comparison, and to ensure I had covered all of the details of SLC on the Severn Estuary. I had not reached absolute saturation by the eleventh interview (i.e. some new ideas were still arising). However, no major new themes were arising, and I felt confident that I had enough information to compare with public perceptions.

Regarding the interview experience, it was an enjoyable as well a productive one. Contrary to Zuckerman's findings (1996, cited in Stephens, 2007) my knowledge was not continually tested during interviews, perhaps due to previous research I had carried out the field of SLC. However, the research phase was a learning process for me, as I did not have much prior experience of semi-structured elite interviews. I struggled to remain totally 'interpersonally neutral' (Fowler & Mangione, 1990), particularly in the first few interviews. For example, I often found myself agreeing with interviewees in an attempt to put them at ease, especially if respondents struggled with the probability elicitation. Such 'ethic of care behaviours' (Matteson & Lincoln, 2009) can bias responses, and it can be a fine line between being 'too friendly' and 'too professional' during interviews; 'too friendly' poses the risk of bias, and 'too professional' poses the risk of 'shutting down' responses.

As stated by Stephens (2007), 'all research is a lived experience'. Indeed, my approach to the interviews changed as I became more confident and as I learned how to get the most useful data from the interview situation. I transcribed the first interview before carrying out any further interviews, and ensured I kept up to date with transcription rather than leaving it all to the end. This meant that issues arising in earlier interviews could be resolved as interviews progressed. The first interview in particular highlighted a number of areas for improvement:

1. I learnt from this first interview that I must avoid talking over participants and appreciate the value of silence.
2. Interview length was reduced from an initial two and a half hours to around two hours.
3. The participant found the semi-structured interview section most tiring so it was refined.
4. A major problem with the probability elicitation in the first interview was incorrect recall of values. Bob drew on a particular source (Shennan & Horton, 2002) but recalled that the units were an order of magnitude larger than they actually were (centimetres rather than millimetres). This meant that his sea-level rise estimates were ten times what they 'should' have been.

Subsequent interviewees were therefore told that they may like to bring trusted sources with them to the interview session, in order to reduce such recall errors. Once Bob realised his error, his estimates were adjusted accordingly.

5. Minor adjustments were made to the protocol format, e.g. the map was changed to one that included topography, and the description of interview objectives was refined.
6. The final stage of the interview initially consisted of the experts evaluating a ready-made influence diagram. This was dropped after the first session because it was deemed to be the least valuable stage. Another study that utilised ready-made influence diagrams also found that their example diagrams were not significantly utilised (Morgan & Keith, 1995).

Semi-structured interviews

Data can be considered reliable if is 'repeatable, stable, or consistent' (Wallsten & Budescu, 1983), and it can be said to be valid when it 'accurately represents the opinion of the person from whom it was elicited' (Wallsten & Budescu, 1983).The validity and reliability of the interview data in this thesis depends on a number of factors including but not limited to:

- The experts' memory (and reliance upon it) during the interview. For example, Bob's recall errors affected his probability elicitations, which would not be the same if repeated once he had re-read the relevant papers that he cited.
- My choice of what questions to ask; and the experts' choice of what to answer and how to answer affects the extent to which the final data set reflects the experts' views.
- Various stages of interpretation and vocalisation, starting with when the expert learns of an issue, through to how they process the information, remember it and say it, through to when I hear it, transcribe it, read it back, and analyse it. 'The data [that the mental models interview] produces reflect how people talk as well as how they think' (Maharik & Fischhoff, 1993, p. 249).

The validity of these semi-structured interviews (and indeed any interviews) is an important one to bear in mind when considering the results of this research. All findings are essentially an interpretation of what I perceive the experts to believe and should be read as such. Participating experts were sent a copy of the model and explanatory notes to check through if they wished to, but only one of the 11 experts responded to this invitation (and he suggested no corrections), so no modifications were made apart from adding to the model notes when new information came to light (e.g. with the publication of new documents) and making minor alterations to allow public perceptions to be mapped onto the model (section 5.2.3).

Cognitive mapping task

The cognitive mapping task was a popular part of the expert interviews (Quote Box 1). Previous work using cognitive mapping methods has also shown that participants often enjoy the process (Kearney & Kaplan, 1997). With lay participants, there is a concern that cognitive mapping can be overwhelming due to 'combinatorial explosion' whereby the number of items grows very rapidly as a result of considering things in combination with each other (Ozesmi & Ozesmi, 2004). Indeed some of the maps did become very complex and did provide a challenge for expert interviewees (Quote Box 1).

1. "This was fun… You could see how the thoughts were coming together" – Bob
2. "This is very different. I've never done anything like this" – Matt
3. "The diagram's quite hard to do, but then I don't know if that's just because my head's like really like…" – Sandra
4. "I do this all time. In essence, we're doing this type of analysis of coastal areas all the time. So in essence you're getting my day job really, in some ways. But it's still a challenge when you have to put it on a blank piece of paper. Because normally you start with- you don't start with blank pieces of paper, you go back to something you've written before" – Jack

Quote Box 1: Experts' comments about cognitive mapping methods

Creating the meta-influence diagram

It was very difficult to organise the information into a coherent structure while including the main points and the main relationships. This became more troublesome as the diagram became more complicated, because the CMap Tools (2013) software that I used crashed every time an item was changed or moved. This meant it was necessary to create each section of the map separately and combine them at the final stage.

Probability elicitations

As stated by O'Hagan et al (2006), expertise in a specialist area is no guarantee of expertise in providing coherent probability assessments. This was the case with the elicitations carried out in this study, and the probability elicitation was the most problematic and challenging stage of the interviews. Although no interview participants refused to participate in the probability elicitation, some were not totally comfortable with the procedure. For instance, Andrew felt that the process was like "almost being asked to deny what other people have done and what other people think". A reluctance to participate in expert elicitations was also noted by Arnell et al. (2005), whereby many scientists preferred to rely on climate model simulations. In this study, some experts stressed that they were *not* an expert at this stage, as shown in the quotes below.

5. "I take no credit for what I know" - Andrew
6. "I'm not an expert" – Matt

Quote Box 2: Experts' comments during probability elicitation methods

Despite some of the experts expressing uncertainty about their level of relevant expertise for such a task (Quote Box 2) all of the participating experts contributed highly valuable information to the probability elicitation and to each stage of the interview. Each helped to facilitate a detailed model of expert risk perceptions and contributed to useful local projections of future SLR. It is to these results that we now turn.

4 EXPERT PERCEPTIONS: RESULTS

This chapter presents and discusses the results of the first empirical stage of this research: the Expert Perceptions Phase (EPP). The purpose of the EPP was to develop an expert model of the risks of SLC on the Severn Estuary, to facilitate a comparison between expert and lay understandings. There were two outputs from this stage: a meta-influence diagram summarising expert perceptions of the risks of SLC on the Severn Estuary, and probability estimates of SLC for the years 2050, 2100 and 2200.

4.1 Expert perceptions Output One: Conceptual model of the risks

4.1.1 How to use the model

Figure 8 shows the expert meta-diagram of SLC on the Severn Estuary. It is designed to visually summarise the literature and the combined understanding of the 11 experts interviewed for the EPP in the summer of 2011. Arrows or "influences" connect related "nodes": the node at the arrow's tail exerts some influence on the node at the arrows head. Nodes (ovals) are organised into sections (sub-boxes), and sections are organised into themes (large boxes). The influence diagram can therefore be scrutinised at three levels of complexity: themes (drivers, physical impacts, socio-economic impacts and vulnerability), sections (e.g. hydrological change and morphological change within the physical impacts theme) and individual nodes (e.g. erosion & accretion in the morphological change section). A summary is provided in Figure 6.

Relationships have been simplified so that only those between themes and groups are included, rather than relationships between nodes in different themes/groups. Key uncertainties (aleatory[45] and epistemic[46]) and disagreements[47] are denoted by dashed lines and dashed borders. The model is accompanied by a 60-page document (Appendix O), explaining and expanding upon each node in the model. These notes are not designed to be read from start to finish, but to be used as a reference tool.

[45] Aleatory uncertainties are not reducible by further research because they arise from factors such as random variability within a system.
[46] Epistemic uncertainties arise from things that we could know, but don't. They can in principle be reduced by further research.
[47] Disagreements within the literature or between expert interviewees.

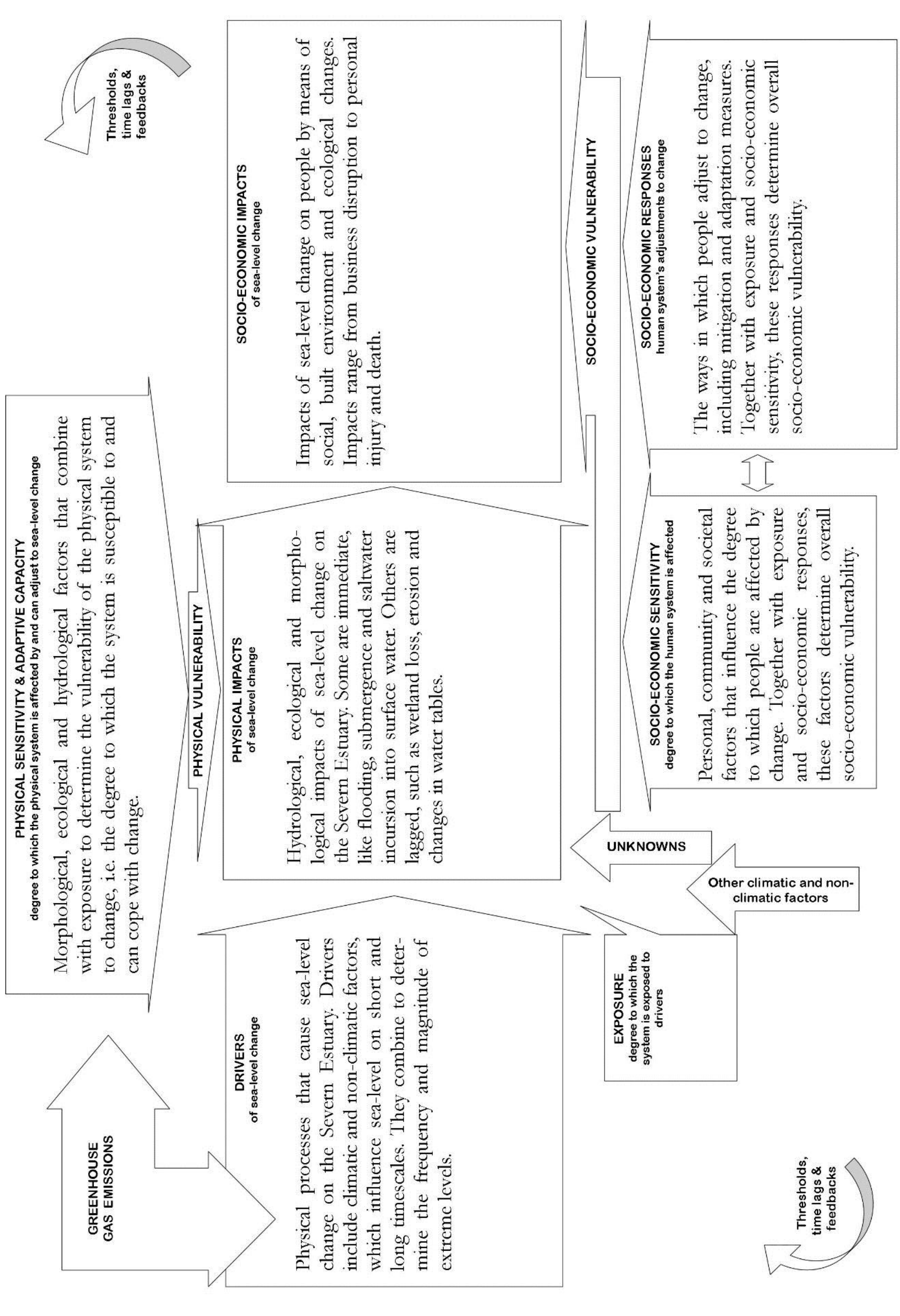


Figure 6: Expert model summary

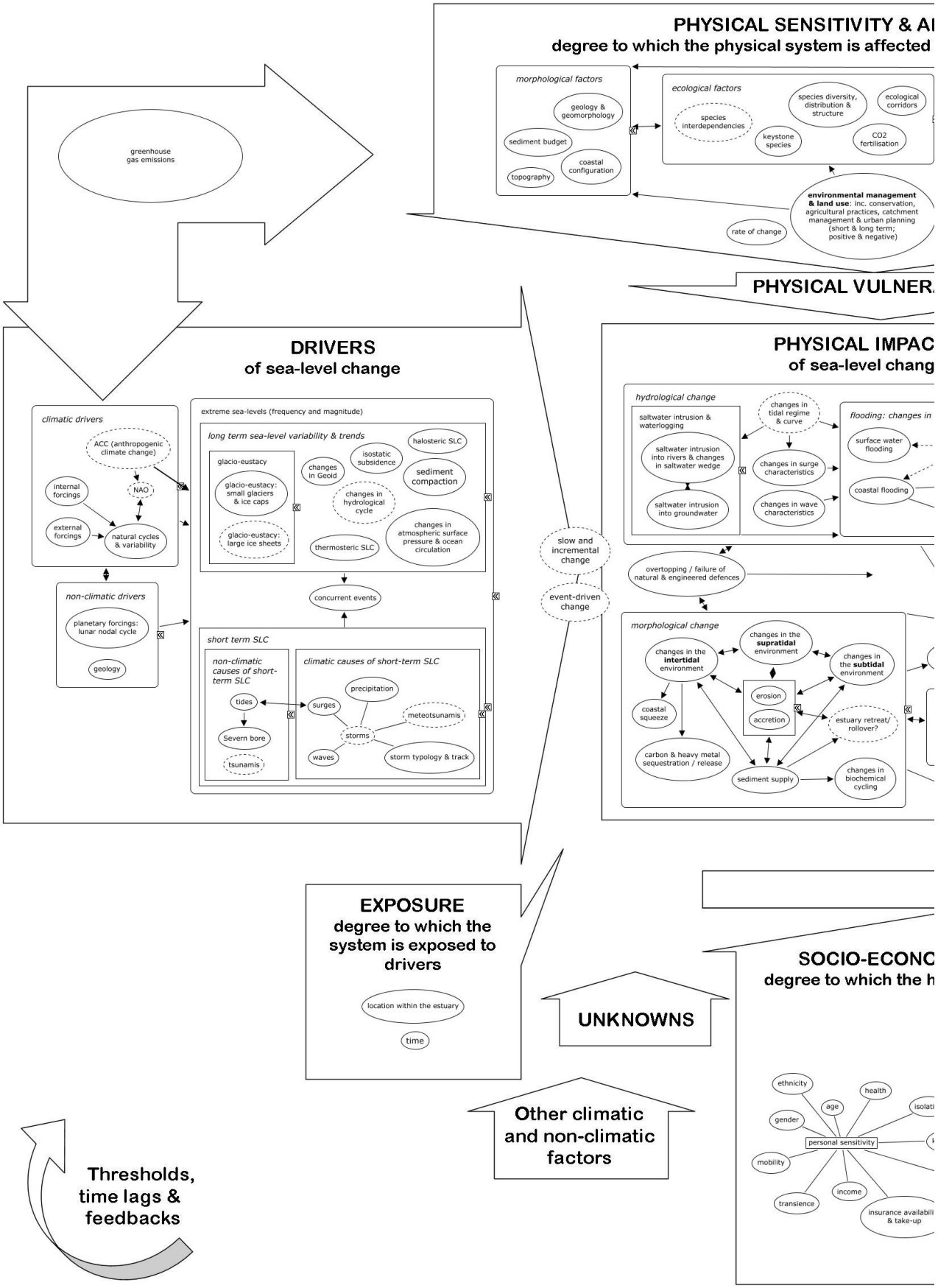
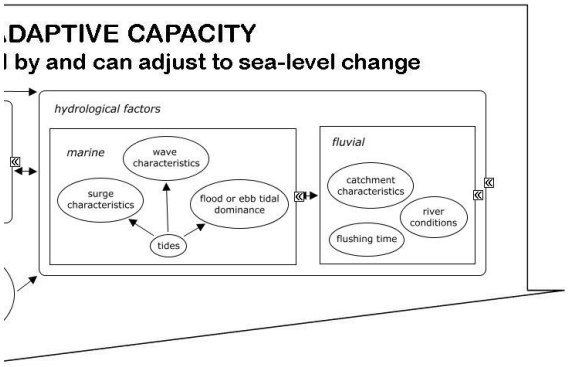
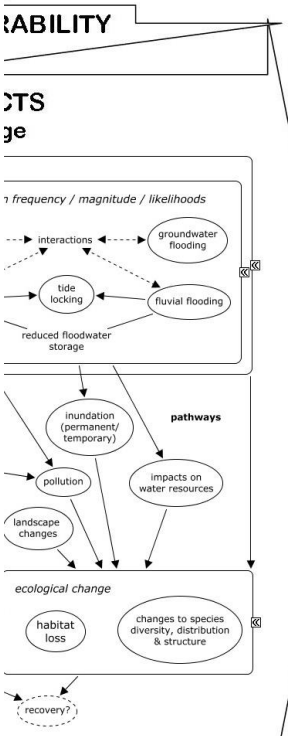
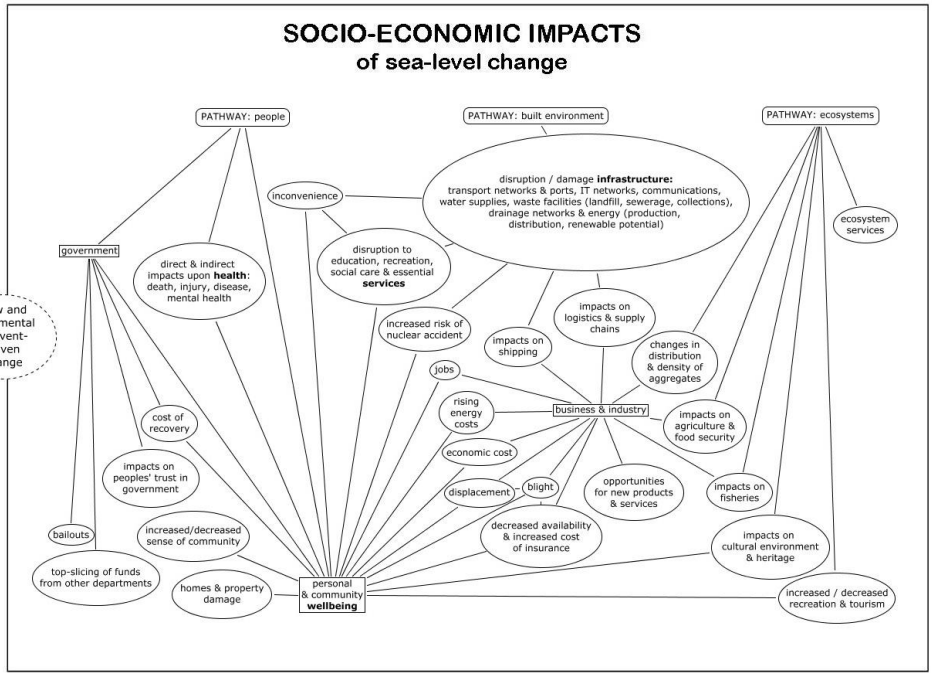


Figure 7: Expert model influence diagram summarising SLC on the Severn Estuary

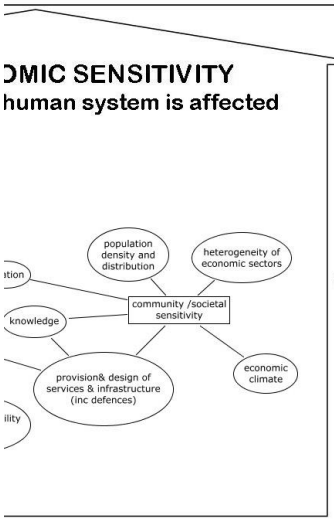


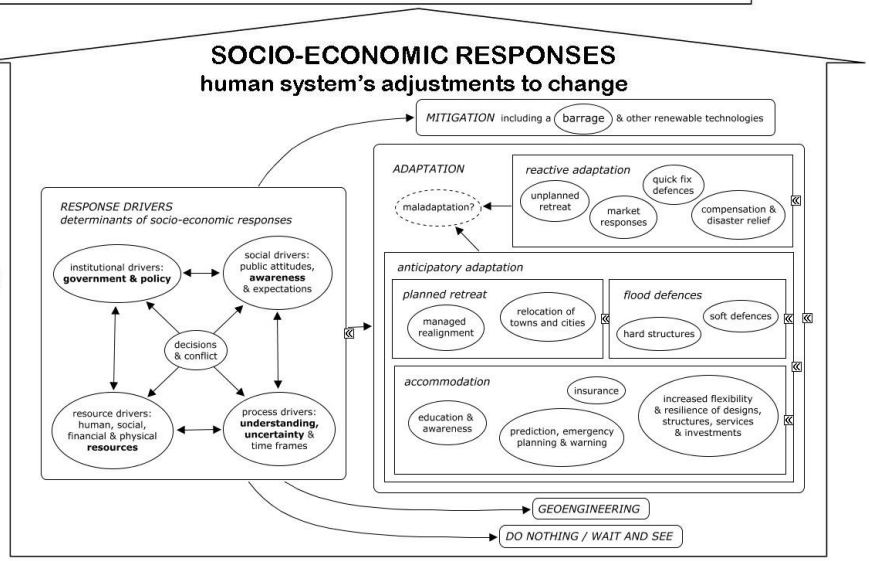




slow and incremental or event-driven change

SOCIO-ECONOMIC VULNERABILITY





4.1.2 The expert model: a summary and discussion

What the model shows

The diagram shows the drivers (causes) of SLC, which can lead to physical and socio-economic impacts. These impacts are moderated by natural and socio-economic vulnerability, which are themselves a function of exposure, sensitivity and adaptive capacity. These form the main themes of the model. The overall format of the model is inspired by decision theory (e.g. Miller et al., 1976) and previous mental models studies (particularly Morgan et al., 2002). The conceptual framework is influenced by a number of sources, notably Nicholls (2010) and the cognitive maps created by experts during the EPP. The model stresses the importance of diagnosing all attributes of the risk; not just the intensity of the drivers but also the vulnerabilities of the systems that stand to be affected. The framework used here is in-line with the event attribution framework by Huggel, Stone, Auffhammer, and Hansen (2013), which has been put forward since the model was developed. These authors stress that event attribution should be framed 'with a more integrated risk concept' where risk is defined as a function of the probability of occurrence of an event and its associated consequences, with consequences being a function of the intensity of the event, the exposed assets and their vulnerabilities (Huggel et al., 2013, p. 696).

The model shows that SLC on the Severn Estuary is complex: a large number of processes, big and small, act over short and long timescales in various habitats and conditions. Closer scrutiny reveals countless interactions, feedbacks and thresholds, many of which are unknown or uncertain. While the model can be read in any direction (indeed the themes interact in non-linear ways), we shall start with the drivers on the left hand side as this is the most intuitive way to understand the basic cause and effect structure. The **drivers** of SLC are the physical processes that cause sea levels to change on the Severn Estuary. They include climatic drivers such as anthropogenic climate change, and non-climatic drivers such as local land movements. Drivers include both global regional and local factors that may influence sea levels on short and long timescales. Together, they determine the frequency and magnitude of extreme water levels. Impacts on the Severn Estuary tend to be most acute when drivers act together, such as a storm surge at high tide.

These extreme sea levels have the potential to cause **physical impacts** at the coast, including changes to hydrological, ecological and morphological systems. Some such impacts are immediate, such as flooding, submergence and saltwater incursion; others are lagged, such as wetland loss, erosion and changes in water tables. Physical impacts occur by way of four main pathways: inundation (flooding), pollution, landscape changes and impacts on water resources. Flooding and habitat loss are expected to be the main physical impacts on the Estuary [Jack][48].

[48] Where the model contains information from experts, their pseudonym is shown in square brackets.

Physical environmental changes have the potential to impact people living around the Severn Estuary through **socio-economic impacts**. This theme is organised into three broad pathways of impacts: people, built environment and ecosystems, and is loosely grouped into three clusters: personal & community wellbeing, business and industry, and government. Impacts include direct impacts such as damage to personal property and an inability to work, as well as more indirect impacts such as declining house prices and impacts on tourism.

As mentioned above, the impacts of SLC upon the physical and socio-economic environment are expected to be mediated through these systems' **vulnerability** to the risks. Vulnerability can be described as the degree to which a system is susceptible to, and can(not) cope with, change (IPCC, 2001). It is like a filter or a moderator for the drivers and pathways, controlling how much impact they have. Vulnerability is a function of exposure, sensitivity and adaptive capacity (Nicholls, 2010), which are divided in the model into their physical and socio-economic aspects.

Exposure describes the degree to which the system is exposed to drivers (Nicholls, 2010). It varies in space and time; for example, the outer estuary is more exposed to waves while the inner estuary is more exposed to changes in river flows; and the estuary is more exposed to flood inundation at high tide than it is at low tide. Physical sensitivity (the degree to which the physical system is affected (IPCC, 2001)) and adaptive capacity (the ability of the system to adjust (IPCC, 2001)) combine with exposure to determine the overall physical vulnerability of the system (Nicholls, 2010). Some physical factors make the Severn Estuary particularly sensitive to flooding, such as its large catchment size, coastal configuration and topography. Others, such as its high tidal range, afford it some resilience.

The extent to which people are affected by SLC (their **socio-economic vulnerability**) is determined by their exposure to the threat, how sensitive they are to change (**socio-economic sensitivity**) and how they respond (**socio-economic responses**). Socio-economic sensitivity consists of factors such as age, income and population density, but in practice it is highly dependent on context. For example, elderly people are often seen as vulnerable, but it is often factors such as health problems, low income or living in isolation that makes them vulnerable, rather than their age (Zsamboky et al., 2011). Socio-economic responses describe the ways in which humans are adapting or might adapt to SLC on the Severn Estuary. They include mitigation, adaptation and geoengineering[49] responses; the choice and execution of which are determined by response drivers such as monetary resources and public attitudes. This theme includes a potential Severn Estuary Barrage, which is considered here as both a mitigation measure (to reduce reliance on fossil fuels and therefore reduce greenhouse gas emissions) and a possible adaptation measure (to reduce

[49] Geoengineering is 'deliberate large-scale intervention in the Earth's climate system, in order to moderate global warming' (The Royal Society, 2009).

coastal flooding). The barrage was a common theme amongst both expert and public interviewees, and is an important consideration in future SLC risks on the Severn Estuary. However, the impacts of a barrage on the processes and responses to SLC are not considered in great detail in the model (or the thesis), for two reasons. Firstly, a barrage might never happen (DECC, 2010; House of Commons, 2013) so knowing about the estuary's response to SLC without one is important. Secondly, the existence of a barrage would have such wide-ranging impacts on the Severn Estuary that it would like change so much of the expert model as to warrant the development of a whole new one.

The final sections of the model summarise a number of **thresholds, time lags and feedbacks** that operate with regard to SLC processes and impacts. Thresholds[50] exist in both physical and socio-economic systems. For instance, anthropogenic climate change may pass key (but uncertain) thresholds leading to the irreversible breakdown of the Greenland Ice Sheet and the West Antarctic Ice Sheet, leading to 13-15m of SLR over a period of centuries (Nicholls, 2011). And from a socio-economic perspective, coastal protection may be viable up to a SLR of 50cm, before it crosses a threshold where managed retreat is more viable for 60cm. Time lags[51] include those caused by the thermal inertia of the deep ocean, which mean that SLR will continue long after climate forcings have ceased (Nicholls, 2011). Feedbacks[52] in the climate system are numerous, and include the release of methane (a powerful greenhouse gas) from surface waters as ice melts (Kort et al., 2012) contributing to further warming.

What the model does not show

The model aims to summarise the processes operating on the Severn Estuary with relation to SLC, but it is not totally exhaustive. Firstly, physically plausible but highly unlikely extreme events (such as a shut-down of the North Atlantic thermohaline circulation[53]) pose equal if not much greater risks to the Severn Estuary than SLC. These factors are not implicitly included in the model, but if they occurred they may interact with the physical or human processes that are included, for example by exacerbating deprivation. Secondly, it is not possible to include all the possible processes and interlinkages while maintaining a visually coherent structure. It has been essential to simplify the model so it is readable. Thirdly, the model is a snapshot of understanding from a finite set of experts and literature at a given time (2011/12), so might change if different experts were interviewed at a different time. In this study, an extensive literature review was used alongside the expert interviews to broaden the scope and knowledge base of the model. However, the meta-influence diagram will always be a function of the contributing sciences (Wood et al., 2012). This

[50] Thresholds are conditions marking the transition from one state to another.
[51] A time lag is a length of time separating two correlated physical phenomena.
[52] Feedbacks occur where changes in one condition cause a response that leads to further change in the initial condition.
[53] Large scale ocean circulation driven by density currents. Part of the 'great ocean conveyor'.

brings us back to a point made in section 2.4.2 regarding the 'truth' of such an expert model. While such a model is necessary to provide a benchmark by which to compare different views, the model presented here is ***a*** model of SLC on the Severn Estuary, not one of 'scientific truth'.

While the model is not time-specific, it does not consider further than 200 years. This is for a number of reasons. Firstly, although the time period was not specified during expert interviews or the literature review, both experts and the literature tended to focus on the next 100 years, with some consideration of the next 200 years. Secondly, many of the processes, particularly socio-economic ones, may have changed beyond recognition by 2300. It should also be noted that although there may be a very small possibility of sea-level *fall* on the Estuary, this is considered so unlikely that it is also not considered in the model. Also, there are elements of the future we cannot anticipate, such as unexpected discrete events and discontinuities in long-term trends, so these unknowns simply cannot be included in the model either.

Finally, though the relative importance of certain nodes is discussed in the model text (Appendix O), the meta-diagram does not show which nodes are most 'important'. This is because the experts were not explicitly asked which were most important during the interviews, and the literature does not often explicitly state such things. However, where the literature or the experts did state the importance of certain factors (such as flooding), this is included in the model notes.

Uncertainties and disagreements

The most notable uncertainties and disagreements in the meta-influence diagram are denoted by dashed lines[54]. While uncertainties are described more in Appendix O, they also warrant a brief discussion here on account of their relevance for public understanding and adaptation planning. There are uncertainties in all themes of the expert model. Some of them are due to gaps in knowledge and can in theory be reduced by further research (epistemic uncertainties), while some are a function of factors such as random variability and cannot be reduced by further research (aleatory uncertainties). Some such uncertainties are shown in Table 8. Note that although they are categorised as epistemic or aleatory, there is a lot of overlap; for example, although uncertainties regarding the North Atlantic Oscillation (NAO) are classified as epistemic, part of the reason why scientists are uncertain about its future response is due to its natural variability; and while anthropogenic climate change is classified as having aleatory uncertainty due to unknown future emission trajectories, it also contains reducible uncertainties (if it did not, there would be no value in continuing climate change research). Experts also cited a number of uncertainties involved in *predicting* future SLC on the Severn Estuary, which are described later in Table 11.

[54] Uncertainties are drawn from those explicitly states by experts and in the literature. There is an element of subjectivity as to which factors are considered the most notable, but including key uncertainties was deemed a valuable addition to the model.

Node	Epistemic uncertainty	Aleatory uncertainty
Drivers of SLC		
ACC (anthropogenic climate change)	The rate and extent of future ACC is unknown in part because the climate system is not perfectly understood or represented in climate models	The rate and extent of future ACC is unknown in part because it has an element of intrinsic (unforced) variability, and will be forced by future unknown greenhouse gas emissions, themselves forced by unknown future economic conditions and value sets
NAO (North Atlantic Oscillation)	Models disagree about future changes to the NAO in response to anthropogenic climate change	NAO responses will be influenced by future ACC, which is itself unknown (see above)
Glacio-eustacy: large ice-sheets	The response of large ice sheets to warming constitutes the biggest uncertainty in the range of future climate–induced SLR	Responses of large ice-sheets will depend on future ACC, which is itself uncertain (see above)
Tsunamis	The absolute tsunami risk for the Severn Estuary is unknown but in theory more research could reduce the associated uncertainties	The tsunami risk could be increased due to ACC through increased incidence of mass movements (see above for ACC aleatory uncertainties)
Storms	Scientists are uncertain as to how storms will change with ACC	Storms are affected by natural variability in climate and weather systems
Meteotsunamis[55]	Further research is necessary to assess the extent to which meteotsunamis may threaten the Severn Estuary coastline in future	Future trends may be affected by many of the same processes governing future trends in storms (see above)
Physical impacts of SLC		
Changes in tidal regime and curve	It is unknown how the tidal range will respond to SLC, and future changes may be affected by morphological feedbacks	SLC will depend on ACC, which itself depends on future emissions, cultural values, global economics etc (see above)
Interactions between flood water bodies	It is not fully understood how different sources of flood risk combine and interact	
Estuary retreat / rollover	Rollover will only be possible if there is room to migrate and if sediments are available. Further research could reduce uncertainties regarding the estuary's response	Sediment supply, and the availability of space for the estuary to migrate, will be influenced by factors that cannot currently be known (e.g. future population growth and land use management decisions)
Recovery?	What constitutes 'recovery' on the Estuary is difficult to define due to ongoing estuary retreat / rollover, the rates of which are uncertain	Recovery will in part depend on natural variability within the system, for example the population dynamics of coastal ecosystems
Physical sensitivity and adaptive capacity		
Species interdependencies	Research may reduce gaps in knowledge regarding species interdependencies	
Socio-economic responses		
Maladaptation?		Future human behaviour (including maladaptive behaviours) cannot be known

Table 8: Summary of uncertainties in the expert model

[55] Meteotsunamis are unanticipated 'long-period waves that possess tsunami characteristics but are meteorological in origin, although they are not storm surges' (Haslett & Bryant, 2009).

As shown in Table 9, there were few disagreements between experts during the EPP, and few disagreements between experts and the literature. A high degree of consensus may be due to a number of factors, including degrees of familiarity with the science (Morgan & Keith, 1995), psychological anchoring (Morgan & Keith, 1995), and the existence of strong evidence to support a consensus.

Disagreement	Details
Spatial vulnerability to surges	There is debate over where on the Estuary is most exposed to surges. It may be that the surge level builds as it travels up the estuary [Matt] and thus threatens the upper reaches more, or that the surge amplitude reduces as water spills out onto the floodplain as it travels [James], thus affecting the lower reaches more
Extreme sea levels	There is debate [Claire, Harry] over whether *extreme* sea levels are actually increasing on the Severn Estuary
1607 tsunami / storm	There is debate in the literature regarding whether the devastating 1607 floods may have been caused by a tsunami or a storm (Bryant & Haslett, 2007; Haslett & Bryant, 2004; Horsburgh & Horritt, 2006).
Dominance of overtopping versus defence failure	Flooding may occur through overtopping or defence failure, and there is debate over which process will be dominant as sea levels rise [Claire, Matt, Roxy]

Table 9: Summary of disagreements in the expert model

The large number of factors that combine to influence the risks of SLC on the Severn Estuary, and the complexities involved in predicting its future response, have implications for designing the next stage of this study (PPP1). While not all of these factors could be covered during either the PPP1 interviews or the PPP2 survey, many had to be included to enable a holistic coverage of the topic. The solution was to design the PPP1 protocol around the core themes in the meta-influence diagram, rather than trying to investigate each separate node in the model. Hence, as shown in Appendix E, the PPP1 protocol included main prompts on each theme: the drivers, the physical impacts, socio-economic impacts, responses, and factors that influence vulnerability.

4.2 Expert perceptions Output Two: Probability elicitations of future sea-level change

4.2.1 Results

The box plots in Figure 8 summarise the distributions of expert estimates of SLC for 2050, 2100 and 2200. They show the range of judged possible values, the 5th and 95th percentiles, the interval spanned by the 50% confidence interval, the median and a 'best estimate'. Wider spreads indicate higher uncertainty; for example, if an expert was absolutely certain that SLR would be 44.4cm (the UKCP09 medium emissions scenario for Cardiff by 2095), all of the symbols would be clustered on 44.4cm. The plots show that all participants projected a high likelihood of future SLR on the Estuary, with three experts asserting very low probabilities (≤2%) of sea-level *fall* for 2100 or 2200. However, they show that despite strong consensus that there will be SLR, there was wide variation in judgements. For example, the upper 95% confidence levels for the year 2050 range from 10.7cm to 95cm (i.e. there is a 5% chance that sea-level rise will exceed this value); median estimates for 2100 range from 20cm to 100cm; and 'best estimates' for 2200 range from 25cm to 280cm, more than an order of magnitude difference.

There was also considerable disagreement regarding how much SLC is *possible* on the Severn Estuary: while James perceived a very remote possibility ($1/10^9$ chance) of 70m sea-level rise by 2050, Bob, Claire and Jack projected an absolute maximum of 0.5m. Figure 9 shows that the trajectories of change also differ: while some experts' median estimates show accelerated SLR after 2100 (e.g. Jack), others (e.g. Bob) show a deceleration. Levels of confidence also vary: while some experts were willing to state absolute maximum and minimum values (e.g. Frank), others were not (e.g. Matt).

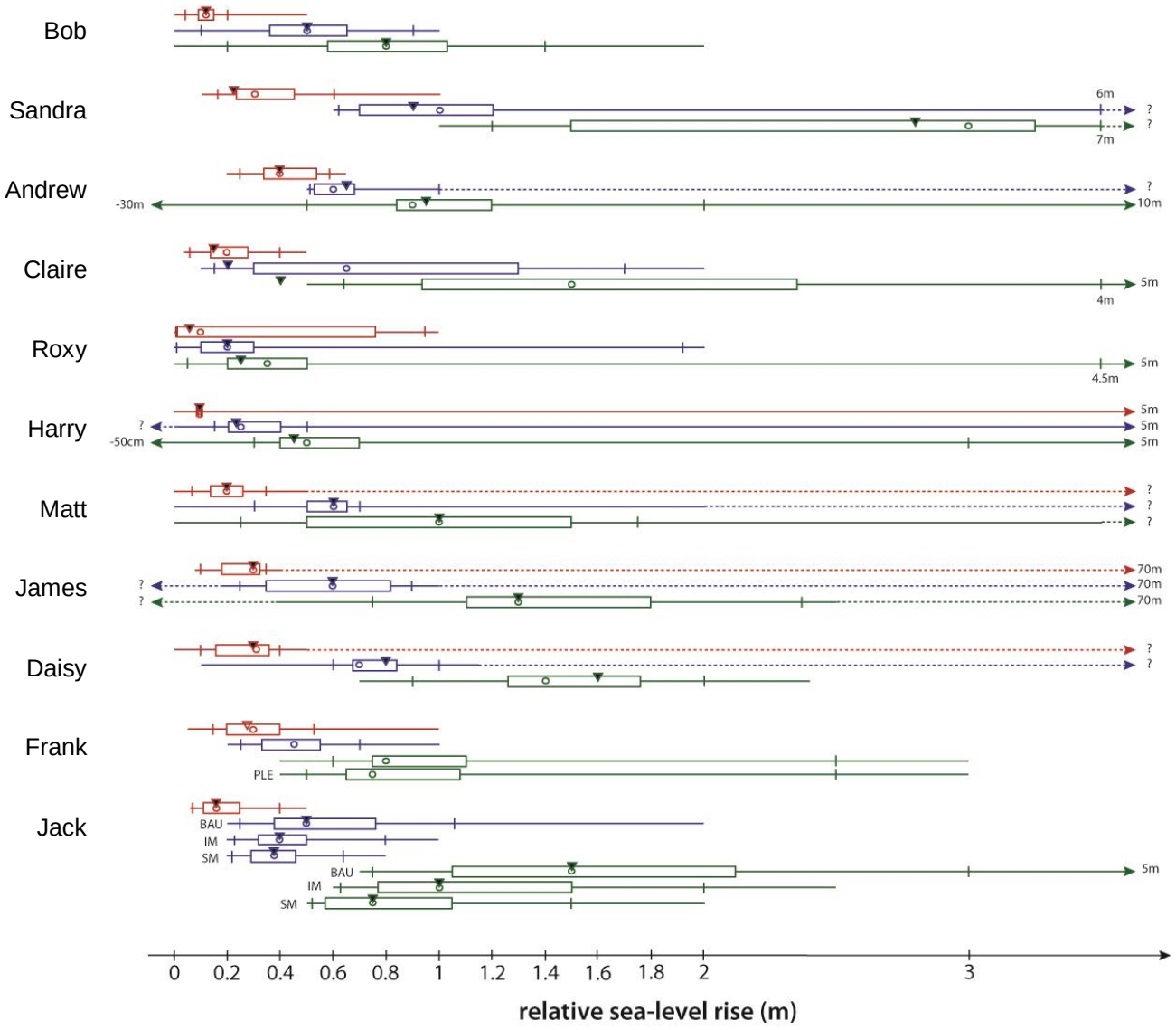
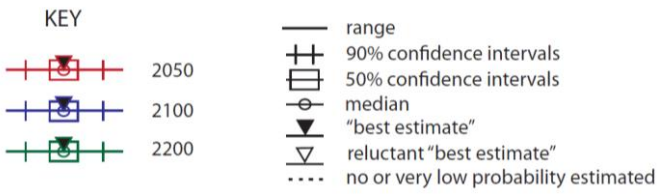


Figure 8: Box plots summarising expert subjective probability distributions

Box plots show results elicited for relative SLC on the Severn Estuary in 2050 (red), 2100 (blue) and 2200 (green). Vertical tick marks indicate 90% confidence intervals, and boxes denote 50% confidence intervals. Open circles indicate medians, solid triangles indicate 'best estimates' (value chosen if the expert were to bet money on it) and the open triangle indicates a reluctantly stated best estimate (Frank was reluctant to give best estimates because he felt it defeats the object of eliciting a probability distribution). Question marks show where no absolute maximum or minimum was stated, and dashed lines show where no explicit probability or very low probabilities (1/10^5 to 1/10^9) were estimated. PLE = possible low emissions scenario; BAU = business as usual scenario; IM = intermediate mitigation scenario; SM = stringent mitigation scenario



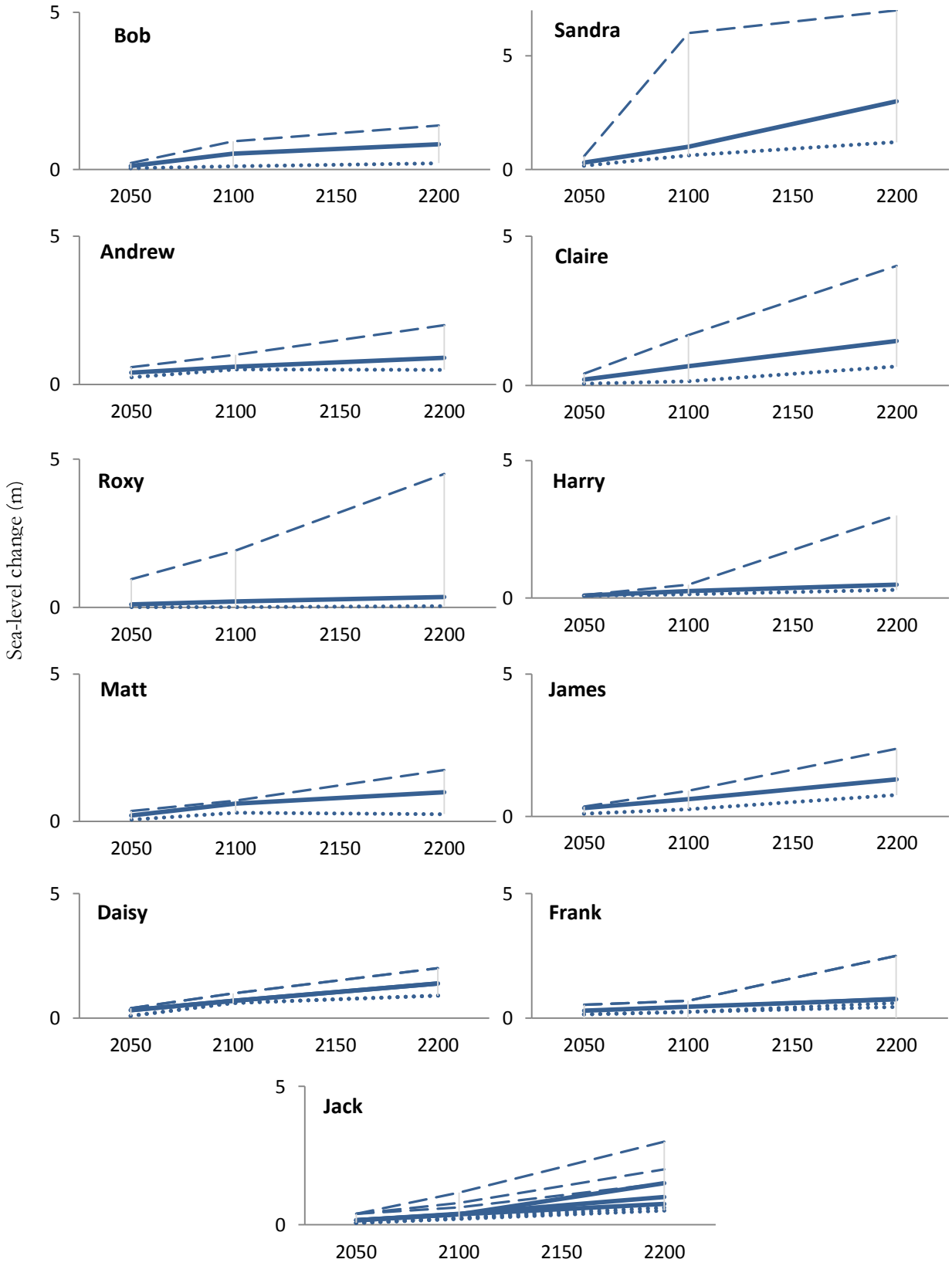


Figure 9: Experts' low, medium and high estimates of sea-level change for 2050, 2100 and 2200.

Low estimates (95% probability of exceedance) are denoted by dotted lines. Median estimates are shown by solid lines. High estimates (5% probability of exceedance) are denoted by dashed lines. Alternative scenarios (by Frank & Jack) are shown. Note the different scale for Sandra's elicitation.

4.2.2 Comparison with projections in the literature

Consistent with a recent expert judgement study (Bamber & Aspinall, 2013), the results indicate a greater diversity of opinion than that shown in often cited reports such as the IPCC (IPCC, 2007, 2013) and UKCP09. While median estimates -which ranged from 9.6cm to 40cm in the year 2050; 20cm to 100cm in 2100; and 35cm to 300cm in 2200- were of the same order of magnitude as estimates in the literature[56], experts' 50% and 90% confidence intervals varied considerably more. These findings support work by Kriegler et al. (2009, p. 5045), who found that in many cases, experts' probability judgements relating to tipping points in the climate system were 'considerably higher than the probability allocated to catastrophic events in current climate damage assessments'. Indeed, in the 20 years from 1989 to 2010, while the range in projected SLR by 2100 has increased in academic papers and in newspaper reports, it has not (so much[57]) in IPCC reports (Rick et al., 2011).

4.2.3 Discussion of the factors influencing expert projections

A thematic analysis of elicitation transcripts indicates that a number of factors may have affected experts' judgements, leading them to be different from each other's and different from mainstream projections such as those of the IPCC (2007). These include the methods and information that experts used, heuristics, and the ways in which experts think about the future.

Methods and sources

Consistent with Spetzler and Stael von Holstein's (1975) observation that people tend to place more confidence in a single piece of 'representative' information than in a larger body of more generalised information, seven of the 11 experts directly or indirectly used UKCP09 (see UK Climate Projections, 2012) to guide their elicitations. This is unsurprising considering that UKCP09, a suite of UK climate projections providing information for adaptation planning, itself consists of probabilistic distributions from an ensemble of climate models. Roxy stated for example that "UKCP09 [is] our best guess at the moment. But that in itself is based on guesses on guesses". Despite UKCP09's high esteem, none of the experts based their projections solely on these data. Other sources included experts' own measurements, satellite observations, IPCC projections

[56] Global average relative sea-level rise estimates in IPCC's Fifth Assessment Report (AR5) are 26cm to 98cm (model based likely range for four RCP scenarios, compared to 1986-2005) by the year 2100 (IPCC, 2013), though these projections were not released until after the expert elicitations took place. Global average relative sea-level rise estimates in IPCC's Fourth Assessment Report (AR4) are 18cm to 59cm (model-based range for six emissions scenarios, compared to 1980-1999) by 2100 (IPCC, 2007), while Titus and Narayanan's aggregated median estimates of SLC are 34cm by 2100 and 81cm by 2200 (Titus & Narayanan, 1996). Some local estimates for Cardiff are 21–68cm SLR projected under a medium greenhouse gas emission scenario by 2095 (MCCIP, 2010), and a central estimate of 44.4 cm by 2095 under a medium emissions scenario (UK Climate Projections, 2012). Other local projections for the Severn Estuary are provided in Table 2.

[57] The latest IPCC report (IPCC, 2013), published since the Rick et al. paper, has a wider range of projections than the AR4.

(IPCC, 2007), the Severn Estuary SMP2 (Severn Estuary Coastal Group and ATKINS, 2010d) and papers published about local and regional SLC (see Table 10). As well as using a variety of information sources, experts chose different methods to construct their judgements. These included: calculating a linear rise from recorded rates of SLC on the Estuary (e.g. Harry); extrapolating from a range of emissions scenario graphs (e.g. Frank); thinking about extreme scenarios, feedbacks and time lags (e.g. Sandra); gut feelings (e.g. Matt); and using indicators from local geomorphology (e.g. Andrew). Harry, who used his own data, had higher confidence in his 2050 projections than any other expert, denoted by the narrowest confidence intervals. Sandra, who thought about extreme scenarios, feedbacks and timelags, had the widest confidence intervals of all 2200 elicitations.

Expert	Sources	Methods
Bob	Shennan & Horton (2002)	Used recorded rates to project future rise.
Sandra	UKCP09	Used UKCP09 emissions scenario graphs, "taking them as rough guidelines and taking my own approximation from there", taking into account that her sources only include certain emissions scenarios. 2200: thought about processes such as feedbacks, ice caps melting, and high emissions scenarios.
Andrew	UKCP09 and academic papers about local SLR	2050: UKCP09 & continuation on a trajectory, "just allowing what we know has happened to carry on happening" 2200 minima: UK coastal geology.
Claire	IPCC (from memory)	Based on other people's measured rates, plus a mental PDF. Rates not worked out accurately, but used as a guide.
Roxy	UKCP09 and SMP2	"A general feel". 2200: extrapolated from 2100, and compared what the world was like 200 years ago with what it could possibly be like in 200 years.
Harry	Own work, other data sets and IPCC reports	Used geological record and his own sea level measurements to extrapolate rates into the future. Also used other data sets with longer time scales, and created a mental curve with an accelerated rise.
Matt	Shoreline Management Plans, UKCP09	"Semi-informed" gut feelings based on background knowledge. Once plotted, looked at graph and spread it out to make it less steep.
James	UKCP09, Defra and various others	Used historical rates, published projection graphs (including Defra and UKCP09), background reading and "general knowledge about what is happening from a climatic point of view".
Daisy	SMP2	Extrapolated from the 2100 1m estimate used in SMP2.
Frank	Variety of published sources, especially UKCP09	Used rates from published sources, extrapolating from a range of emissions scenarios; as well as thinking about extreme scenarios, time lags, and physical processes.
Jack	IPCC, literature, observations (including satellite).	Used rates and trends, graphically by drawing a curve and families of curves, using instincts for 2200, increasing the ranges due to the greater uncertainties associated with making projections specific to the Severn Estuary.

Table 10: Sources and methods used by experts to estimate future SLC on the Severn Estuary

The ways in which experts think about the future

Transcripts indicate that the ways in which experts think about the future influenced their probability judgements. The first aspect regards the uncertainties implicit in predicting future sea-levels. Almost all elicitations show wide probability ranges and confidence intervals, indicating large uncertainties in projections. Uncertainty increases over longer timescales in all elicitations, and is greatest for the year 2200. Table 11 lists sources of uncertainty cited by expert participants.

Expert	Source of uncertainty: aleatory uncertainties
Bob, Sandra, Claire, Roxy, James, Frank, Jack	Uncertainties in future conditions e.g. emissions scenarios, possibility of a Severn Barrage
Matt	Unknowables
	Sources of uncertainty: epistemic uncertainties
Sandra, Andrew, Harry, Matt, James, Jack	Process uncertainty, e.g. ice sheet response to warming, feedbacks, time lags, regime shifts
Sandra, Andrew, James, Frank	Climate model uncertainty
Matt, Daisy	Availability of and confidence in data
Sandra, Roxy	Unavailability / non-existence of projections for long timescales (most of the sources upon which experts based their judgements do not make projections beyond 2100)
James	Uncertainties regarding what parameters are included in guidance projections

Table 11: Sources of uncertainty in expert judgements of future SLC on the Severn Estuary

Experts tended to find it particularly difficult to think about the future beyond 2100, as shown in Quote Box 3. This is unsurprising because uncertainties increase with time due to the chaotic nature of the climate system and unknowns such as emissions scenarios. Lenton et al. (2006, p. 2) suggests that our focus on short timescales also 'surely reflects the human lifetime' and our difficulty in contemplating the world 'long after we cease to live in it'. These results echo stakeholders' difficulty in thinking about the future in the context of rapid SLR on the Thames Estuary, many of whom commented on the difficulty of making decisions over long timescales (Lonsdale et al., 2008). Research suggests that people think about time in different ways (Moser et al., 2011). Experts interviewed for this study showed varying reliance on each of the two repertoires discussed by van Asselt et al. (2010)[58]. This was revealed by their methodologies: trend interpolation (e.g. Andrew) and using indicators of past sea levels from local geology (e.g. Harry) are historic determinist approaches, whereas thinking about extreme scenarios (e.g. Sandra) is more aligned with futuristic difference.

[58] As discussed in section 2.6.1, van Asselt et al (2010) identified two 'temporal repertoires' describing how experts think about the future: historic determinism, where the future is conceptualised as being determined by the past and present; and futuristic difference, where the relationship between the past, present and future is looser, and discontinuity is key. They suggest that despite foresight practice being more aligned with the futuristic difference repertoire, there is a strong tendency to resort to the historic determinism repertoire.

7. "What's the purpose of the outlandish [2200 elicitation]?" – Andrew

8. [for 2100] "there's a problem here though, because it's going to be so dependent on the futures, isn't it. And so it gets less like simple probability. [It is now] conditional probability. Which makes me very uncomfortable because it's just like guessing" [... for 2200,] "200 years and 1000 years, you know, it is really difficult to actually think that far ahead…" - Claire

9. "[2200] It's a stupidly long time" – Roxy

10. "[2200] It's all these ifs ifs ifs ifs ifs" – Harry

11. 2100: "Gosh we're really guessing, aren't we. That's so far away that so many things can happen" – Matt

12. "200 years. I have NO confidence in my estimates AT ALL that far ahead, because it's just TOO far ahead to conceive of, really... It's so far ahead in the future as to be completely meaningless… These are now WILD guesses" – Daisy

13. 2200: "for a median change, I feel- well, we're getting into the realms of science fiction here" – Jack

Quote Box 3: Experts' future thinking

Heuristics

The influence of heuristics in probability judgements has been well documented (Tversky & Kahneman, 1974). Heuristics that were particularly evident in these elicitations are anchoring, where an initial estimate is used as an anchor on which to base subsequent estimates, and herding, where others' opinions are incorporated into the experts' own. Despite efforts to encourage experts to concentrate on ranges of possible outcomes rather than anchoring elicitations on particular values, some experts calculated their distribution directly from median values in the published literature (Quote Box 4).

14. "I have been institutionalised, if you like. I've fed myself a diet of about 40cm" – Andrew, academic

15. "I've been brainwashed, haven't I? By lots of clever scientists" – Roxy, consultant

16. We talk very much about 1m by the end of the [SMP] plans, which is 100 years. So I don't tend to do anything below that [laughs]. I tend to talk about 1m in 100 years – Daisy, government

Quote Box 4: Experts' anchoring heuristics

Another heuristic increasingly recognised as important in decision making is the optimism bias, whereby people tend to believe they are less likely to experience negative events, and more likely to experience positive events than other people are (Weinstein, 1980). Transcripts indicate that the optimism bias may have influenced some experts' elicitations, consistent with a growing body of

research regarding the relationships between probability estimates, optimism and pessimism (McKenna, 1993; Vosgerau, 2010; Windschitl, Smith, Rose, & Krizan, 2010) (Quote Box 5). For instance, where Frank and Jack provide alternative scenarios, they are for lower emissions rather than higher emissions, which may indicate an optimistic stance. Interestingly, those experts who vocalised their optimism did not project lower SLC: as James remarked, "one man's pessimism is another man's optimism" and such outlooks are subjective. However, it is reasonable to suggest that if they were not being optimistic their SLC judgements may have been higher.

17. "[it's the] optimism in me thinking that we'll have hopefully curbed some emissions" – Andrew

18. "I can't envisage sea levels in the Severn Estuary being more [than 5m]."
[facilitator] Why not there but elsewhere? "Well… I'm not sure- I don't know. I don't have any reasons." - Claire

19. "I'd like to think it would be nearer 20 than 50. So we had actually got a grip on it... We can do it… Fighting with my optimism and my pessimism." – Roxy

20. "I'm not going to advocate vast amounts of melting of glaciers and ice caps [...] I personally think it will be low. But I guess that's more of a vested interest because I'm uncomfortable with the idea of it being higher… It feels like a lot of water; it feels like a very big impact. It feels like a big problem" – Daisy

Quote Box 5: Experts' optimism

4.3 Summary: expert perceptions of sea-level change on the Severn Estuary

The expert model (Figure 8) illustrates the complex nature of SLC on the Severn Estuary, showing that there are many facets of change, many interactions, and much uncertainty. Quantitative analyses of subjective probability distributions underscore the uncertainties implicit in predicting the Estuary's future response. While they show that experts perceive future SLC on the Estuary as highly likely, there is wide variation between judgements and much uncertainty regarding the magnitude of future SLC, particularly over longer timescales. Qualitative analyses of elicitation transcripts indicate that experts' judgements may have been influenced by their choice of methods and information sources, heuristics, and the ways in which they think about the future. As well having a number of implications outside of this research (see 9.2.1), the EPP has provided a model to compare with public perceptions in the next phase of the study. It is to this phase that we now turn.

5 PUBLIC PERCEPTIONS: METHODS

This chapter discusses the methodology employed for the second and third empirical stages of research: mental models interviews with members of the public living around the Severn Estuary (N=20), and a wider public survey of the Estuary population (N=359). The rationale and methods are outlined, and the limitations discussed.

5.1 Introduction

This chapter details the methodology used to explore public perceptions of SLC on the Severn Estuary. This investigation involved two stages. Public perceptions phase one (PPP1) consisted of qualitative interviews with members of the public living around the Severn Estuary (N=20), and public perceptions phase two (PPP2) involved a quantitative survey of a wider sample of the population living around the Severn Estuary (N=359). Broadly, PPP1 was designed to scope public beliefs, while PPP2 was designed to further explore the perceptions raised during PPP1. The two stages complement each other, and thus their results are discussed in parallel in Chapters 6, 7 and 8. Table 12 outlines the research questions answered in PPP1 and PPP2.

Research Question	**Data**	**Data collection methods**	**Data analysis methods**
Is SLC a salient issue for the public?	Public opinions of SLC, and its comparison with other issues	PPP1 mental models interviews, PPP2 introductory questions	Thematic analysis, descriptive statistics
What does the public know about SLC on the Severn Estuary?	Knowledge and beliefs about SLC on the Severn Estuary	PPP1 mental models interview, picture sorting task and cognitive mapping task; PPP2 knowledge questions	Thematic analysis facilitating assimilation into a public meta-diagram of the risks; descriptive statistics
How much SLC does the public expect on the Severn Estuary?	Estimates of future SLC	Mental models interview (PPP1), sliding scale to gauge broad perceptions of magnitudes (PPP2), true/false questions (PPP2)	Thematic analysis; descriptive statistics
What factors in addition to knowledge affect public perceptions of SLC on the Severn Estuary?	Opinions, feelings and values	Mental models interview (PPP1); PPP2 questions about values, concern and future thinking	Thematic analysis; exploratory statistics (multiple regressions) to explore relationships
How might SLC best be communicated with the public?	Media preferences, opinions about communications	PPP1 mental models interviews, PPP2 questions about media use and trust in information sources	Thematic analysis, descriptive statistics

Table 12: Research summary: public perceptions (PPP1 & PPP2)

5.2 Public perceptions phase one methods: qualitative interviews

5.2.1 Introduction

This section reports the second empirical phase of the research, the first of the public phases (PPP1). It involved mental models interview sessions carried out in 2012 with members of the public living around the Severn Estuary (N=20). Each session included a semi-structured interview, a picture sorting task, and a novel approach to the creation of a cognitive map. The purpose of this phase was to explore perceptions amongst members of the public, to a) compare with expert perceptions, and b) inform the development of a wider survey (section 5.3).

5.2.2 Rationale and methodology for PPP1

Overarching rationale

Administering a questionnaire 'presumes that one knows in advance the full set of potentially relevant lay beliefs and misconceptions, as well as the terms in which they are intuitively phrased' (Morgan et al., 2002, p. 23). Structured tests also risk communicating the experts' knowledge and may encourage compliance bias. Open ended interviews, on the other hand, place no such constraints on the interviewee and allow people to express their beliefs more naturally (Read et al., 1994). Focus groups would be an alternative means of eliciting such beliefs, but individual interviews are preferred as the 'behaviours in question are generally at the individual level and because, in focus groups, a few people can influence others' thoughts or propensity to speak, leading to incomplete or inaccurate elicitation.' (Austin & Fischhoff, 2011, p. 126).

Interview methodology

The purpose of the interview sessions was to find out what people already perceive regarding SLC on the Severn Estuary. The interviews therefore provided participants with minimal new information and aimed to give them plenty of scope to talk about everything that (s)he considered relevant to the topic. The methodology was adapted from the mental models methodology developed by Morgan et al. (2002), designed to allow participants to talk about their beliefs in a way that is meaningful to them. There are a number of ways to elicit a mental model. Some approaches aim to do it 'directly' through a diagrammatic interview approach, while others aim to recreate the mental model from other data such as interview transcripts (Jones et al., 2011). The approach adopted for this study used a combination of methods, comprising three separate parts of the interview session, each exploring participants' mental models in slightly different ways.

The first stage of the session was a semi-structured mental models interview, designed to elicit a 'core dump' of the participants' thoughts on the topic, before each of these initial thoughts was followed up in more detail and more themes were introduced for discussion (Morgan et al., 2002). Questions were open ended in order to elicit as much information as possible, without leading the participant. The second stage was a picture sorting task, designed to prompt discussion on topics that did not arise during the mental models interview. The third stage was a cognitive mapping task, designed to explore how participants grouped and linked ideas.

Interview sessions typically lasted around 90 minutes, and were carried out in the participants' home or place of work. All sessions were audio recorded and transcribed. Prior to the interviews commencing, the methodology was piloted with family and friends (N=5) to allow for familiarisation with the interview questions and process, and to refine the methodology. Changes were made to the protocol at this stage, particularly a simplification of the cognitive mapping task on account of participants finding the original method (adapted from Tikkanen, Isokaanta, Pykalainen, & Leskinen, 2006) too constraining.

Sampling

The aim was to recruit a demographically diverse sample of participants living close to the Severn Estuary. All participants were aged 18 or over, and it was desirable that participants should have no obvious connection to the topic (Morgan et al., 2002). However, it was not possible to guarantee that participants held no formal expertise in SLC, as participants were not told prior to the interview that it would be about SLC. One participant (Laura) did have some prior experience of the subject having worked on policy documents for the region.

The number of interviews I could carry out hinged upon how much time and money was available, and how many people were willing to be interviewed. Previous research suggests that between 10 and 25 interviews is sufficient for mental models studies (de Bruin & Bostrom, 2013; Morgan et al., 2002) and cognitive mapping studies (Tikkanen et al., 2006) in order to reveal most of the common beliefs held by the population. After about 20 interviews, saturation is reached and very few new concepts arise (Morgan et al., 2002; Ozesmi & Ozesmi, 2004). Due to time constraints, 20 participants were interviewed for the current study. This seemed sufficient; although themes were occasionally still emerging in later interviews, saturation of *major* themes appeared to have been reached by this point. Due to the exploratory nature of the study more interviews would have been desirable, but were deemed unnecessary.

A purposive sampling technique was used whereby I asked acquaintances ('gatekeepers') who live in the target areas to pass my contact details on to people who might be willing to participate (methodology suggested by Warren, 2001). The acquaintances were not made aware of whether the recommended person would be or had been contacted, in order to preserve each participant's

confidentiality. Chain-referral sampling was also used (Heckathorn, 2011), whereby participants passed my details to other potential willing participants from target areas. Finally, three participants had been previously involved in studies undertaken by the research group of which I am part (the Understanding Risk Group), and had given written consent to be contacted for future projects. Key demographic information was collected during each interview, and the sampling frame became smaller and more specific as interviews progressed, in order to ensure the final sample was sufficiently diverse. Demographic statistics and approximate interviewee locations are shown in Table 13 and in Figure 10.

Demographic variable	**Sample statistic**	
Location	Wales 30%	England 70%
Gender	Female 50%	Male 50%
Age	18-47 45%[59]	48-69 55%
Housing situation	Owned 85%	Rented/living rent free 15%
Highest Qualification	Graduate 60%	Non-graduate/withheld 40%
Member of local interest group	Yes 20%	No 80%
Member of environmental group	Yes 20%	No 80%

Table 13: Sample statistics, PPP1

Appendix K shows national population statistics for England and Wales. It shows that the gender split of interviewees is nationally representative, but that the housing situation and level of qualifications is not nationally representative. Fully 64% of the English and Welsh national population own (or mortgage) their homes, compared to 85% of the PPP1 sample; 27% of the English and Welsh population have achieved graduate level qualifications, compared to 60% of the sample population.

[59] Mean=47, Range=18-69

Figure 10: Map showing approximate residence of PPP1 interviewees

Aside from the drawback of a sample skewed towards highly educated home owners, the benefits of this sampling strategy were as follows:

- Results should not be biased by targeting respondents who are interested in the topic, which would have been more likely if I had advertised it in a newspaper or by way of a poster inviting participants to contact me.
- Results should not be biased by targeting respondents who knew a lot about the topic, which would have been more likely if I had approached interest groups such as the Severn Estuary Partnership.
- The strategy meant that the number of recruits and their demographic characteristics could be carefully moderated. Each time I asked a gatekeeper to forward the email to their contacts, I specified that it should only be forwarded to people living in a certain area, of a certain age range and so on.
- The method was cheap, requiring no external advertising costs, and quick, requiring no lengthy cold-calling sessions.

Ethical considerations

Participants were initially contacted via post and/or an email requesting an interview and providing them with a clear description of the project and example consent forms (Appendix D). Participants

were told that the interview would be about 'change on the Severn Estuary' rather than about SLC, so as to avoid participants engaging in research prior to the interview. Once the prospective participants had agreed to the interview in principle, they signed formal consent forms prior to the interview beginning. During the interview session, opportunities were made available for participants to ask any questions they had, and these were answered at the end of the session. A debrief sheet was provided at the end of the interview, containing further information about the project and contact details in case participants wanted to find out more about the study and their input. Participants were paid an honorarium of £10 to thank them for their participation.

The data collection process entailed strict confidentiality in accordance with The British Psychological Society's 'Code of Human Research Ethics' (2010) but was not entirely anonymous due to the nature of the research (the need to transcribe and possibly follow up on interviews). Once the data had been transcribed and digitised, transcripts were made anonymous and pseudonyms were used from there on. Only pseudonyms and non-identifying generic terms (e.g. gender, age and geographical area) are used to describe participants throughout the thesis.

Mental models interviews

Rationale

The mental models interviews constituted the first 40 minutes or so of the interview session. The purpose of these interviews was to elicit as much of the participant's mental model on SLC as possible, in a way that was meaningful to them. As recommended by Morgan et al. (2002), the direction of the interviews were largely determined by the participants' discussion. Participants were not asked every question on the protocol; rather, the emphasis was drawn from the conversation itself. For example, if a respondent mentioned the Severn bore, their beliefs regarding the Severn bore were probed further.

Methods & Protocol

The full interview protocol can be found in Appendix E. The protocol for the mental models stage was arranged on one page, with topics ordered hierarchically to follow the rough structure of the influence diagram, as advised by Morgan et al. (2002). As recommended by Fowler and Mangione (1990), the protocol began with a brief introduction in order to 'train' the respondent as to what was expected, including information about the style of the interview and the fact that I would keep relatively quiet but may ask for clarification. A simple opening question was then used to start the interview. The interviewee was first asked to talk about the Severn Estuary in general, and then about SLC in particular. (S)he was encouraged to talk for as long as s(he) could, with simple prompts such as "anything else?" or "can you tell me more about that?" When a topic was mentioned, it was marked on the protocol sheet, so that it could later be followed up. Once

participants had made a 'core dump' of all of the information that came to mind, they were asked to elaborate on topics that they brought up (Morgan et al., 2002). The interview then became more directed, and the participant was asked to talk about each major area on the influence diagram if they had not already discussed it. These topics included processes, future changes, impacts and adaptation measures, and were considered to be such basic concepts that their omission from prior discussion was deemed an oversight rather than ignorance (Maharik & Fischhoff, 1993). As before, participants were asked to elaborate on each topic that they raised. Changes to the protocol during the interview phase were kept to a minimum.

Picture sorting task

Rationale

The next stage of the interview session was designed to make sure that nothing important was missed during the mental models interview. A number of methods could have been used for this, including picture sorting tasks, providing definitions of terms, and solving problems (Morgan et al., 2002). The picture sorting task was chosen because it was accessible, relatively easy and visually interesting.

Methods & Protocol

Participants were given a stack of 69 photographs and asked to sort them into two different piles; one with pictures relating to SLC on the Severn Estuary, and one with pictures unrelated. In each case, they are asked to explain what the picture showed, and why it was or was not related to SLC on the Severn Estuary. As they were talking, themes were noted on post-its for the final stage of the interview, the cognitive mapping task. The pictures used for this stage are shown in Appendix F. Some were illustrations; others were photographs that I had taken or downloaded from Wikimedia Commons (2012). Some were adapted using Photoshop, such as image 12, which shows an 'elderly people crossing' sign. After the first five interviews (Lynne, Darren, Betty, Owain and Karen), four of the images (39, 46, 47, and 65) were dropped due to topic duplication, two were added to improve clarity (images 71 and 72), and one (73) was added to show the Severn bore, which was not previously represented.

The pictures showed a variety of topics from a 'cross section of human life and activities' (Morgan et al., 2002, p. 67) in addition to pictures specifically relevant to the topic, for example sea-defences and flooded land. Images could be (and were) interpreted in a variety of ways, often in ways initially unintended or unexpected. For instance, image 67 of boiling water was intended to represent the thermal expansion of water, but prompted discussion of needing to boil water contaminated during a flood. Broadly, around one third of the images were intended to be related to impacts, around one third were related to causes and other factors, and one third were not directly related to SLC

at all (Appendix F). The images that were not related to SLC were important so that respondents did not feel they had to find relevance in each picture (Morgan et al., 2002). Figure 11 and Figure 12 show the contents of two participants' picture sorting piles.

Figure 11: Christine's picture sort, PPP1
The picture sort shows showing related images on the left, unrelated images on the right, and 'don't knows' at the bottom

Figure 12: Paul's picture sort, PPP1
The sort shows unrelated images on the left and related images on the right

Cognitive mapping task

Rationale

The purpose of the cognitive mapping stage was to further prompt discussion of the topics, and to investigate how ideas are linked together. Therefore, maps would ideally incorporate all the aspects that the participant thinks are relevant to SLC on the Severn Estuary, and show how these aspects are connected and grouped together. Each should be a 'visual display that expresses a participant's unique knowledge structure' (Kearney & Kaplan, 1997, p. 599). The main use of the maps however was to provide additional verbal data for both qualitative and quantitative analyses and to clarify topics raised during earlier stages.

Methods & Protocol

Methods of cognitive mapping include concept mapping, semantic web analysis, and decision-analysis-based mental models approaches (Wood et al., 2012). Decision-analysis-based mental models approaches focus on how one variable influences another, often quantified probabilistically (Wood et al., 2012). Semantic webs can take a similar format, but are more qualitative in nature; and concept maps map concepts closer or further apart according to their similarities and differences (Wood et al., 2012). This phase of the research encouraged participants to develop a simple semantic-web style map using methodology adapted from Kearney and Kaplan's (1997) conceptual content cognitive map (3CM) method. The protocol ran as follows:

1. During the picture sorting task, topics related to SLC were noted on post-it notes. Major points noted on the protocol sheet during the mental models phase were also added to the list of post-it note topics.
2. The purpose of the task was explained, with a brief description of how cognitive maps can be created.
3. All of the post-it notes were laid out in front of the participant, and the participant was asked if there was anything else that they thought was relevant to SLC on the Severn Estuary. They were told that they could add to the list at any time.
4. The participant was then asked to arrange the topics on the page in a way that was meaningful to them, placing the cards on a large sheet of paper and drawing relationships between them, similar to methodology used by Dray et al. (2006).

One of the main benefits of this method is that, like the 3CM method, it does not aim to distinguish between those items that are consistent and inconsistent with an expert model (Kearney & Kaplan, 1997), and allows an expression of the relationship between topics. Through the use of post-its, it also reduces the problem of 'limited channel capacity' whereby we can only think of a certain number of issues at one time (Kearney & Kaplan, 1997). With this method, the participant could use many items without having to think about them all at once; an approach particularly suitable

for exploring participants' understanding of complex domains such as SLC. Example cognitive maps are shown in Figure 13 and Figure 14.

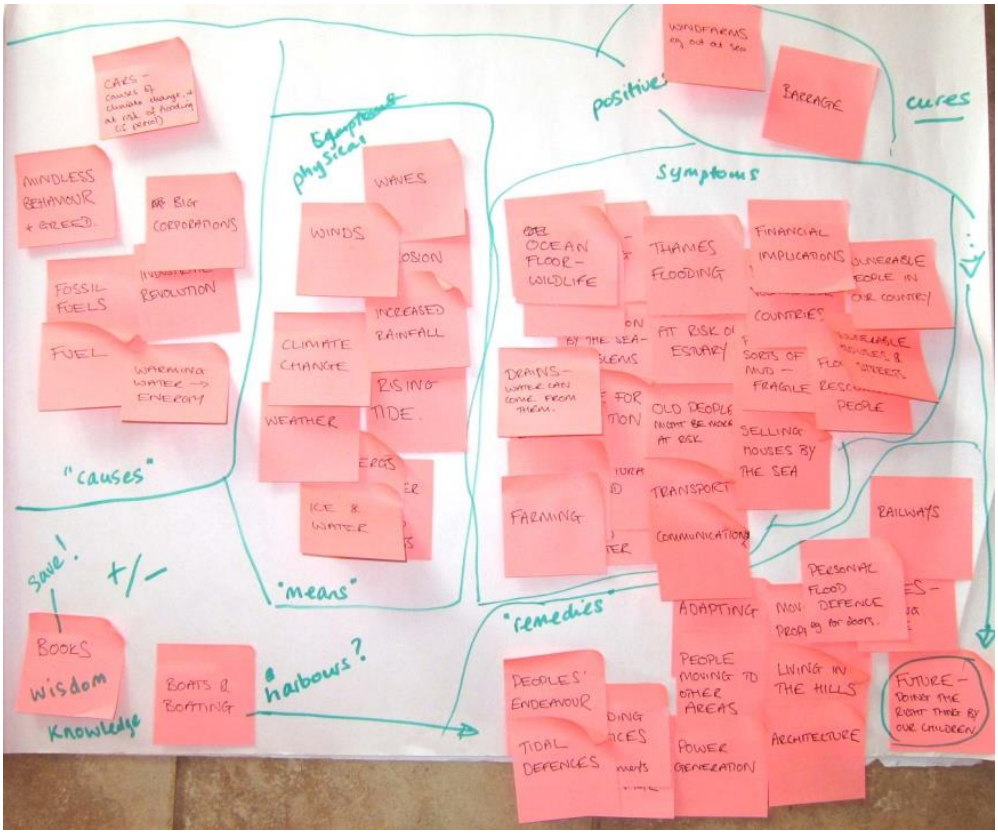


Figure 13: Cognitive map created by Betty, PPP1

Figure 14: Cognitive map created by Jessica, PPP1
Unused concepts are on the clipboard and folder, left

One participant was not confident in creating a cognitive map, so a 'back-up' method was used (see Appendix E for protocol). This method, adapted from Tikkanen et al. (2006), involved first grouping the items, then naming the groups and putting them in order of importance before organising them into a map structure on the page.

PPP1 Analysis methodology

Around 230,000 words were transcribed during the public interview phase, using the same transcription methodology as in the expert phase (Section 3.3). Once transcription was complete, analyses were in two parts; a content analysis of the 'knowledge factors' in the transcripts to facilitate a comparison with the expert model, and an interpretive analysis to explore non-knowledge themes.

Content analysis of knowledge factors

All of the nodes in the expert model were entered into an Excel spreadsheet. Each of the public transcripts was read through, and at the first instance a theme was mentioned in a way consistent with the expert model, it was entered into the spreadsheet. On account of the latter parts of the interview becoming increasingly reactive (Morgan et al., 2002), the responses were assigned a different value depending on how much the response was prompted. Topics mentioned in the 'core dump' stage at the beginning of the mental models interviews were assigned a '4', topics mentioned after a prompt or during the picture sorting/cognitive mapping stage were assigned a '2' (Table 14). These scores were then used to draw up 'salience tables' for each theme, whereby salience is calculated as a percentage of PPP1 participants who mentioned a node in the expert model (100% indicates that everyone mentioned the topic in the core dump phase, and lower percentages indicate that fewer people mentioned the topic or that it was mentioned during the later stages of the interviews). The scores were also summed for each participant to calculate a 'mental model completeness score' (Appendix H). Differences (topics inconsistent with the expert model) and 'new concepts' (absent from the expert model) were listed in separate spreadsheets.

Nature of item	Code assigned
mental model core dump	4
after prompt or during later stages of interview	2
confused theme (not clear whether participant understands theme)	*
fragmentary beliefs (i.e. the theme was mentioned but without context or was talked about without reference to SLC)	#

Table 14: Coding framework for public meta-influence diagram, PPP1

Where a participant suggested that something *might* be linked to SLC, it was coded as present in their mental model. This is because a) one cannot know how certain a participant is; women for example tend to express more uncertainty than men (Rapoport, 1985), and b) the experts are also uncertain about many aspects of the model, so uncertainty would be a poor reason to omit something.

These content analyses facilitated the development of a combined public mental model of the risks in the form of a meta-influence diagram, which graphically shows knowledge gaps and the most salient concepts. To create the diagram, the scores for each theme were summed, and were assigned varying shades depending on the number of people who discussed them. The result is a choropleth-style meta-influence diagram, where the nodes mentioned by the most people are represented by darker blues, and the nodes least mentioned are represented by light blues.

Interpretive analyses of non-knowledge / contextual themes

An interpretive thematic analysis of the interview transcripts addressed non-knowledge themes such as worldviews, trust and efficacy. A structured coding system (c.f. Hansson & Bryngelsson, 2009) was developed largely from notes made during transcription. The themes were identified during a process of 'analytic induction' (Carolan, 2010, p. 310) that is, the concepts 'emerged' from the interviews, and the codes were developed to fit the data. These predefined codes included concepts such as 'future thinking' and 'care'. Codes were added to and refined during the coding phase. The final coding framework is shown in Table 15.

Table 15: Coding framework for thematic analysis of PPP1 interviews

Codes and sub-codes	Example	Code frequency
Communication, rationale	I'll be really interested to know if it is rising or falling – Christine, Uphill	22
Content		
First thoughts	big green banks and a bore wave – Betty, Bridgwater	31
How much SLC	I don't know. Feet? A few feet? Three feet? – Anthony, Bristol	51
Importance of issues	the flooding is a big, big issue – Ruby, Penarth	45
Known from experience and from talking with people	The Severn bore thing is to do with the tides, but again, because I'm not a sailor I haven't got any knowledge of it – Lynne, Coedkernew	104
Known from media	I've seen programmes on the TV which show ice caps melting and that kind of stuff – Paul, Bristol	28
Known from school / university	I think I'm just making it up, but it might be a bit of my old geography degree from 15, 20 years ago, I don't know [laughs] – Jessica, Cardiff	12
Main issues before SLC mentioned	probably renewable energy, I would say. And then maybe pollution – Darren, Gloucester	32
Uncertainty	experts say one thing and then somebody else says something else, and I don't know – Yasmine, Caldicot	6
Influences		
Affect		
Agency	global warming, which we can't do much about – Christine, Uphill	28
Avoidance	I do try not to think about it too much – Ellen, Oldbury	7
Care	we have to do the right thing by our kids – Betty, Bridgwater	42
Excitement, enjoyment	Flooding happens. It is quite exciting at the time. That's terrible, isn't it. It's nice going out and seeing- it's fascinating – Karen, Gloucester	11
Negative experience	having been flooded it's not a nice experience – Steve, Kingston Seymour	10
Feelings	I feel actually quite sad – Paul, Bristol	18
Humour	Me mate lost nearly all his turkeys [laughs]. No, that was pretty horrendous that was – Terry, Wick St Lawrence	26
Optimism/pessimism	Trying to think positively. I think over the next 200 years we're going to run into peak oil – Jessica, Cardiff	36
Personal experience	It's always been a part of my life. So maybe there are things that happen and things that are different because of the Severn than elsewhere. But I don't notice them – Lee, Frampton	3
Worry, concern	I can't do anything about it, I can't worry about it – Karen, Gloucester	61

Continued…

Table 15 continued: **Coding framework for thematic analysis of PPP1 interviews**

Codes and sub-codes	Example	Code frequency
Environmental Justice	I guess some people would benefit, some people would suffer. It's kind of the way, isn't it – Lee, Frampton	8
Blame	Giant international conglomerate, contributing greatly to all sorts of dreadful things, including no-doubt, sea level, because they're just evil – Betty, Bridgwater	27
Dissatisfaction & unfairness	It seems a bit unfair in some ways that they needed the extra land here [for managed realignment] rather than spread out along the whole length of the estuary – Steve, Kingston Seymour	107
Distrust	I'm plucking figures out of the air. A bit like some of the people seem to as well [moderator: scientists?]... yeah. – Anthony, Bristol	28
Government	You could call that on the parliament, and cause them to change it that way. Decrees and stuff like that – Owain, Marshfield	33
Self interest	I don't care if they do it in about 80 years time, when I'm about to die. But I don't want it now – Lee Frampton	5
Trust	I kind of have a trust in people and in God – Betty, Bridgwater	10
Future thinking	I can't see that far into the future. You know, it's difficult to tell, isn't it. who knows what will have happened by then [2100] - Darren, Gloucester	44
Heuristics	dramatic pictures on the news of the flooding in Gloucester, you know, it sticks in peoples' minds you know – Laura, Barry	4
Place & Identity	The tide's very important to Weston. Because we have a wonderful beach [...] the beach at Clevedon is a rubbish beach – Christine, Uphill (Weston-Super-Mare)	73
Community	it's like anything with the British isn't it, anything with a bit of a crisis, people pull together – Karen, Gloucester	22
Psychological distance	Bangladeshis – that's quite a low lying country, isn't it? "White man will always be ok". [Moderator: do you think that's true?] yeah, to be honest at the moment I do – Darren, Gloucester	97
Values	I like the country. I don't like big cities – Lee, Frampton	3
Climate scepticism	I'm not a believer in all that stuff to be honest with you – Darren, Gloucester	30
Gaia, people, nature	it's not the world that's going to end, its only the people who are on it – Glenda, Chepstow	85
God	I think eventually the Sahara will be covered in water, because I think a lot of the biblical prophecies come- well, that's only personal – Christine, Uphill	5

Continued…

Table 15 continued

Codes and sub-codes	Example	Code frequency
Human world & false sense of security	We just kind of feel like we're in a safe little bubble and nothing will really hurt us – Anthony, Bristol	46
Money	Money's linked to everything. Everything. – Lee, Frampton	15
Nature of science	I know computer modelling is amazing, but can you really tell what's going to happen when you put a barrage up? – Christine, Uphill	52
Mental model structure	I'm trying to make something very complicated, and by its nature, I'm trying to simplify it into something, you know, that makes some sense, but it doesn't really – Anthony, Bristol	22
Cause-effect	I have a systems brain, so I see things as inputs and outputs – Betty, Bridgwater	16
Spontage[60]	keep giving it the kinetic energy the sunlight's keep reflected in, so there's not enough time for the, as soon as the water molecules evaporate – Owain, Marshfield	8
Model construction from fragments & theories	we've got the hole in the ozone layer, which is theoretically something to do with the build-up of greenhouse gases – Yasmine, Caldicot	40
Positives & negatives	That's the negatives, that's the positives, that's the contingencies – Lynne, Coedkernew	3
Spontaneous models versus reflective models	I'd say I've probably thought about most of them before, but not terribly deeply, which is why I wasn't able to give great deep answers – Glenda, Chepstow	15
Methodology	The pictures were a great help in a way because you know, I hadn't really a direction for my thoughts. But that has helped me. Crystallise what I think – Christine, Uphill	34
Miscellaneous	And with SLR, it's bound to happen more frequently, as you know, the dice is rolled, you don't need a quadruple 6 anymore, you just need a triple 6 to get your house flooded – Fred, Oldbury	44

Table 15: Coding framework for thematic analysis of PPP1 interviews

[60] The term 'spontage' was coined to refer to when participants used 'spontaneous geographical terminology', volunteering technical geographical terms without context. This would relate to the concept of 'ownership' posited by Kearney and Kaplan (1997). They suggest that a verbal understanding of a concept, i.e. being able to name a concept and perhaps state which words are appropriately associated with it, should be distinguished from *owning* a concept, i.e. having a deeper grasp of the concept and what it refers to, being able to use it confidently and apply it to real situations (Kearney & Kaplan, 1997, p. 588).

5.2.3 Limitations and reflexive account of PPP1

Sampling

Samples can be a source of error when they do not adequately represent the population upon which they are drawn, and when members of the sample refuse to participate or selectively avoid or refuse to answer some of the questions (Fowler & Mangione, 1990). Although the geographical spread, age range and gender split of participants was good, the sample was skewed towards highly educated home-owners, which may have biased the results. However, representativeness was not essential in this research stage because its purpose was to scope the variety of beliefs held by the public rather than gauge the prevalence of these beliefs.

Methodology

If a participant did not talk about a particular theme, it does not necessarily mean that (s)he did not know about it. It might be because (s)he did not want to talk about it. Or it might be because the mental models interview, card sorting task and cognitive mapping task did not elicit their thoughts on that topic. It might also have been because the interviewees did not have time to talk about all that they wanted to. Indeed, interview lengths varied; Steve's transcript was over 24,000 words long (compared to the shortest transcript of 4749 words, and an average transcript length of 11,566 words) and although I was happy to sit for hours, some participants gave themselves much less time to talk about the issue than others. Participants seemed to enjoy the experience; with some explicitly stating that it had been fun (Quote Box 6). Others commented that they had learnt about SLC during the interview process. Some of their comments (Quote 26 and 27) lend support to the rationale behind this research: Christine's comment for example suggests that if she knew that sea levels were rising by more than an inch per year, she may consider moving. Sea levels are not yet rising by this amount, but if they were Christine would want to know about it.

21. "It's been a really interesting morning" – Christine

22. "I've quite enjoyed it [laughs]" – Karen

23. "Well that [the picture sorting task] was fun" – Glenda

24. "I haven't really ever heard of the issue [SLC on the Severn Estuary] before" – Anthony

25. "I suppose I've tended to think about it in the past as a bit science fiction. [...] it's interesting to bring things together, yes, to think of how they interconnect" [...] "I think people should think about a lot more than they do" - Betty

26. [Moderator: how do you feel about the issues that we've talked about so far?] "Well, I don't feel, at the moment, they're relevant. I mean if sea levels were definitely rising, like if they rose an inch last year and forecast to rise another inch this year, I suppose we might think about selling our house. [...] Because there's obviously a lot I don't know about the consequences of presumably sea-level rise or even sea-level fall, because either would be bad, for us. So I'll be really interested to know if it is rising of falling. Because I've sort of assumed that you know, the sea is the sea, and it's always there in the same place. [This session] has made me think, and it's made me much more aware [...] So you're doing me a favour" – Christine

27. "You don't get really a lot of information about [SLC] apart from this whole thing that you know, it's going to rise and flood us. [...Moderator: do you think people will be interested in knowing more about it, or-] well I hope so, I am. After doing this, you know, it's been really interesting, yeah. It's made me sort of think a bit more- made me realise, oh god, you know, I don't really pay as much attention as I should probably. Especially locally. Because you know, you always hear about the wider issue, don't you, the climate change. And with the Maldives and Bangladesh and stuff, but locally, what is going to happen? What is potentially going to happen, I suppose. I want to know" - Ruby

28. [Moderator: how do you feel about the issues that we've talked about so far today?] "probably not that strongly because I don't really know about any of them" - Yasmine

Quote Box 6: Participants' comments on the interview process, PPP1

While the use of three different methodologies was an efficient and engaging way to elicit a wealth of information in a relatively short period of time, there were of course drawbacks and limitations to each stage, discussed below.

Mental models interview

Some participants felt that the mental models interview was like a test, with Paul (Bristol) exclaiming "Oh God! This is like a test! Its general knowledge" and Lee (Frampton) asking "Is this a geography lesson?" Although I tried to make it seem less like a test by telling participants that I was more interested in "perceptions and views; what you think" than in facts, it was impossible to ignore that I was interested in what people know about SLC.

Picture sorting task

The picture sorting task was a popular part of the interview, with Ellen commenting that it was accessible to people who might struggle with more wordy tasks; she said "I applaud you for your

pictures". People approached the task in different ways. For example, some were very specific, only putting pictures in the linked pile if they could give detail on the link. Others guessed links or tried hard to think up relationships between the picture and SLC. For example, one participant exclaimed "I know it's linked but I'm not sure how", and another said "anything with water goes in that pile". Indeed, the pictures 'induced inferences' (Morgan et al., 2002), with Anthony inducing from a picture of molecules that sea levels would rise because they are hotter, and Ellen inducing that 'according to that [picture about isostatic subsidence], we're sinking'.

Some of the photographs were perceived as emotive by some participants, which may have influenced answers. For example, Henry noted unhappy-looking people in Asia (picture 64), while Anthony stated he did not see any association between a happy-looking father and child (picture 10) with flooding. These photographs were not chosen to reflect happiness/unhappiness in either country, but were interpreted this way. These factors may have introduced bias into this stage, which should be noted when considering the data. Regardless of these drawbacks, the methods worked as they were designed to: they prompted thoughts and encouraged participants to talk around the subject, in some cases thinking about aspects that they had never considered before.

Cognitive mapping task

The mapping stage was also popular. Kearney and Kaplan (1997, p. 611) found that participants of the 3CM approach discovered relationships they were previously unaware of and found the process 'satisfying and enlightening'. This was echoed in this research, with Christine stating "well it's not very neat, but I think that sums up what I feel. But you've helped me to think about it. Thank you". Another way to look at this is that the 3CM model may force participants to think about the themes in a way in which they usually would not. Anthony (Bristol) thought that the method "structures something that is not structured".

As suggested by (Ozesmi & Ozesmi, 2004), I constructed my own cognitive maps before beginning the interviews so that I could question my own assumptions and not let my own ideas about the system influence participants. However, there will always be an element of bias from my own input, which was substantial in this stage. Although participants created their own maps and were free to organise, group and link themes in any way that they wanted to, topics in cognitive maps were dependent on the pictures in the picture sort and what I wrote down on the protocol sheet during the mental models interview. Although participants were invited to add to the list of post-it notes used for the cognitive mapping task, few did. Betty noted that she would not have been able to do the task without the post-its.

Interviewer bias

Interviewers can become a source of error by misreading questions, leading or directively probing, through bias from the way in which the interviewer relates to the respondent, and through mis-

recording answers (Fowler & Mangione, 1990). A degree of interview error was minimized by carrying out all of the interviews myself and using a script. These factors led to higher standardization of the interviewing process (Fowler & Mangione, 1990). However, the way in which interviewers relate to respondents can also introduce bias, and this was the case in these sessions. Interviewers should take a neutral, non-judgemental stance to all answers, and should not provide any personal information, values or feedback at all during the session as this undermines the professional relationship and may directly affect answers, introducing bias (Fowler & Mangione, 1990). However, as with the expert interviews (section 3.4), my 'ethic of care behaviours' (Matteson & Lincoln, 2009) may have influenced results. These behaviours consisted of at times agreeing with interviewees in an attempt to put them at ease, particularly when respondents sought reassurance.

Data reduction and analyses

The subjectivity implicit in deciding whether to code a statement as a 4, 2 or # in the public meta-diagram will have inevitably introduced some error. For example, an unprompted "I don't know whether they have flood warnings in place" suggests Ruby knows that flood warnings are important, so this was coded as a 4 despite nothing more being said about them. However, when a participant told me stories that indicated there was community spirit during a flood event, but only mentioned it incidentally and did not actually talk about this community spirit *per se*, it was coded as # (fragmentary beliefs). This is because (s)he might not link it to SLC or see it as at all important. The coding for this stage was made more difficult due to the complexity of the expert map: many themes feed into a number of other themes and sections, and thus decisions had to be made as to where in the diagram themes should be coded if they were open to interpretation. Some themes in the expert model needed to be adapted slightly (for example split into two separate nodes) to allow for public beliefs to be mapped onto them.

At times during the public meta-model creation stage, I felt uneasy deciding whether public beliefs were correct or not because much of the science is conditional, nuanced and uncertain. For example, Christine did not think SLC would affect the Severn bore, and it might well not. And when Glenda stated that "whether it [the sea level] carries on rising depends on whether we get another ice age" she was technically right, even though this would be very unlikely during the next few hundred years. Furthermore, some 'differences' may not be actually wrong; they are just different from the expert views. Each was considered on an individual basis and coded accordingly. My own interpretation of the data is also important to consider. For example, when Owain said that "80% of the ice is below the sea level and ice is less dense, therefore when it melts into water, it will- its density shrinks, well no, its density increases, and therefore its volume shrinks, and therefore it would make no change whatsoever" I interpreted this to mean that melting icebergs

does not add to SLR, which is in agreement with the expert model. But this was an interpretation of what he had said, and he may have meant something else.

Finally, whether a topic is 'owned' by a participant (i.e. the participant knows how to use and apply the term), is not clear in the combined public meta-influence diagram. For example, even though some people knew about a theory whereby a tsunami caused severe damage to the Severn Estuary in 1607 (Haslett & Bryant, 2007), some did not think it was at all a risk to the Severn Estuary. So merely mentioning the theme does not indicate that their interpretation of the theme is aligned with experts' interpretation that a tsunami on the Severn Estuary is theoretically possible (Defra, 2005). Conversely, themes mentioned in the later stages of the interviews were assigned a '2' rather than a '4'. This does not necessarily mean that themes are *not* 'owned'. For example, Steve had so much to say about SLC that I didn't ask him about its causes until during the picture sorting task, so he didn't talk about them before then. Melting icebergs were therefore assigned a 2, when he may have known enough about them to warrant a '4'. Thus, mentioning a theme does not mean that it is 'owned', and not mentioning a theme does not necessarily mean that it is *not* owned. Therefore, the combined map must be considered in conjunction with the table of differences (Appendix I), and the more detailed public interview results presented in Chapters 6-8.

5.3 Public perceptions phase two methods: quantitative survey

5.3.1 Introduction

This section reports the third empirical phase of the study, involving surveys carried out in March 2013 with members of the public living around the Severn Estuary (N=359). The purpose of this phase (PPP2) was to explore public perceptions amongst a wider sample of the Severn Estuary population, and to investigate the *prevalence* of perceptions raised in the qualitative interviews (PPP1). PPP2 followed up on a number of findings from PPP1, but was necessarily selective due to resource constraints and a desire for a high response rate.

5.3.2 Rationale and methodology for PPP2

Rationale

Qualitative interviews are labour intensive, meaning PPP1 could only focus on a small sample of participants. In line with the Mental Models Approach to Risk Communication (Read et al., 1994), a wider survey (PPP2) was necessary to explore the prevalence of perceptions raised during PPP1. While its primary focus was on knowledge aspects (what people know about SLC), contextual

themes such as values and concerns were also investigated. There were two key research questions for this stage:

1. Are the findings of PPP1 representative of the wider population around the Severn Estuary? It was hypothesised that some of the differences between expert and public conceptions of risk (for example the low salience of thermal expansion as a cause of SLC) would be common amongst the wider public, while others (such as the idea that sea levels were falling) would be less prevalent. These hypotheses are listed in Appendix J, alongside the specific PPP2 survey questions that addressed them.
2. Are contextual themes such as future thinking and values related with perceptions of SLC on the Severn Estuary? A number of hypotheses regarding these contextual themes arose from PPP1 (and in some cases EPP). For example, it was hypothesised that participants who were optimistic may project lower amounts of SLC. These hypotheses are also listed in Appendix J, alongside the specific PPP2 survey questions that addressed them.

Methodology

Online survey methodologies

The sampling aim was to recruit a demographically diverse sample of participants who were resident around the Severn Estuary. Online surveys have become increasingly popular over recent decades (Evans & Mathur, 2005) and have been used to explore a wide variety of subjects, including climate change perceptions (e.g. O'Neill & Nicholson-Cole, 2009) and SLR perceptions (Ryan et al., 2012). Research shows that face-to-face questionnaires and internet questionnaires yield different results (Aoyagi, 2012). For example, face to face questionnaires increase social desirability bias[61], but internet surveys may have 'professional respondents' who regularly fill out surveys, which may also affect their responses (Aoyagi, 2012). Other drawbacks of online surveys include low response rates and a bias towards internet users. But they benefit from speed, low administration costs and ease of data entry and analysis (Evans & Mathur, 2005). An online protocol was deemed appropriate for this study because it meant that the survey could be easily distributed over a wide but specifically targeted geographical area, it allowed a variety of question styles and formats (including interactive maps), and it was quick to administer and collate results. The survey was designed and carried out using the Qualtrics online survey platform (Qualtrics, 2013). Qualtrics was chosen because of its flexible question formats and data outputs, its availability, and its compatibility with Maximiles (2013), which was used to distribute the survey.

[61] Social desirability bias is caused by the 'desire of respondents to avoid embarrassment and project a favourable image to others' (e.g. Fisher, 1993, p. 303).

Survey content and structure

Survey content was informed by the results of EPP and PPP1. The public meta-influence diagram and list of differences (Appendix I) informed knowledge questions, while the thematic analysis of contextual themes informed questions on responsibility, affect and future thinking. It was desirable to restrict the survey time to around 20 minutes so as to not dissuade participants and to reduce financial costs, so it was not possible to include everything. Items had to be prioritised, and some topics that emerged from the qualitative analyses were therefore omitted from the survey. These were the wider causes of SLC (e.g. greed and big business), affective themes (e.g. excitement and terror), unfairness and blame.

The survey was 25 pages long, consisted of 18 sections, and took participants a median time of 19 minutes to complete (a mean of 36 minutes was skewed by participants who paused the survey to return after hours or days to complete it). Before launching the survey, it was piloted with family, friends and colleagues (N=15) to check for usability, robustness of scientific content and design. It was refined during this piloting stage to reduce the number of items and to improve clarity, particularly of knowledge items that needed to be both scientifically accurate and relatively jargon-free. The final survey structure with explanatory notes is shown in Appendix J, and is summarised below.

1. **Introduction and Consent**. A welcome page contained details of the study, information on how data would be handled and stored, contact details, consent details and a consent box that had to be ticked before proceeding to the survey.
2. **Issues facing the Severn Estuary (Q1)**. One multiple-choice question investigated the salience of SLC on the Severn Estuary. Participants were asked to tick up to five of 11 issues (with an additional 'other issues' free text box and a 'no issues' option).
3. **Rates of sea-level change (Q2-5)**. This section was designed to investigate how much participants thought sea levels would rise or fall in future. It consisted of three questions. The first had three simple sliders representing sea-level rise and fall (significant, moderate, slight or no change) by 2050, 2100 and 2200. The second consisted of two multiple-choice items asking participants to state whether sea-level rise and sea-level fall would pose a major risk, slight risk, neither a risk or a benefit, slight benefit or major benefit to the Severn Estuary. The third listed 5 items about the future magnitudes of SLC, asking participants to state the likelihood of each on a seven point scale from very unlikely to very likely.
4. **Concern (Q6)**. This item was designed to investigate levels of concern. It consisted of a single multiple choice question with four response options: not at all concerned, not very concerned, fairly concerned and very concerned.

5. **Causes of SLC (Q7)**. This item was designed to explore participants' knowledge of the causes of SLC. It asked participants to choose whether 11 statements about SLC were false, maybe false, maybe true, or true, with an additional 'don't know' option. Similar true/false response scales have been used in previous mental models survey studies (Cox et al., 2005; Read et al., 1994; Reynolds et al., 2010).
6. **Scepticism (Q8&9)**. Participants were asked to what extent they agreed with 10 statements about climate change and SLC, on a 5-point response scale ranging from strongly disagree to strongly agree. The statements consisted of 3 items from a climate change scepticism scale developed by (Whitmarsh, 2011), 6 items from the same scale with the words 'climate change' substituted with the worlds 'sea-level change', and an additional item "The science of sea-level change is uncertain". For more information about the scales used in PPP2 and their reliability, see Appendix M.
7. **Trust in information sources (Q10)**. This multiple-choice question asked participants to tick up to five of 13 information sources that they would most trust to get information about SLC on the Severn Estuary.
8. **Sea-level change information**. This section provided a short introduction to SLC, outlining its causes and projected magnitude by 2100. Its purpose was to ensure that participants had enough information to answer subsequent questions.
9. **Physical impacts of sea-level change (Q11)**. Using the same true/false format as section 5, participants were asked to decide whether ten statements about SLC were false, maybe false, maybe true or true, with an additional 'don't know' option.
10. **Socio-economic impacts of sea-level change (Q12)**. Using the same true/false format as sections 5 and 9 above, this question consisted of 14 statements about the possible socio-economic impacts of SLC.
11. **Concern about socio-economic impacts (Q13)**. A multiple-choice question asked participants to tick one or more of 17 potential impacts that would personally concern them, or to tick none if none concerned them.
12. **Spatial vulnerability (Q14)**. Participants were asked to click on up to five areas on a map of the Severn Estuary, indicating which they thought would be most affected by SLR by the year 2050.
13. **Mitigation (Q15)**. A multiple-choice question asked participants to select up to three of seven measures that would be most effective in limiting the amount of SLR on the Severn Estuary, regardless of which options they preferred. Two exclusive options were also available: 'NOT APPLICABLE: I don't think SLC is an issue', and 'NOT APPLICABLE: I don't think the amount of SLC can be limited'.
14. **Adaptation (Q16)**. Using the same format as section 13, a multiple-choice question asked participants to select up to five of 11 measures that would be most effective in reducing

the impacts of SLR on the Severn Estuary, regardless of which options they preferred. Two exclusive options were also available: 'NOT APPLICABLE: I don't think SLC is an issue', and 'NOT APPLICABLE: I don't think the impacts of SLC can be reduced'. Questions 15 and 16 address a knowledge gap regarding public knowledge about the climate-related effectiveness of behaviours and policy measures, suggested by Tobler et al. (2012) to be a future avenue for research, though they have previously been examined in the context of Alpine flash floods and landslides (Wagner, 2007).

15. **Miscellaneous opinions (Q17-18)** This section explored a number of constructs, including responsibility, efficacy, feelings, informedness and vulnerability. Responses to 17 statements were measured on a five-point agree/disagree bipolar scale.
16. **Values and Beliefs (Q19-23)**. This section consisted of five questions designed to explore participants' values and beliefs.
    a. The first question asked participants to state their level of agreement with nine statements about the future, derived from van Asselt et al's (2010) 'temporal repertoires'. I was interested in whether the ways in which the public think about the future are related with their perceptions of SLC. To my knowledge, there is currently no scale to measure the repertoires, so the items in this question were designed to facilitate the development of such a scale.
    b. The second question asked participants to what extent they agreed with ten statements constituting an optimism scale (Cronbach's $\alpha = .85$) developed by Scheier, Carver, and Bridges (1994).
    c. The next three questions asked participants to tick the box next to diagrams that best described their relationship with nature, their local community and the Severn Estuary. The three scales each consisted of 7 overlapping circles, ranging from one (circles not touching) to seven (circles totally overlapping). The scales were modified from the Inclusion of Other in the Self (IOS) scale originally developed by Aron, Aron, and Smollan (1992) and adapted by Schultz (2001).
17. **Demographic questions (Q24-31)**. These questions were designed to provide a demographic profile of the sample and to enable comparisons across groups. They consisted of questions about gender, age, children/dependents, living situation (owned/rented etc.), previous flood and erosion experience, highest qualifications, highest qualifications in a science-related subject, residential area, rurality, distance from the Severn Estuary coastline, amount of time resident around the Severn Estuary, and media use.
18. **Debrief and further information**. A debrief page thanked participants for their time, reiterated the purpose of the study and provided contact information. Participants were then directed to the Maximiles website to claim payment.

Sampling and distribution

Respondents were recruited by Maximiles (2013), a specialist participant recruitment agency specialising in online panels. Maximiles was chosen because they were able to target a specific area, were affordable, and had been successfully used by colleagues. Maximiles emailed the survey link to members of their panel that lived within ten miles of the Estuary shoreline, shown on the map below, courtesy of Kate Walker-Springett who extracted a list of 52,876 postcodes from the region using ArcView geographical information systems (GIS). Maximiles used these postcodes to identify potential participants, who were rewarded with Maximiles points on completion of the survey.

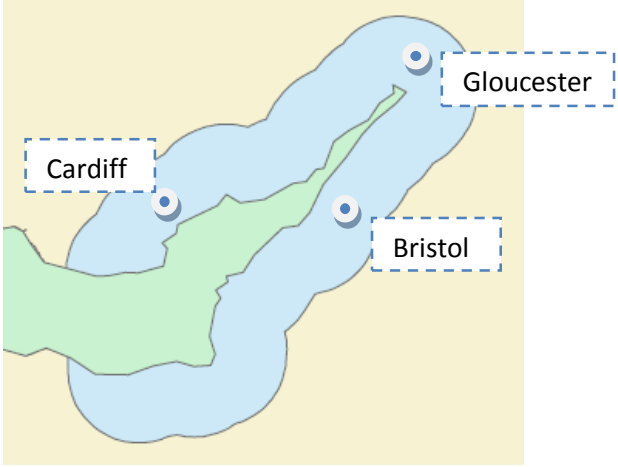


Figure 15: Ten mile coastal zone sampled for the PPP2 survey
The zone sampled is shown in blue (map courtesy of Kate Walker-Springett)

Maximiles emailed the survey to a total of 3843 people, and the survey was open for a period of four days. The survey response rate, calculated as a percentage of the number of people sampled, was 9.6%. Most non-respondents were those who did not respond to Maximiles emails inviting them to participate. However, non-respondents also include 45 people who either accessed the survey after the cut-off time (5pm 12th March 2013) or began the survey and did not complete it within one week. The dropout rate was 12%, with drop outs evenly distributed throughout the survey.

Appendix K shows the sample statistics in detail. In summary, 58% of the sample was female, and 47% had children/dependents. Fully 38% lived within five miles of the Severn Estuary, and 73% had lived around the Estuary for more than ten years. A total of 61% lived in England, 35% in Wales, and 2% close to the border (exact locations are unavailable due to response mode; percentages do not total 100 due to rounding effects). The age profile was as follows: 17-24 (5%), 25-34 (20%), 35-44 (18%), 45-54 (23%), 55-64 (21%), 65-74 (10%), 75+ (2%). Appendix K shows a comparison of PPP2 survey data with national statistics (England and Wales). It shows that the age profile of the survey sample is biased towards middle-aged participants, with an underrepresentation of the oldest and youngest groups. The sample is also overrepresented by

people with higher qualification levels, and is overrepresented by females (58% of PPP2 respondents were female, compared to 51% of the national population). Rates of home ownership are approximately in line with national figures.

Ethical considerations

Respondents were made aware of their right to withdraw at any time and could decide not to take part in the questionnaire at their own discretion. Aside from the consent box, any question could be omitted should the participant not wish to answer it, including all demographic questions. All data is held anonymously and cannot be linked back to any individual person. At no point did I know the names or addresses of participants.

Data analysis

The raw survey data was cleaned before analysis commenced. This involved the removal of 11 responses from the dataset due to speeding, duplication and flat-lining, leaving a final dataset of 359 respondents. The following procedure was used to clean the data:

a) **Speeders:** Six respondents completed the survey in less than six minutes so were judged to be not reading or answering the questions appropriately. The cut-off point was set at six minutes in-line with the minimum survey time recommended by Bainbridge (2009), which is 30% of the median response time (30% of 19 minutes is 5.7). This seemed sensible considering I was able to skim read and answer all questions in no less than 5 minutes 50 seconds.
b) **Flat-liners**: Eyeballing each participant's data identified four respondents as 'flat-liners', i.e. individuals who had answered every answer the same.
c) **Duplicates**: One respondent was identified as having responded from the same Maximiles link twice. His second response was deleted.

Data were screened for outliers, abnormalities and violations of normality, and appropriate tests were selected accordingly. Results were analysed using SPSS (Statistical Package for the Social Sciences version 12), and Microsoft Excel 2007 was used to summarise and present results. Statistical tests included Wilcoxon Signed Ranks tests, analysis of variance (ANOVA), Spearman's correlations and multiple regression analyses. Existing scales were used to measure scepticism and optimism, and a 'futures' scale was developed for the purposes of this research. In addition to these, knowledge scales were calculated from participants' true-false responses, SLC magnitude and mitigation efficiency responses. Finally, a concern scale was developed from five items embedded throughout the survey. Details of scale development and reliability analyses are discussed in Appendix M.

5.3.3 Limitations of PPP2

It was simply not feasible to ask everyone who lives around the Severn Estuary what they think about SLC. Therefore, it was necessary to study a sample of the population instead. However, sampling introduces the potential for bias when the sample does not adequately represent the population upon which it is drawn (Fowler & Mangione, 1990). While 100% of participants in this study were internet users, only 80% of households in Britain had internet access in 2012 (Office for National Statistics, 2012). People with internet access may be more highly educated, younger, and higher earning than those without (Aoyagi, 2012), thus the sampling strategy is likely to have introduced some bias in this respect. Indeed, the profile of respondents was more highly educated than average. The benefits of using this strategy (reduced potential for social desirability bias, and ease of distribution over a wide geographical area) are considered to outweigh these potential costs.

The low response rate of 9.6% could also raise concerns over bias. However, the demographic profile suggests a broad range of participants (Appendix K). The possibility of an 'interest' sample (one biased towards those already interested in the topic) was minimised by two factors: participants were not made aware of the specific topic (SLC) until they had begun the survey; and participants were paid for their time via an arrangement with Maximiles.

Another limitation of this study is that this survey, as with all surveys that use researcher-defined rating scales, render participants unable 'to say what really matters to them about the question under investigation' (Bickerstaff et al., 2006a, p. 5). Furthermore, the analyses of aggregate survey data 'elides individual and group differences in risk perceptions' (Bickerstaff et al., 2006a, p. 5). However, as discussed in section 2.7, a key benefit of employing the mixed-methods approach used in this thesis is that these quantitative methods can be complemented by the qualitative data from PPP1. For this reason, and to aid conceptual clarity, the results from PPP1 and PPP2 are analysed together. It is to these analyses that we now turn.

6 PUBLIC RESULTS: ORIENTING DISPOSITIONS

This chapter discusses participants' orienting dispositions; those factors that may predispose an individual to make particular choices or decisions, such as their personality and the information sources that they use. It begins with a discussion of the sources of public beliefs about SLC, before discussing personality variables such as concern and scepticism.

6.1 Sources of information about sea-level change

6.1.1 Introduction

This section explores the sources of information that public participants use for information about SLC, and to what extent such sources are trusted. Figure 16 shows the percent of PPP1 survey participants who trust different sources for information about SLC on the Severn Estuary. It shows that respondents tend to most trust the Environment Agency and Natural Resources Wales[62] (66% respondents), with scientists a close second (63%). Trust has been shown to be an important consideration in risk perceptions, with distrust in information sources constituting a barrier to public engagement with climate change (Lorenzoni et al., 2007). Trust is discussed further in section 7.3.3, while the rest of this section explores information sources in turn.

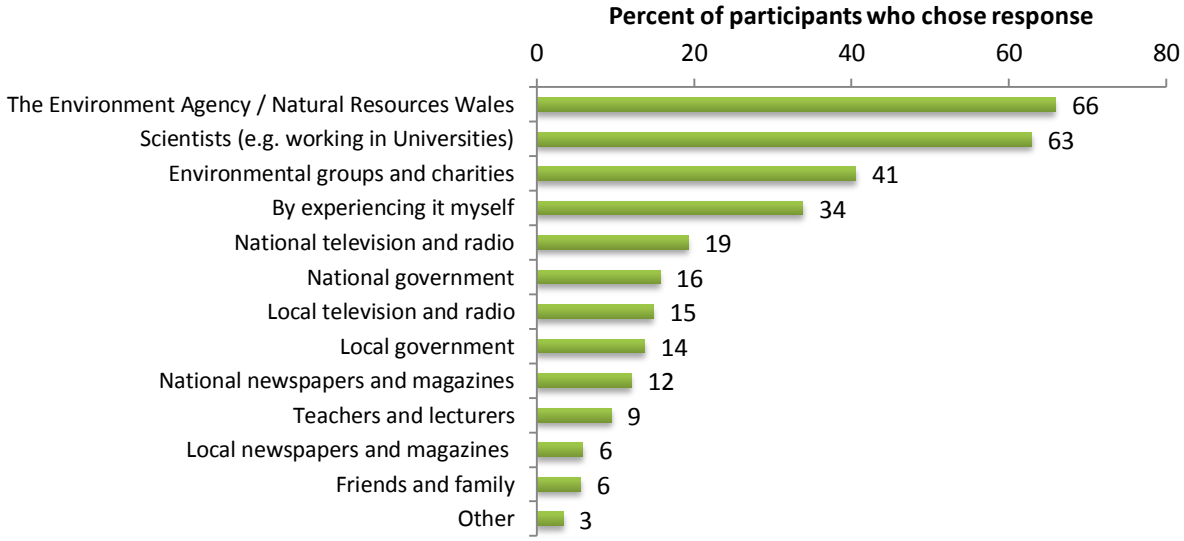


Figure 16: Trust in information sources, PPP2

Responses to PPP2 Q10 "Which sources of information would you most trust to get information about sea-level change on the Severn Estuary?" Respondents could tick up to five sources. N=358.

6.1.2 Formal education

PPP2 respondents rated teachers and lecturers relatively low on their list of trusted sources of information about SLC on the Severn Estuary, with just 9% of respondents ranking them in the top five (Figure 16). Geography was the main subject cited by interviewees for information about SLC (Ellen, Jessica, Owain, Ruby, Steve, Yasmine), and Owain also drew on ideas from Chemistry

[62] Environment Agency Wales merged with the Countryside Council for Wales and the Forestry Commission Wales to form a single environmental body, National Resources Wales, on 1st April 2013. This was after all interviews and surveys were carried out. 'Natural Resources Wales' was however included in the 'Environment Agency Wales / Natural Resources Wales' survey category on account of the survey running so close to the merge date.

lessons. As discussed earlier, our time exposed to science at school is small compared to our time exposed to science elsewhere (Falk & Dierking, 2010)[63], and individuals draw on information from a variety of arenas. It is to these other sources that we now turn.

6.1.3 Media

As shown in Quote Box 7, PPP1 interviewees cited a variety of media sources for their ideas about SLC, including national radio, local and national newspapers, and television documentaries. These sources provided not only factual information, but also food for thought or a reference point (Quote 36). Figure 17 shows media use among PPP2 participants. Results are consistent with previous research that shows TV is among the most common sources of scientific information (Hargreaves et al., 2003) and information about marine climate change issues (CLAMER, 2011a). This may be related to PPP1 interviewees' desire to *see* change in order to believe it (see section 6.1.5). Consistent with other research (CLAMER, 2011b; Hargreaves & Thomas, 2002), TV is also among the more trusted media sources (Figure 16). PPP1 respondents expressed more trust in sources such as the BBC and Radio 4 than in newspapers (Quote Box 7). 'Local newspapers & magazines' were also the joint least trusted source of information about SLC by PPP2 respondents, with national newspapers and magazines also low on the list.

Quote Box 7 indicates that the media can be simultaneously trusted and distrusted, consistent with previous research (Hargreaves et al., 2003). However, as also noted in other research (e.g. Butler & Pidgeon, 2009), Lynne does not passively absorb and blindly trust whatever she does read (Quotes 35 and 50).

Figure 18 shows the prevalence of news items relating to SLC in mainstream media. It shows that SLR and the Severn Estuary are not covered as widely as climate change and the recession. However, SLR did receive significant attention, with 317 articles mentioning SLR on the Guardian website in 2012. Despite coverage of SLC in mainstream news media however, PPP1 participants noted that sources tended to provide general rather than local information (Quote 30) and that they tend to hear about the issue of SLC in relation to other places, not their locality (Quote 31); a trend also noted by Harvatt et al. (2011) with regards to flooding and SLR in the UK, and indicated in Figure 18 by the low mention of SLR in the Somerset County Gazette (just two articles). Indeed, for PPP2 participants, national media was a more trusted source of SLC information than local media (Figure 16).

[63] This paper refers to work carried out in the USA. However, their calculations are broadly in line with the contact UK school pupils also receive.

29. "I watch **BBC Natural World** sort of things, that sort of stuff. I try and, you know- **the odd newspaper article**, but they're generally dramatisations and such, you know, trying to sell papers, that I don't really pay a lot of interest in them. I suppose more like BBC programmes or whatever. Or that sort of Natural World kind of thing. You feel that they're probably not trying to dramatise it so much to get figures so much"- Anthony

30. "**I'm led by the media** to believe that they've risen. I've got no reason to doubt that. But on a very general- yes, sea levels have risen, and are rising, and will continue to rise. In particular to the Severn, I've got no knowledge of anything particular" - George

31. "I don't really pay as much attention as I should probably. Especially locally. Because you know, you always hear about the wider issue, don't you, the climate change. And with the Maldives and Bangladesh and stuff" – Ruby

32. "I think the **radio** is actually better because programmes on the radio can be based on one element of the news, and they can go into it more fully. Cheers for **Radio 4**" – Glenda

33. "I do watch these weird programs on **Discovery Channel**. And I don't know how true it was, but it seemed quite true because it wasn't like one of those cheap knock-off documentaries. Looked like they'd spent some money on it" – Lee

34. "I think it's because of the dramatic pictures on the news of the flooding in Gloucester, you know, it sticks in peoples' minds" – Laura

35. "I'm the dreaded **Daily Mail** reader" – Lynne

36. "When I was about seven or eight, there was a **Spitting Image sketch**, and it was when global warming was first coming in as a theory. It's the one thing that jumped into my mind. And it was the Michael Fish puppet with his glasses on, and it cut to 2050 or something, and there was just a big blue screen behind him with a tiny little green dot and he said 'the southeast is going to be very, very wet, apart from the top of Ben Nevis, which is going to be very, very crowded'. And that was it. And that's always stuck with me. That's my first thought about SLR, global warming, is Michael Fish telling me that everyone's clambered to the top of Ben Nevis because everywhere else has flooded. That really is the first thing that springs to mind. [...] glaciers melting and Michael Fish telling me that Ben Nevis is crowded are my two overriding images of SLR. Yeah" – George

Quote Box 7: Media use, PPP1

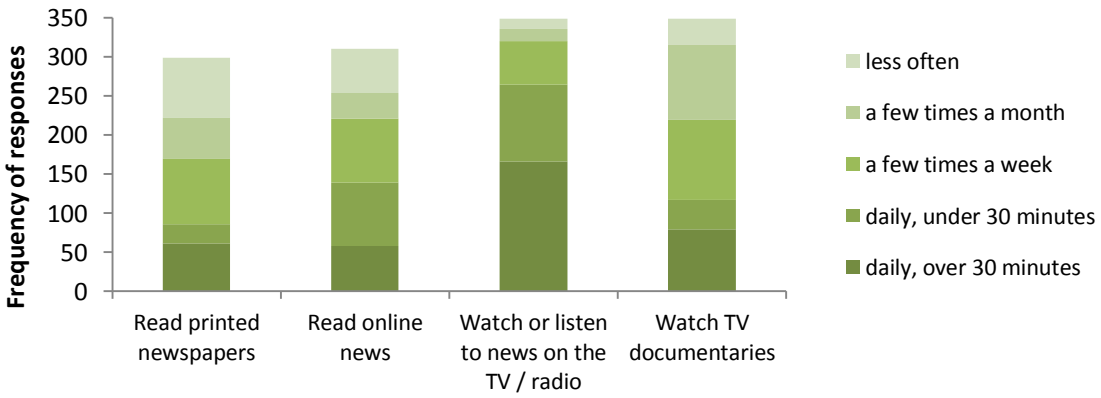


Figure 17: Media use, PPP2

The columns are different heights because participants did not have to answer each question; lower column heights indicate lower response rates.

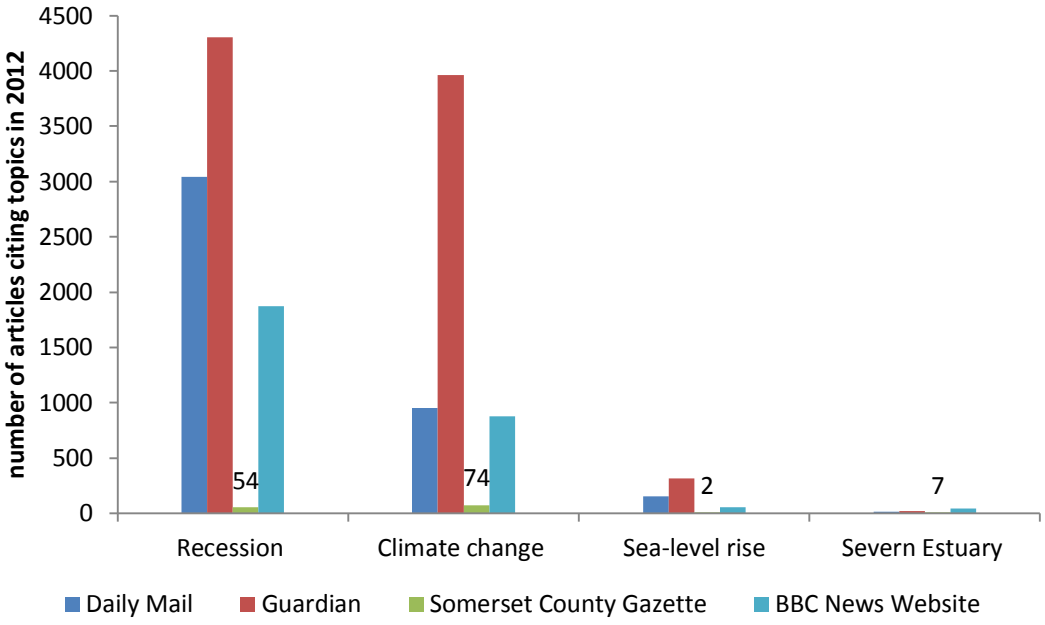


Figure 18: British news articles citing SLR and other topics in 2012, by news source[64]

The frequencies of articles in the Somerset County Gazette are labelled.

6.1.4 Science

Fully 63% of respondents ranked scientists in their top five most trusted sources of information about SLC on the Severn Estuary (Figure 16), consistent with previous research showing the high trust placed in scientists as sources of information (CLAMER, 2011b; Ding et al., 2011; Hargreaves et al., 2003; Whitmarsh et al., 2005). However, a significant proportion of respondents (17%) strongly disagreed or tended to disagree with the statement "I trust scientists to tell me the truth about SLC" (see section 6.2.2). This distrust was noted by Shuckburgh et al. (2012) in regard to climate change, where one third (34%) of respondents disagreed with the statement that 'climate scientists can be trusted to tell us the truth about climate change'. It hints at the complex relationship between the public and science, also revealed by PPP1 participants. On one hand, participants see science as a beacon of truth, whilst also viewing experts with suspicion and sometimes holding expert authority in contempt (Quote Box 9). Some PPP1 respondents appeared to perceive science as an inaccessible 'other' possessing 'unique powers', as noted in previous research (Bickerstaff et al., 2008; Bickerstaff et al., 2006a; Michael, 1992). This is demonstrated by comments such as "I'm not a scientist, I don't know" (Quote Box 8).

[64] This data was obtained by carrying out a search for articles containing the terms 'sea level rise', 'climate change' 'recession' and 'Severn Estuary' on the respective news websites, May 2nd 2013.

37. "I'm not a scientist, but I would have thought that there's got to be a way of stopping water with something" – Lynne

38. "I'm not a scientist, I don't know" – Terry

Quote Box 8: Science-in-general, PPP1

These quotes suggest that to some extent, participants hold science on a pedestal. However, it is not a simple case of positioning one's self or one's own knowledge as subordinate to science. While science was at times seen as an inaccessible other, at others it was ridiculed or treated with suspicion or contempt, even by the same interviewee (Terry, Quotes 38, 39)[65]. For instance, Anthony remarked that he was "plucking figures out of the air. A bit like [scientists] seem to as well, [...] fitting in with whatever they're trying to argue". One way in which expert authority is challenged is through undermining theoretical knowledge by common sense McKechnie (1996), as indicated by Terry (Quote 39), and explicitly referred to by Steve (Quote 40).

39. "They came, I said 'well that ain't going to work', he said 'I know', he said 'I know'. But their engineers, they done a computer module [sic] and that's how it's got to be. Well within a month, they're back there, correcting it. But it's still not working". [...] I don't think some of the experts are experts, but that's a matter of opinion [laughs]" – Terry

40. "All the locals said 'that'll flood, that's a stupid place to build houses' but the developers said 'no we're building it there' so they went to the government. Government said 'yeah you can build there'. They built on it and it flooded. No one was surprised that lived up there, because they all knew the local conditions. So that was a case of big business I think overruling common sense" - Steve

Quote Box 9: Challenging expert authority, PPP1

6.1.5 Experience: direct and vicarious

Direct experience

'By experiencing it myself' was the fourth most trusted source of information about SLC on the Severn Estuary amongst PPP2 respondents (Figure 16), consistent with PPP1 findings (Quote Box 10) and other research that highlights the high trust placed in personal observation in the context of flood risks (Whitmarsh, 2008). For example, PPP1 participant Paul stated that "unless somebody's going to the trouble of faking all this stuff, which would be quite expensive to do, then you have to go with your own eyes". Indeed, the interview theme 'known from experience' was the second most commonly coded theme in PPP1 interviews (Table 15).

Individuals gain local knowledge through a variety of experiences. Quote Box 10 shows that participants had learnt through direct experience of SLC processes (Glenda), impacts (Henry,

[65] Note that Terry's initial comment 'I'm not a scientist, I don't know' could have been ironic.

Karen, Steve) and alleviation measures (Lee). Some participants also gained local knowledge through working as part of or alongside organisations such as the drainage board or the Environment Agency (Laura, Steve, Lynne and Terry). Direct experience of actual events however is unnecessary, and PPP1 results show that knowledge can also be induced[66] from local observations as shown in Quote Box 11.

41. "when we went to Alaska, we could see this glacier that is you know, disappearing" – Glenda

42. "We had a major flood in 1980 I think it was. When the sea water came up to the field at the bottom here [...] I've been affected by it because I couldn't get to work one day because the levels had flooded" - Henry

43. "So I had a phone call at work 'the water's coming in, I can't keep it out', 'ooh, Dad, I'm coming!' [laughs]. So I drive up there, and I was wearing flip flops" [...] "The flood of 2007 is the one that sticks in my mind, obviously, because it was so big. It had an effect on us because work was closed, [...] water pumping station for the area got flooded" – Karen

44. "But we have been overtopped here once, in 1981, and we had salt water up through the house here" – Steve

45. "I only know about the [stop-lock] in Epney because it's right by my house and I used to play there as a kid" – Lee

46. "That's what I've learnt by being with the water company. That when sea levels rise, drainage is the big problem" – Lynne

47. "I have had a little bit of insight into it because I have had meetings with the Environment Agency" [...] "That's [knowledge about flood defence budgets] from my bit of knowledge picked up on these committees I've been on" – Steve

Quote Box 10: Direct experience, PPP1

48. "I thought to myself when I had just moved here, the way those large pieces of tree are lying about, you'd think they'd been left there by a river going away"- Glenda

49. "We had to fly across the tip of Greenland and the pilot said "we're just going over Greenland now" he said, he says "some of those mountains you see there, is just the tops of the mountains" he says "there's something like 3 miles of ice or snow" it was miles deep on the internal part of Greenland. And you couldn't imagine it. So I was thinking if- that's an awful lot of fresh water up there being stored. So if it did melt I mean we would be in trouble I think" – Steve

Quote Box 11: Induction from experienced observations, PPP1

[66] Induction is a 'bottom-up' approach to reasoning whereby specific observations are generalised into broader theories. Induction is discussed further in section 7.2.7.

Vicarious experience

Experience can also be vicarious, through other peoples' experiences. Amongst PPP2 respondents, friends and family were the joint least trusted source of information about SLC on the Severn Estuary (6%). However, this contrasted with indications from PPP1 respondents, who often cited information provided by friends and family (Quote Box 12). This difference might be due to a social desirability bias whereby PPP2 participants felt that friends and family were not externally viewed as reliable sources of information, even though they are implicitly trusted. Lynne felt there was a conflict of information between media sources and what her family had told her (Quote 50).

50. "And [my nephew] said it was twice as deep, the ice cap, when he first started taking notice and interest in skiing and walking groups up there. So that's in his lifetime, so you could have said in the last 30 years, it's about 10 years ago I was talking to him. So although underneath I'm sceptical, that is one fact that has been verified by somebody I know. Not by a friend of a friend. You know, when you know something first hand, it does make you pull up a bit. Every other bit of information I've had is sort of second or third or fourth through either Radio 4 or the Daily Mail. You know. I think it's conflicting" - Lynne

51. "I haven't seen that [flooding] happen, but you know, talking to other dog walkers, that's what they've been telling me" – Glenda

52. "I was chatting to an old seadog sailor up at the pub last week, and he told me [the local power station] was nuclear" – George

53. "And the time when it flooded before that was [when] my grandmother [was] probably a very young child, about the turn of 1900s or 1890s, and the old lady that used to live here, [...] she came here once and she was in her 80s then, she said "when I was a little girl" she said "my mother was upstairs having one of my sisters or brothers or something and having the baby at home" she said, "and I was only about three or four, but my job was just run down the stairs and tell them how high the water is coming". That was her memory. She died probably in about 1980, I expect, and she could remember that when she was a very small child. So that was the previous time to that when the sea had come in" – Steve

54. [Facilitator: where's that come from for you? Is that from seeing stuff or reading stuff or-] "more from being with him [boyfriend]; it wouldn't have occurred to me previously except that his uncle goes up to the shooting range, which you know, [you] hear bits of conversations" – Yasmine

Quote Box 12: Vicarious experience, PPP1

The importance of local knowledge

A number of participants directly referred to the importance of local knowledge. For example, Steve (Kingston Seymour) noted that some people who do not closely experience the estuary do not have such local knowledge, stating "I don't mean someone who lives in town that's looking at [...] national trends, but if you lived down here, you'd know that there's less bird life than there used to be [...] there's a lot of people that live in the village, they've never been down there, they don't know what the issues are". This local knowledge could be called 'local knowledge-in-general',

after Michael's (1992) 'science-in-general'. In Michael's account, the public address science as 'an abstract entity or principle' (p313) and differentiate themselves from it, being 'not mentally equipped to comprehend science' (Michael, 1992, p. 318). During PPP1 interviews, local knowledge-in-general emerged as a special kind of knowledge that was only accessed by privileged groups such as 'old timer families' (Ellen, Quote 55) and people who have lived around the Severn for some time; a rich local knowledge that is respected by others, as noted by McKechnie (1996). While science-in-general is 'an other from which one is permanently banned from entering' (Michael, 1992, p. 319), local knowledge-in-general can be entered through experience. A number of respondents spoke of learning about the estuary from sailing on it, and Lynne noted that she didn't know about the Severn bore because she wasn't a sailor. Irwin et al. (1999, p. 1319) suggest that forms of local expertise are 'intimately linked' to specific activities such as these. For PPP1 interviewees, sailing (Jessica, Fred, Ellen, Laura, Darren, Steve) and farming (Steve, Terry) were dominant activities.

55. "Old timer families around here very readily trip off these little tales. So I think it's something people are conscious of, and I suspect people generally have a better understanding about tides and flooding [...] than they do in other places" – Ellen

56. "The Severn bore thing is to do with the tides, but again, because I'm not a sailor I haven't got any knowledge of it" – Lynne

57. "People that just buy a nice little house from Barratt homes [have] no connection to the local- they just think they're living in a nice housing estate. And then all of a sudden you know, nature comes knocking on the door. [I] can imagine that being a different perception of risk and a lot more pain and shock and distress as a result, but my friend lives in Granny's house, "oh yeah, Granny's house always used to get flooded" um. So I think the older communities have learnt." – Fred, Oldbury

Quote Box 13: Local-knowledge-in-general, PPP1

Local experience should not be underestimated (Irwin et al., 1996). One PPP1 participant in particular could be described as an 'experience-based expert', having gained knowledge through experience rather than through qualifications (Collins & Evans, 2002). This is Steve from Kingston Seymour, whose highest science-related qualification is a Geography O'Level, but whose experienced-based knowledge of the Severn Estuary rivals those with more formal knowledge. He covered the greatest proportion of the expert model of all participants (Figure 19), and had ownership (a working understanding) of many of the more complex issues in the expert model, including recurrence intervals, coastal squeeze and isostatic subsidence (Quote Box 14).

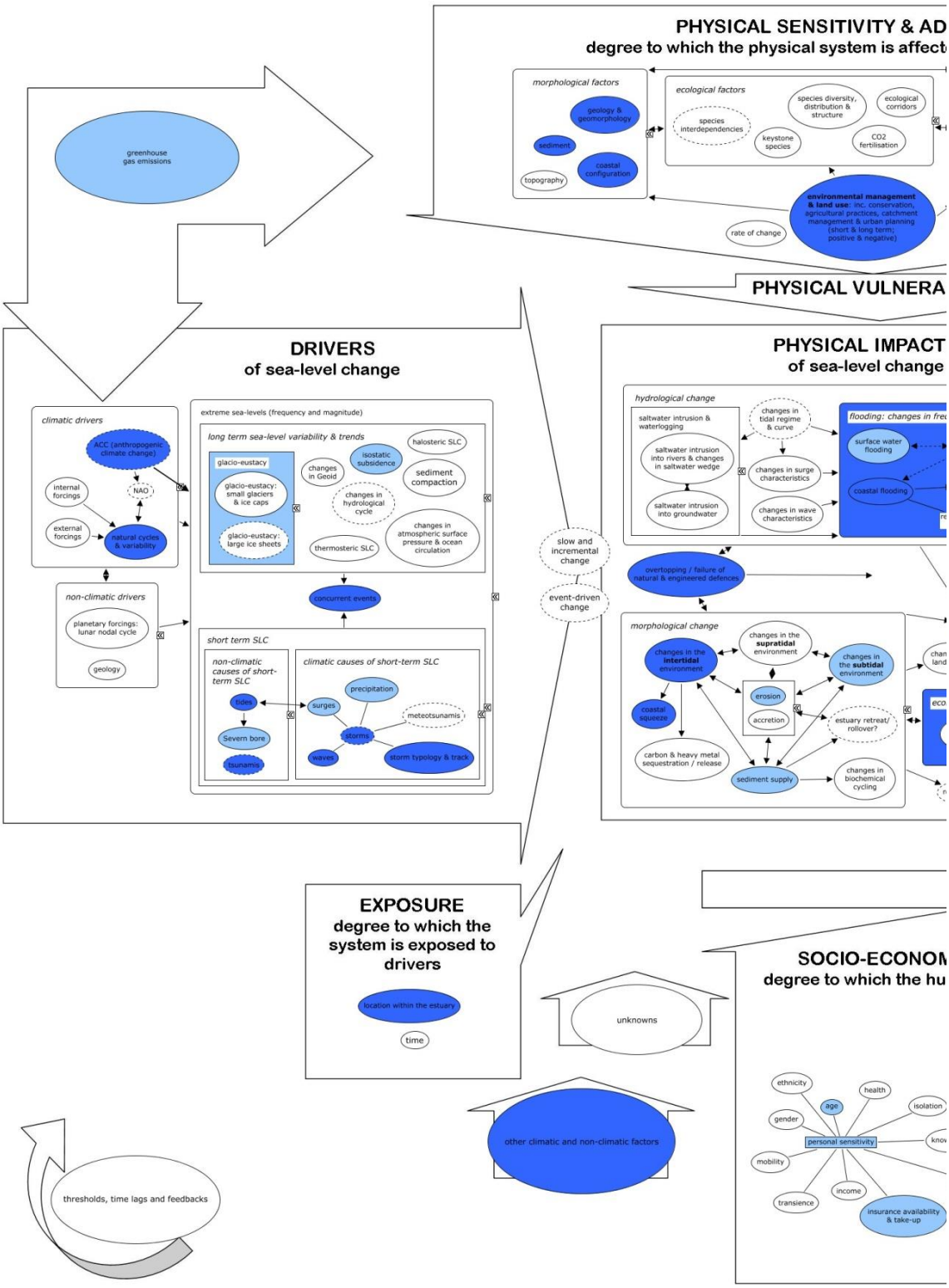
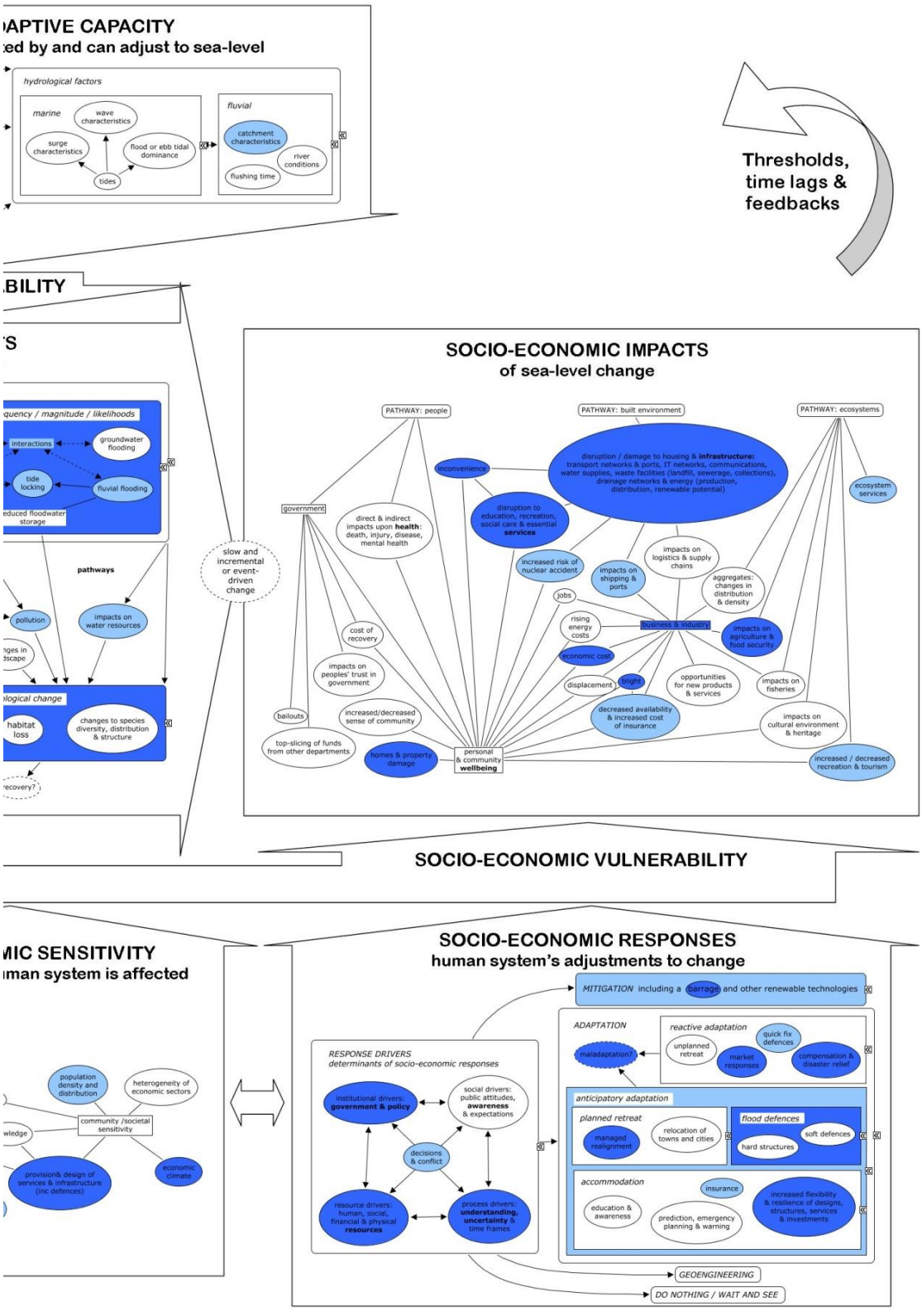


Figure 19: Steve's PPP1 interview data mapped onto the expert model

Dark blue nodes are those that he mentioned during the 'core dump' phase (during the mental models interview); light blue nodes were mentioned during the rest of the interview session. Nodes not mentioned at all are white.


APTIVE CAPACITY
ed by and can adjust to sea-level
hydrological factors
marine
wave characteristics
surge characteristics
flood or ebb tidal dominance
tides
fluvial
catchment characteristics
river conditions
flushing time
Thresholds, time lags & feedbacks
BILITY
S
quency / magnitude / likelihoods
interactions
groundwater flooding
tide locking
fluvial flooding
educed floodwater storage
pathways
pollution
impacts on water resources
ges in scape
ological change
habitat loss
changes to species diversity, distribution & structure
ecovery?
slow and incremental or event-driven change
SOCIO-ECONOMIC IMPACTS
of sea-level change
PATHWAY: people
PATHWAY: built environment
PATHWAY: ecosystems
government
inconvenience
disruption / damage to housing & infrastructure: transport networks & ports, IT networks, communications, water supplies, waste facilities (landfill, sewerage, collections), drainage networks & energy (production, distribution, renewable potential)
ecosystem services
direct & indirect impacts upon health: death, injury, disease, mental health
disruption to education, recreation, social care & essential services
increased risk of nuclear accident
impacts on shipping & ports
impacts on logistics & supply chains
aggregates: changes in distribution & density
jobs
rising energy costs
business & industry
impacts on agriculture & food security
economic cost
cost of recovery
impacts on peoples' trust in government
displacement
blight
opportunities for new products & services
impacts on fisheries
bailouts
increased/decreased sense of community
decreased availability & increased cost of insurance
impacts on cultural environment & heritage
top-slicing of funds from other departments
homes & property damage
personal & community wellbeing
increased / decreased recreation & tourism
SOCIO-ECONOMIC VULNERABILITY
MIC SENSITIVITY
man system is affected
population density and distribution
heterogeneity of economic sectors
community /societal sensitivity
wledge
provision& design of services & infrastructure (inc defences)
economic climate
SOCIO-ECONOMIC RESPONSES
human system's adjustments to change
MITIGATION including a barrage and other renewable technologies
ADAPTATION
reactive adaptation
quick fix defences
unplanned retreat
maladaptation?
market responses
compensation & disaster relief
anticipatory adaptation
planned retreat
managed realignment
relocation of towns and cities
flood defences
soft defences
hard structures
accommodation
insurance
education & awareness
prediction, emergency planning & warning
increased flexibility & resilience of designs, structures, services & investments
RESPONSE DRIVERS
determinants of socio-economic responses
institutional drivers: government & policy
social drivers: public attitudes, awareness & expectations
decisions & conflict
resource drivers: human, social, financial & physical resources
process drivers: understanding, uncertainty & time frames
GEOENGINEERING
DO NOTHING / WAIT AND SEE

Recurrence intervals and concurrent events

58. "Whereas it might be only once or twice a year when you get a very high tide and there's risk of it coming over [...] there's going to be more tides which will fall into the category in 100 years time if you're two foot higher or a foot higher. Because if you get a bit of wind behind it, obviously you increase the risk of it coming over."

Bum in the bath[67]

59. "The other things is they say 'well if you develop in the floodplain', which is fair enough, you're pushing the water onto somewhere else."

Coastal configuration

60. "We're in the perfect shape here aren't we, because we're a funnel"

Coastal squeeze and managed realignment

61. "Well you put a bank there and a bank there, the water can't spread out, so it's got to go up. So I can understand that point, so why they want to basically bring the banks back to allow for these greater areas"

Building resilience

62. "you cannot say 'there's no development going to take place in the floodplain' but what you can say is that houses have to be more flood resilient [...and] if you're putting in a substation somewhere obviously you've got to build that up on a certain height"

Isostatic subsidence

63. "Yeah I know this part of the country is sinking isn't it. Yeah we're basically capsizing I suppose"

Knock-on impacts

64. "Because everyone's going to be affected [...] if you're looking at the world scheme of it, there's obviously countries would be flooded, those people have got to go to other places in the world, crowded world, so they'll be habituating [sic] land which aren't going to flood, where there's people already living, so I think that's going to affect people who have a knock on effect all round the world."

Quote Box 14: Complex knowledge, PPP1 participant Steve (Kingston Seymour)

Experiential knowledge is important because people new to the area may have less relevant knowledge than those who have lived in the area for a long period of time (Fred, Quote 57). Wagner (2007, p. 676) for example found that the 'biggest differences in the completeness of the

[67] 'Bum in the bath' was a term used by EPP expert James. It describes the scenario in which a structure on the floodplain displaces the water around it, causing water levels to rise (like the water rises around you when you get in the bath).

mental models [of Alpine flash floods and landslides] were between newcomers and inhabitants with long hazard experience'. Indeed, Steve, with the most complete mental model, has lived within about a mile of the Severn Estuary for 53 years. The second and third highest scorers (Ellen and Laura) had lived around the Estuary for 16 and 60 years respectively. The lowest three scorers (Yasmine, Owain and Darren) had lived around the Estuary for 5 years, 17 years, and 2 months respectively (though Owain is 18 so much of these 17 years would have been spent as a child and perhaps not thinking about the Severn Estuary a great deal!). Indeed, there is a significant positive correlation between the amount of time that PPP1 respondents had lived around the estuary and their mental model completeness score[68] (r_s = .47, $p<.05$). It should be noted however, that this sample was very small (N=20), and there could be a number of factors that could have affected these results. For example, those who have lived around the estuary for longer tend to be older (although there is no significant correlation between age and mental model completeness scores), and tended to talk for longer, perhaps due to their affiliation with the Estuary.

Learning from experience does have its drawbacks. Weber (2010) suggests that learning about climate change from personal experience is difficult because observations are spaced in time and memory of past events can be faulty; I would argue this is the same for SLC. Indeed, no lay participants said that they had noticed or observed SLC, and some noted that it was too slow to notice (Quote Box 30). Second, as discussed in section 7.2.7, inducing from local observations can cause problems when inducing from 'erroneous' premises.

6.2 Personality variables

6.2.1 Concern

When asked directly about their level of concern about SLC, PPP2 respondents were evenly split, with 51% being fairly/very concerned and 49% being not at all/not very concerned (Figure 20). Responses tended to be conservative, clustering around the middle options rather than the polarised "not at all concerned" and "very concerned" options. PPP1 responses were mixed, with comments ranging from Darren's "[SLC] wouldn't be the end of the world" and Owain's "neither here nor there" to Henry stating that he feels "passionate" about the issues. Generally, SLC is not something that PPP2 respondents think about a lot, nor is it something that frightens a large

[68] Mental model completeness scores have been calculated using the following method. At the first instance a theme was mentioned in a manner consistent with the expert model, it was coded with a score of 4 if it was mentioned in the core dump and 2 if it was mentioned later. The total scores were then summed to give a completeness score. See 5.2.2 for methodology and Appendix H for completeness scores for each participant.

proportion of individuals (Figure 21 and Figure 22). PPP2 respondents expressed lower concern about SLC than that expressed by the wider European public[69] and by respondents in the USA[70].

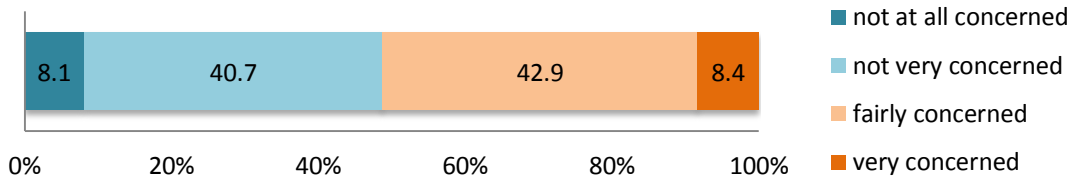


Figure 20: Concern about SLC, PPP2

Percent responses to Q6: To what extent are you concerned about future sea-level change on the Severn Estuary? (N=359)

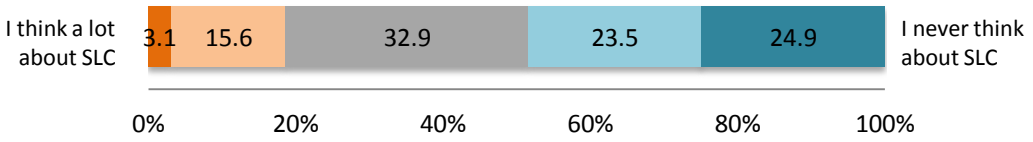


Figure 21: Thoughts about SLC, PPP2

Percent of PPP2 respondents agreeing with bipolar statements "I think a lot about SLC" and "I never think about SLC" (Q18). N=353. Bipolar response scales were unlabelled apart from the 'opinion' at each end of the scale, thus the five response options represent an opinion somewhere between the two extremes (see Appendix J for question structure)

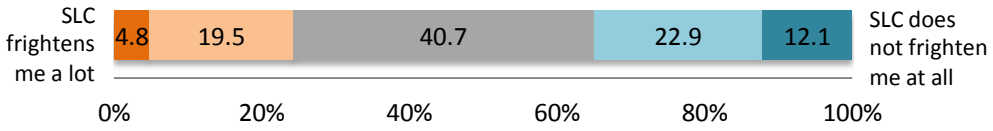


Figure 22: Fright about SLC, PPP2

Percent of PPP2 respondents agreeing with bipolar statements "SLC frightens me a lot" and "SLC does not frighten me at all" (Q18), N=354

These findings are significant for communications because unconcerned individuals who do not think about SLC a lot and are not frightened by it may be less inclined to seek related information.

[69] 70% of CLAMER respondents reported being concerned about SLR (CLAMER, 2011a)

[70] 70% of respondents to Hamilton's polar survey said they would be bothered a great deal if sea levels rose 20 feet, flooding coastal areas (Hamilton, 2008). Note that Hamilton's question is very different from that asked in the current survey, because it explicitly links SLR with coastal flooding. Hence it is not surprising that participants were more concerned.

However, people who are not frightened may be less likely to engage in avoidance behaviour (section 8.3.2). Indeed, fear is a complex issue (see Spence & Pidgeon, 2010 for a discussion), and if it is used in communications it should be done carefully. Concern is also complex. Quote Box 15 shows that participants' concern includes concern for one's self and for others, concern for now and concern for the future. Some interviewees expressed their level of concern as a function of their character, for example some were fatalistic or saw no point in worrying if they could not do anything about it (also see Efficacy, section 7.3.2). Some respondents expressed a lack of care for the future, a subject considered in section 6.2.4.

65. "I'm fairly **philosophical** about it. I think well if it'll happen it'll happen" - Betty

66. "This sounds really pathetic. **I try not to be too concerned with things**. I try not to let things wind me up or get me down, or worry me. If there's something happening that I can do something about, that's fine. But if I can't do anything about it, I can't worry about it."- Karen

67. "I don't really think about SLC too much. I'm a little bit- **what I don't see doesn't hurt me**, if you know what I mean" – Lee

68. "Whether **I'm just getting more scared in old age**. Because when you're younger you're a bit cavalier about everything" – Lynne

69. "It worries me more for my niece I think, because she's six, and you know, what her world is going to be like. Because in 50 years time, I might not be here. You know, but she'll still be alive hopefully, and then her children, **I do worry for the future"** – Ruby

70. "**I just worry about the poor people**, I suppose" – Betty

71. "2100. Do you know how old I am? **Do you think I even care**? No, that's a little harsh; of course I care" - Paul

Quote Box 15: The intricacies of concern, PPP1

Concern about impacts

Figure 23 shows the percent of respondents concerned about given SLC impacts, colour coded by type of impact (physical impacts and immediate/lagged socio-economic impacts). It suggests that immediate socio-economic impacts (dark orange) and physical impacts (green) are of more concern than lagged socio-economic impacts (light orange)[71]. A total of 58% of PPP2 participants are personally concerned about flooding, which was also the most salient node in the public mental model from the PPP1 interviews (see also Quote Box 16). However, the high level of concern amongst PPP2 respondents regarding travel disruption from flooding (about which 37% respondents were concerned) contrasts with PPP1 findings that showed that inconvenience scored

[71] Note that impacts were subjectively categorised into physical/socio-economic and immediate/lagged during data analysis; respondents were not asked directly about these three categories.

just 20% salience[72]. Low concern about lagged socio-economic impacts amongst PPP2 participants may be due to a temporal distancing of the risks, whereby future impacts are seen as less concerning (see Psychological Distance, section 6.2.5).

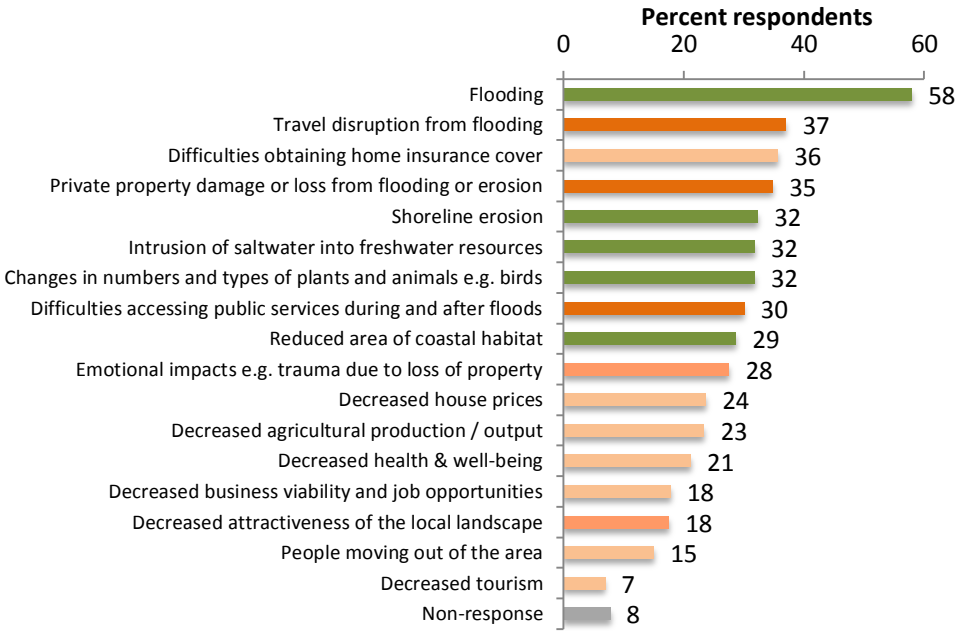


Figure 23: Concerns regarding SLC impacts, PPP2

Percent respondents personally concerned about impacts of SLC (N=359). Green = physical impacts, dark orange = immediate socio-economic impacts, light orange = lagged impacts

72. "I suppose yes, [flooding] would be a concern for me" – Anthony, Bristol
73. "Flooding is always an issue, it's never far from peoples' minds" – Fred
74. "I do worry about flooding" – Lynne
75. "Flooding definitely I think is the main problem" – Karen
76. "My wife and I have given reasonably serious thought to whether we should move, because we're only a couple of metres above sea level here, which is not a lot in the grand scheme of things" – Henry

Quote Box 16: Concern about Impacts, PPP1

Concern relative to other issues

While many PPP1 participants expressed concern about SLC, it did not factor highly when compared with other issues (Quote Box 17). They tended to be more concerned about issues such as the economy, poverty, local nuclear power, personal/family concerns, sustainability and the potential for a Severn barrage. Some participants did however express concern about flood

[72] Salience is calculated as a percentage of PPP1 participants who mentioned a node in the expert model (see 5.2.2).

defence, managed realignment and climate change *per se*; factors that are linked with SLC. Ruby alluded to the 'finite pool of worry' discussed by Weber (2006), noting that there are levels of concerns about things, and that her main concerns are more society-based. Previous research has similarly found that climate change receives a low priority compared to day-to-day issues, particularly personal economic security (Lorenzoni et al., 2007; Zsamboky et al., 2011).

77. [Facilitator: how do these issues compare in importance to other issues that might concern you today?] "Not even the slightest, to be honest with you [laughs]" – Anthony

78. "Well, I don't feel at the moment [the issues] are relevant" – Christine

79. [Facilitator: we've all got lists of things that worry us; would these sorts of things register on that list for you?] "Not very high, no" – George

80. "I'm not going to worry too much about the Severn Estuary. Maybe I should of course. I think it's quite high for me actually. [Facilitator: SLC per se rather than on the Severn Estuary, or-] "Yes, personally yes. On a broad scale" – Paul

81. I suppose there's like levels of concern about things. [... SLC] is lower down, because it is just a big thing. And I suppose my concerns are more social concerns. You know. About how society is going, I think it's more human based [...SLC] doesn't come very high, but it's always there" – Ruby

Quote Box 17: Concern about SLC in relation to other issues, PPP1

In relation to other risks *specific to the Severn Estuary*, PPP2 respondents factored SLC relatively highly when presented with a list of potential concerns. Responses are shown in Figure 24, which shows that SLC is joint third on that list. Flooding, which is expected to be the main physical impact of SLC on the Severn Estuary, featured most highly.

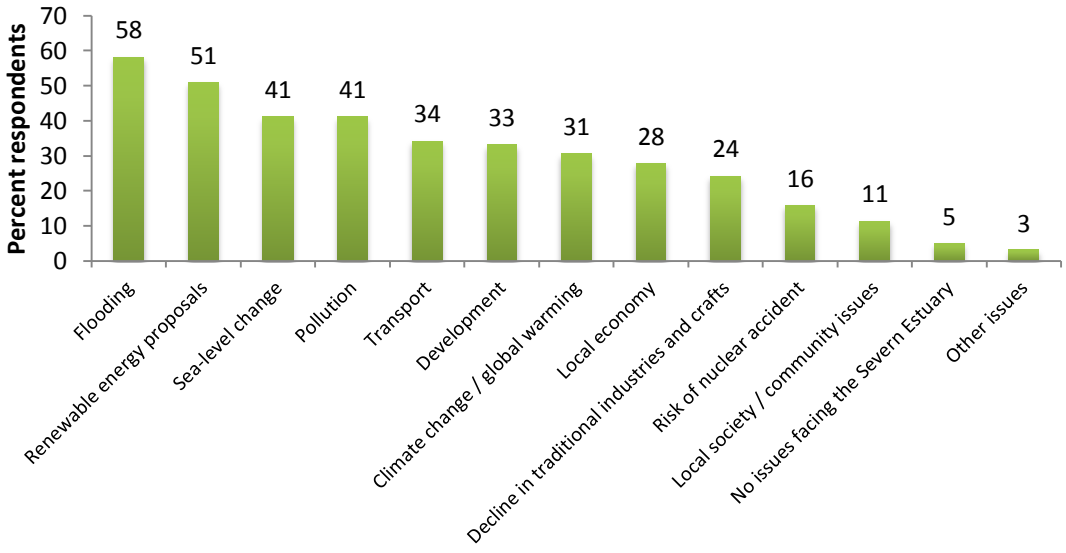


Figure 24: Main issues of concern on the Severn Estuary, PPP2

Responses to Q1: Please read the list below, and tick those that you think are main issues of concern around the Severn Estuary today and for the next 20 years (tick UP to 5)

6.2.2 Uncertainty and scepticism

Uncertainty

Perceived scientific uncertainty was a theme in both PPP1 and PPP2. A total of 28% of PPP2 respondents agree with the statement "The science of SLC is uncertain", while 21% disagree (a slight majority of people, 51%, neither agreed nor disagreed with the statement). The perceived uncertainty amongst PPP1 interviewees (Quote Box 18) is unsurprising. Over the period 1989-2009, the reported range of SLR projections and the uncertainty associated with them increased in newspaper reports (Rick et al., 2011), for example. Quote Box 18 shows that PPP1 participants perceive uncertainty in a number of aspects of SLC, not just the rates of rise. This indicates that whilst amongst experts there is little uncertainty that SLC is happening (Solomon et al., 2007), genuine uncertainty about rates may be spreading to generate uncertainty about other aspects amongst the public (termed 'uncertainty transfer' by Spence et al., 2012).

82. "Other scientists say it [climate change] isn't [happening], but most seem to think it is. Some still don't believe in global warming at all. They say it's just a fantasy" - Betty

83. "I can't give you a figure [for SLC]. The experts can't agree on a figure" - Henry

84. "And you keep hearing contradictory views. One minute the ice cap is melting and the sea is going to rise, and then the next minute you get another professor somebody or other saying it's not fact at all, it's all- it depends how you interpret what's happened" - Lynne

85. "There seems to be these people on one side, who kind of say '[climate change is] absolute baloney; it's just nonsense' [...] and they seem to be scientists and things, and they don't seem to be connected to the oil industry or anything of that nature that might have an axe to grind" - Paul

86. "There's such a variation, if you have one expert that says something's going to happen, I'm sure you'd find another expert that would say almost the opposite is happening. [...] The only consistent thing I'm really finding is that most people seem to think that tides are rising, but they don't know at what speed. There's one lot that says 'not hardly at all' and the other ones says a metre, you know, in 100 years" – Steve

Quote Box 18: Perceived scientific uncertainty, PPP1

Scepticism

Interviewees held a range of opinions about the reality of climate change (Quote Box 19). Darren is "not a believer in all that stuff", while at the other extreme Ruby and Laura perceived that they had actually noticed change. There was a common perception that climate change was caused by a combination of natural causes and human agency, while Terry expressed the belief that climate change might have been exaggerated.

87. "I'm not a believer in all that stuff [climate change] to be honest with you" – Darren

88. "I don't know whether global warming is ENTIRELY man-caused" – Christine

89. "We're definitely contributing to it" - Jessica

90. "I think the jury's out on it still, in my opinion, but there probably is an impact that man has made on it. I would say" – Steve

91. "I'm one of those people that says 'but hasn't that [SLR] been happening since the ice age?' you know [laughs]. I have no doubt its speeding up, but then it's probably always has been speeding up. So I'm not quite sure where I sit on it" - George

92. "There is slight climate change, increase, say the Berwick Swans will always go to Slimbridge, they're staying up North now, rather than flying down [...] well probably its global warming, but um, I'm er, not totally convinced on that one actually [laughs]. I think it's a good way of frightening people and then they cough up a lot of tax because they think they're saving the planet. But [laughs]. [...] I think a lot of people make a lot of money out of these things. [...] I'm not over convinced on global warming" [...] [Facilitator: SLC might not be happening, is that right?] "Yep. Well no, it's happening, but not on their grand scale. Yep. That is the main thing [...] obviously global warming does cause SLC. Well that's what I think [...] well, it's rising sea levels, but not- don't go over the top on it mind" [Facilitator: ok. Shall I put rising sea levels question mark?] "Yeah yeah. Well done" – Terry

93. "I'm not a denier [...] but I think there is a multitude of things that play a part in the change" [...] "It does seem to be there seems to be many more natural disasters occurring. Whether that's a greenhouse gas thing or whether it's just a natural course of the Earth's cycle, I don't know" – Ruby

94. "We don't get seasons like we used to" – Laura

Quote Box 19: Climate change scepticism, PPP1

PPP2 results show that SLC and climate change scepticism among PPP2 participants is relatively low (Figure 25), with the majority of respondents agreeing (tend to agree or strongly agree) that climate change (66%) and SLC (69%) is really happening. However, a significant proportion of PPP2 participants were sceptical about some aspects of SLC, with 20% agreeing that "I am uncertain that SLC is really happening". And while most think that SLC is a real problem, 12% do not. Fully 18% think that the evidence for SLC is unreliable, and 17% agree that "too much fuss is made about SLC". SLC and climate change scepticism amongst PPP2 respondents were highly correlated: people who are sceptical about climate change are also sceptical about SLC (r_s = .78, $p<.01$). This is unsurprising considering that participants perceive climate change as the main driver of SLC (Section 7.2.3). Levels of climate change scepticism and SLC scepticism are not significantly different[73].

[73] SLC scepticism (M = 1.50, Mdn = 1.50) is not significantly greater than CC scepticism (M = 1.46, Mdn = 1.33), z = -1.77, n.s.

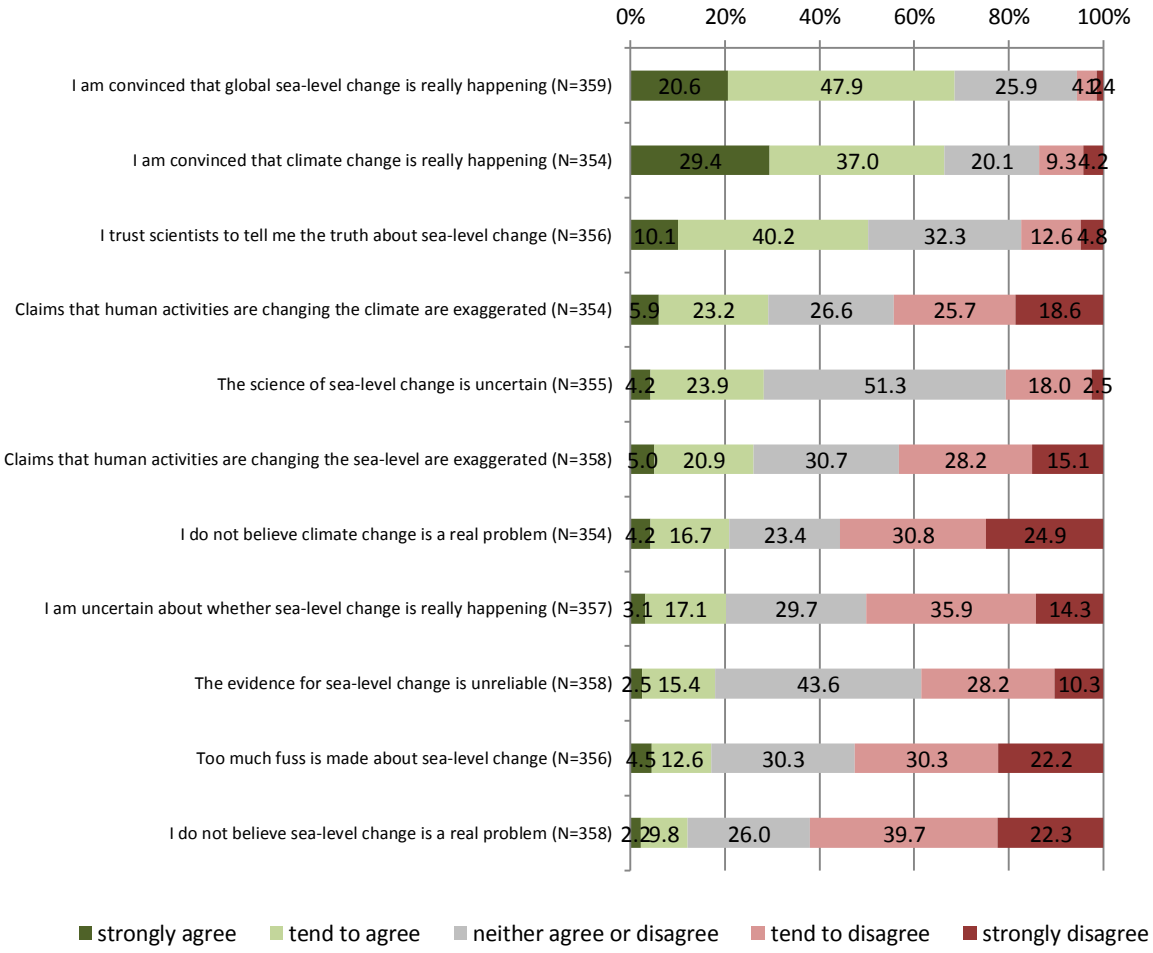


Figure 25: Climate change and sea-level change scepticism, PPP2

Percent respondents agreeing with statements regarding SLC and climate change

6.2.3 Values and worldviews

Values were not followed up in detail in PPP2 due to space and time constraints, but as they form an important part of risk perceptions (Douglas & Wildavsky, 1983), this section briefly considers relevant findings from PPP1. A dominant worldview articulated by PPP1 participants regarded the power of the Earth and the insignificance of humans (Quote Box 20).

Earth is powerful and resilient

95. "I think of Slimbridge. The birds and all those big open grasslands. To me it's a very pure thing. A very primeval kind of- Gaia, Mother Nature thing. Very powerful. [...] Gaia kind of re-sorts herself" – Betty

96. "I am aware that the old timers say 'it's all very well having a sea wall, but if the river wants to come and join us, it will'. [...] At some point, man will be defeated, and the results will be catastrophic" [...]"The more effort than man puts in to keep nature at bay, the eventual breakdown will be worse" - Fred

97. "Even with better sea defences we'd probably still be at risk of flooding [...] If we had a tsunami of course, sea defences wouldn't be a lot of good, so we'd all flood" - Steve

98. "I suppose part of me thinks that nature will do what nature always does, which is recover from these situations" – Anthony

99. "There may not be people on it, but the Earth will be ok" – Betty

Humans are small and insignificant

100. "It almost reminds me of how small we are, you know, bustle about doing these really important things, we're so worried about it all [...] I think sometimes we have a bit of an inflated sense of our own importance. [...] I wonder if we're just like a flea on the skin of something and it's like- yerouh!- just flick it off" - Betty

101. "[SLC] is just something that happens. You know, I think we're making too much of it. Yeah. We think we're too important or something [...] We'll be alright, and if we're not, so what?" – Darren

102. "I think people are temporary on the planet" – Ellen

103. "The Earth will carry on regardless of what we do" - Fred

104. "It's not the world that's going to end, its only the people who are on it" - Glenda

105. "I think we always think we're somehow superior. I think, but really, we have no control over things that are stronger than us. And more powerful than us" - Ruby

106. "Things change, you know. People don't like it [laughs], but things change" – Laura

107. "I'm not anxious about things generally, I have a- I kind of have a trust in people and in God, I suppose. And what goes on, and so I tend to think well, it is as it is. I don't think we're going to get anywhere by ever panicking, or- and I think our efforts are so puny" – Betty

Quote Box 20: 'Powerful and resilient Earth' worldview, PPP1

Such worldviews are important because they can affect the ways in which people expect nature to respond to change (Tansey & O'Riordan, 1999), and can influence perceptions of self-efficacy. For example, Betty has a 'trust in God' (Quote 107), which research suggests may affect risk her risk perceptions (Alam, 1990; Slimak & Dietz, 2006). Sims and Baumann (1972) suggest it is the belief

that the locus of control lies with an external power (i.e. a personal lack of agency) that affects behaviours: those 'who believe that God (or fate or luck) controls their lives [...] confront a tornado in a manner that is consistent with their attitudes [...]; they await the fated onslaught, watchful but passive' (Sims & Baumann, 1972, p. 1391). This idea of agency is why beliefs regarding the Earth's power and resilience are so important in risk perceptions. 'Externally-oriented respondents [...] tend to refrain from action, express feelings of powerlessness, [and] experience debilitating rather than facilitating anxiety' (Baumann & Sims, 1978, p. 190). Thus, people who think the Earth is all-powerful may refrain from personal engagement. On the other hand, inaction may also be justified by a worldview perhaps antithetical to the 'powerful Earth/insignificant humans' view: that is, the view that humans are resilient to these 'big forces' (Quote Box 21). For example, Christine, Henry, Terry, and Fred all have faith in their local flood defences. Such faith in anthropogenic structures can lead to a 'false sense of security' and can in some cases increase vulnerability (Baumann & Sims, 1978, citing an unpublished NOAA manuscript 1972). This is discussed further in section 7.3.3.

108. "I think human beings are very adaptable" – Betty

109. "Power station. They're well built, they'll survive [...] we've got good engineers so they can deal with [SLC] perhaps?" – Jessica

110. "I think things are going to change quite quickly in terms of technology. There's such wonderful technology coming along now. Especially by 2050, I wouldn't expect anyone to be contributing in the way we are now to the effects of climate change"- Laura

111. "I reckon eventually it would change and go back to freezing. [Facilitator: naturally or…] Naturally, but I reckon we could intervene if we needed to" - Owain

112. "We've been flooded in our garden before. But there's defences been built since then. [...] Over the past two or three hundred years Uphill's flooded about every 80 years. But it won't anymore. [...] I mean it's made a huge difference to us. Knowing that [...] if a really high tide is forecast, half an hour before it comes, they shut them. It's really good" – Christine

113. "I feel pretty comfortable about the defences- they look pretty robust. So that does fill me with confidence, yes" – Henry

114. [Facilitator: so the flooding thing doesn't worry you because the defences are there, or- ?] "Yeah, Yeah. No, they're good defences" – Terry

115. "I'm not too worried at the moment, here, and also you could say that we're hiding behind the power station [which has good defences]" - Fred

Quote Box 21: 'Powerful and resilient Humans' worldview, PPP1

6.2.4 Future thinking

As discussed in section 2.6.1, van Asselt et al (2010) identified two 'temporal repertoires' to describe how experts think about the future: historic determinism and futuristic difference. In section 4.2.3 we saw that experts interviewed for this study showed varying reliance on each of the two repertoires. This was also the case during the public interviews (PPP1), as shown in Quote Box 22.

Historic determinism: the future is determined by the past and the present

116. "I would be happier if I looked into the past to give me some idea" – Lee

117. "I remember the old meandering rivers thing from school, where they get cut off and then go straighter and then it happens again. But again, it's taken hundreds of years to do that. It doesn't happen overnight, [...] you can only see it happening with hindsight over a lot of years [Facilitator: so why do you not think it might change quickly now?] well why would it? I can't see… I mean the only thing that might make it is something like science fiction type thing, where maybe a massive meteorite hit us" - Lynne

118. "That's 40 years then isn't it? Near as damn it. In 40 years. I don't know, they'd probably extrapolate and say between the last 40 years its risen this much or within the last 10, 15, 20 years its risen this much and take it forward" - Paul

119. "It's a lot easier to say, this is what we think has happened in the past; this is what we think is going to happen in the future" – Andrew, Expert (Academic)

***

Futuristic difference: relationships between the past, present and future are looser; discontinuity is key

120. "The future's a long time, isn't it [...] something pretty major might have happened by 2100 [Facilitator: like what?] ANYTHING" – Darren

121. "I had a nightmare that there was a tidal wave coming up on the Knap (Barry). Like a tsunami, and I woke up and I thought "wow, that'll NEVER happen here" and then you hear about the Canaries, and the fact that you know, it might fall into the sea, and we might get- so, who knows? [laughs]" - Laura

122. "These [extreme scenarios] can all potentially happen" – Sandra, Expert (Government)

Quote Box 22: Temporal repertoires, PPP1 and EPP

Although Darren and Laura expressed a futuristic difference standpoint, interviewees tended to place a strong emphasis on historical determinism, often talking about evidence and using the past to think about the future. This is important because people who subscribe to this approach may be less likely to consider the possibility of surprises such as a big event on the Severn that has not

happened before. See 'temporal distance' below for a further discussion of findings relating to how PPP1 and PPP2 participants think about the future.

6.2.5 Psychological distance

Figure 26 shows PPP2 survey results pertaining to social, geographical and temporal psychological distance. Findings relating to each of these from PPP1 interviews and the PPP2 survey are then considered in turn.

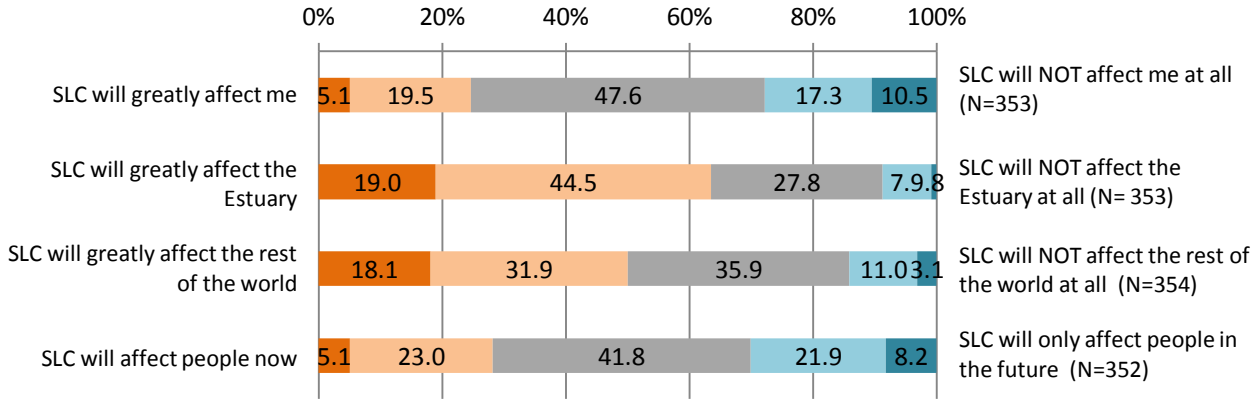


Figure 26: Psychological distance, PPP2
Percent agreement with bipolar statements relating to social, geographical and temporal distance. Q17: "Please indicate which opinions about sea-level change you most agree with"

Geographical distance

PPP1 participants tended to view SLC as something that would affect other places worse than it would affect their local area. As shown in Quote Box 23, a number of participants felt that SLC would greatly affect other parts of the world, particularly Thailand, The Maldives and India. Closer to home, PPP1 participants talked about SLC and flooding as a risk to the south and east of the UK, London, and places around the Severn Estuary *other* than where they lived (apart from Karen, Ruby and Betty who recognise local risks as well).

Interestingly, significantly more PPP2 respondents thought SLC will affect the Severn Estuary than thought it will affect the rest of the world. However, they still tended to believe that SLC would affect the rest of the world more than it would affect them personally. Also, it should be noted that this survey item was slightly ambiguous: although the Estuary was defined at the beginning of the survey as the shaded area on a map including the surrounding land, 'the Estuary' could have been interpreted as the natural rather than human environment. If this was the case, these results are consistent with a recent survey that found Welsh respondents to be most concerned about wildlife and the natural world, followed by concern about effects on Wales and developing countries, and least concerned about effects on them personally (Capstick et al., 2013).

123. "**Gloucester** doesn't really stand much chance, does it, in the middle" – Karen, Gloucester

124. "**We're going to get it first**, the impact on us is going to be quite huge isn't it? As a small island that we are" – Ruby, Penarth

125. "The whole thing fills me with horror when I think of people living in **Thailand** and these very low places where they are living just up off the sea [...] and how devastating that's going to be. [...] I feel quite **vulnerable living here**- the docks. [...] I'm about zero I think here" – Betty, Bridgwater

126. "In that part of the world [Severn Estuary] I don't think [SLC is] going to be much of a difference" – Darren, Gloucester

127. "SLC, when I think about it first I always think about on the **east coast**, which is the coast which is being eroded" – Betty, Bridgwater

128. "For some reason I thought about general SLR elsewhere. **East Anglia**" – George, Portishead

129. "**Gloucester**, I suppose I would see as the main area which is affected by SLC. And flooding and so on.[...] This again looks like **Maldives** or somewhere. So I mean they are experiencing the same, only worse, than Gloucester. Like people in Gloucester might eventually have to move. The Maldives, the whole shebang's going to have to move by the sound of it" – Laura, Barry

130. "**Cardiff** is sort of closer to the sea than Bristol. I mean Weston's obviously close, but as it's further down it might be different" – Christine (Uphill, Weston)

131. "In England we feel quite safe and secure for one reason or another, and we don't seem to have such terrible things happen to us, you know, ridiculous storms" – Anthony, Bristol

132. "I can't see it impacting on the individual so much here, whereas if you're living in a **sampan** or a little piece of **rice paddy** just by the water, and that salt comes up, yes" – Betty, Bridgwater

133. "This person represents third world areas, possibly. Particularly **Indian subcontinent** area, where they are much more likely to be impacted by rising sea levels on a very very severe level, than anyone in this country is. And indeed they already are to some extent" – Ellen, Oldbury

134. "[SLC is] not good news, especially if your postal address is **Bangladesh**. Yes, not good. I've always wondered what- how easy it is to get a long term you know, like a 25 year mortgage if you live in **Holland**" – Fred, Oldbury

135. "This is going to happen first in **Bangladesh** and **India** isn't it because they're particularly low lying" – Glenda, Chepstow

136. "People in certain parts of the world, mainly **Bangladesh** and places, very susceptible to SLR" – Steve, Wick St. Lawrence

Quote Box 23: Geographical distance, PPP1

Temporal distance

There was a widespread belief among PPP1 participants that the impacts of SLC would be felt by future generations, rather than themselves, as shown in Quote Box 24. PPP2 participants were ambivalent, with a slightly greater proportion of respondents choosing responses closer to the statement 'SLC will only affect people in the future' (30%) than responses closest to the statement 'SLC will affect people now' (28%). A 'not in my lifetime' mentality was also noted by Zsamboky et al. (2011). Unlike indications from other research however (c.f. Fernandez-Bilbao, 2012; Zsamboky et al., 2011), this view was not limited to older PPP1 participants. Having said this, PPP2 results do show that the oldest groups were less concerned about SLC than middle-aged groups (see section 8.5.4).

137. "I don't think it'll happen in my lifetime" – Christine, age 69

138. "SLC in general, I haven't really thought about it in terms of the Severn Estuary. It seems as though it's something that might happen to somebody in the future" – Jessica, 36

139. "I just think 'oh well, I won't be around by the time it rises to a serious level'. How selfish is that, but that's the way you think" – Karen, 48

140. "I don't think anything is going to happen in the short term, and probably after I'd died. If I was honest. I don't think anything's going to move that quickly" – Lynne, 66

141. "If [SLC] does happen through natural causes it will be long after I've gone, or I'd like to think so anyway, you know" – Paul, 59

Quote Box 24: Temporal distance, PPP1

Despite a 'not in my lifetime' mentality, some residents voiced concerns about the impacts of SLC on future generations, as shown in Quote Box 25. Indeed, PPP1 participants expressed variable feelings of compassion for the future, which are both evident in these quotes from public participants, and also in expert interview results (Quotes 153 and 154). PPP1 participants who expressed a lack of concern for the future sometimes couched their comments in a joke or a flippant remark that was then retracted (Paul, Quote 146). It is impossible to gauge participants' actual concern; it can only be surmised from what they have said. Furthermore, these comments should be taken in context of the rest of the interviews; for instance in another part of Paul's interview, he stated that he is 'quite sad' about the issues. Also, as discussed later in section 7.2.7, PPP1 participants' views may have been constructed on the spot, and may change with reflection, as indicated in Paul's retraction in this quote. However, if participants *do not* care about the future, and it is not unreasonable to suggest that some will care about the future less than others, this may have a bearing on how they respond to the risks of SLC. For example, those who do not care about the future they may be less inclined to support long term mitigation or defence proposals.

142. "We have to do the right thing by our kids" – Betty

143. "It worries me more for my niece... I do worry about the future" – Ruby

144. "It's not fair on the people to come, is it?" – Glenda

145. "Once you've got kids, you definitely start considering the world beyond your lifespan" - Laura

146. "2100. Do you know how old I am? Do you think I even care? No, that's a little harsh; of course I care" – Paul

147. "At the end of the day, how long have I got? 20 years? I'm not going to be worrying for 20 years. And it probably won't happen in the next 20 years" - Lynne

148. "I don't care if they [build a barrage] in about 80 years time, when I'm about to die. But I don't want it now" – Lee

149. "It's going to be such a long time in the future... It's human nature; you don't worry about something now that you could put off until tomorrow. And it's something that's creeping up, isn't it. Rather than just happening instantly"- Anthony

150. "I think if people knew that if they changed their behaviour they'd have jam tomorrow, they would deal with it, they would get on with it, or most- more people would. But if you tell people that if they change their behaviour their great grandchildren might live in a better, safer world, they know that nobody else will do it either. So they don't do it"- Ellen

151. "300 years is nothing really is it, in the grand scheme of things, but to us, its 300 years, well, we're going to be gone so [laughs], you know. But hopefully it won't happen in 10 years"- Ruby

152. "[The Environment Agency is] looking at the long term view of if you build a house it's got to be there for 100 years. So in 100 years time, obviously they've got to try and think what the conditions will be in 100 years. Whereas, I'm looking for my lifetime or my son's lifetime, which isn't 100 years, you know. But it could be in my grandson's time, you know" – Steve

***

153. "I won't be around to find out anyway" – Matt, Expert (County Council)

154. "If it goes over 2m, I'm not going to be here, what do I care?" – Daisy, Expert (Government)

Quote Box 25: Thinking about the future, PPP1

Social distance: the 'other'

Social psychological distance refers to the perceived remoteness of people who are deemed to be 'unlike me'. Social psychological distance was mainly expressed through reference to people in other countries, rather than people perceived to be different within the UK (see spatial distance

above). Indeed, participants stated that quite opposite to a social distancing effect, "SLC would affect everyone" (Steve) and "be no respecter of age, disability or how nice they are" (Ellen). Darren was the only participant who hinted that SLC risks might be different for socially distant people than they would be for him, a 28 year old White Briton (Quote Box 26).

155."Bangladeshis – that's quite a low lying country, isn't it? 'White man will always be ok'. [Facilitator: do you think that's true?] yeah, to be honest at the moment I do" – Darren

156."[Old people will] probably be top of the list to be moved" – Darren

Quote Box 26: 'The other' distance, PPP1

Psychological distance: summary

The findings from this study should be taken in context. PPP2 and PPP1 participants tend to think that SLC will affect the rest of the world more than it will affect them, and this is valid if we take the rest of the world to mean places like the Maldives and Bangladesh, which will probably be affected more than the Severn Estuary. On a more local scale, while Weston may be affected to a similar to extent to Cardiff (in contrast to Christine's Quote 130), Barry is unlikely to be as severely affected as Gloucester (consistent with Laura's Quote 129). Also, PPP1 participants widely talk about SLC predominantly affecting future generations (PPP2 responses are ambivalent on this subject), which is also likely to be true when we consider future rates of rise and time lags (see the expert model in Appendix O).

The psychological distancing of SLC can thus be interpreted in a variety of ways. First, it can be interpreted as a rational evaluation of the evidence: the impacts of SLC are indeed expected to be greater in future, and in low-lying developing countries (Nicholls & Cazenave, 2010). Second, it can be interpreted in the context of the availability heuristic (Tversky & Kahneman, 1973). Ruby for instance thought Gloucester was vulnerable to SLC, and linked it to recent events there that she easily recalled: "I mean there was the huge flood wasn't there? A few years ago, Gloucester way". Finally, such downplaying of risks to an individuals' self could be interpreted as 'a manifestation of a personal denial about direct effects and, more importantly, dissociation from any personal involvement in possible solutions' (Lorenzoni & Pidgeon, 2006, p. 82).

6.2.6 Emotions

SLC evokes negative feelings amongst PPP1 interviewees, who described SLC and its impacts as "quite frightening" (Ruby), or something that fills them with "horror" (Betty). The influence of such negative feelings upon SLC perceptions were not followed up in PPP2, but it would be remiss not to include a brief discussion here because such feelings have been shown to be key

considerations in risk perceptions (Slovic et al., 2004). SLC is an emotionally charged subject for many, especially those who are set to be impacted by managed realignment schemes, which is one governmental response to SLC on the Estuary. Interview participants talked about their own feelings during and after flood events, or imagined how flooding would feel (Quote Box 27).

157. "That was quite horrific really [...] I was so frightened. It really was a scary thought, that, it really felt like the car was being washed away at times" - Karen

158. "Having been flooded it's not a nice experience. When you see all these pictures of flooding they had up around Tewkesbury a couple of years ago, my heart went out to them because I know exactly what's it like, and everyone would tell you the same thing, you get this stinking layer of mud there, and it is, it's really evil, it just gets everywhere" – Terry

159. "It's a terrifying thing, water, when it does that. And people coming out of their houses with all this stuff wrecked. We're so territorial, and we kind of like our little houses. All ruined. All the carpets"- Betty

160. "Because we'd just insured everything new for old [laughs] and my husband was beckoning it in [laughs]. No, we wouldn't really want to be flooded. It would be dreadful. It was dreadful for the people who lived at the village, because a lot of old people here, and all their memories were destroyed, all their photos, and [exhaled breath]. It was so sad for them [...] it must be SO dreadful. To be forced out of your home" – Christine

161. "Even if you are insured it's just a hideous thing to have to go through" - Ellen

162. "Severn mud. Can you imagine if you got flooded? F*** that would be crazy. All that clean up. It stinks as well. It absolutely stinks" - Lee

Quote Box 27: Negative feelings associated with SLC, PPP1

Although PPP1 respondents largely associated SLC and flooding with negative feelings, it should be noted that a number of interview respondents talked about the excitement associated with flooding, SLC and extreme events, as long as their own property was not affected (Quote Box 28). Stories of past flood experiences were also sometimes told with humour (Quote Box 29). This humour may have been a reaction to shyness or feelings of awkwardness during the interview process; indeed, George, Karen and Ruby laughed a lot throughout the interview regardless of what they were saying. It may also have served as a coping strategy for a difficult or sensitive subject, providing emotional release after traumatic events. Humour can also provide a means of saying the unsayable in ways that are culturally permissible (Parkhill, Henwood, Pidgeon, & Simmons, 2011). For instance Ruby used humour to describe the potential plight of the city of Cardiff. Finally, laughter may have been a reflection on how much participants had enjoyed the interview process!

163. "Flooding happens. It is quite exciting at the time. That's terrible, isn't it? It's nice going out and seeing- it's fascinating. Yeah, you can drive out and you can see all the floods [...] Whilst it is terribly upsetting for a lot of people to have their houses or whatever flooded, for the people that haven't quite got flooded, it is quite exciting" – Karen

164. "But it's no good just sitting in victim hood, because it's happening, you know, its part of a bigger scheme of nature, so you know. Enjoy it if you can, I suppose [laughs]" - Laura

165. "It used to flood in the town. The teenagers in the town used to love it because it used to flood Etams shop [...] It used to be a good way of getting a spring frock" – Betty

166. "Being a scientific person, I was thrilled to wake up on the last morning to hear the [flood] sirens go off [in Venice]" - Fred

Quote Box 28: Excitement, PPP1

167. "Me mate lost nearly all his turkeys [laughs]. No, that was pretty horrendous that was" – Terry

168. "People say, it's almost a bit of an assumption in Portishead, of this new estate bit, you know, 'oh be careful of the flooding' [small laughs]. Um" – George

169. "So I had a phone call at work 'the water's coming in, I can't keep it out', 'ooh, Dad, I'm coming!' [laughs]. So I drive up there, and I was wearing flip flops. And a skirt" - Karen

170. "She was a lovely old lady; she was a farmer's widow up the road. Well I suppose you'd class her as eccentric. But oh, she was so funny. And [laughs] they had her in the boat. Oh, we laughed and laughed over that [laughs]" – Terry

171. "Because it's your time on the planet, but things change so much, so- you know, what we can't envisage now, in a few hundred years time, 'oh that city, Cardiff, that existed all those years ago' [laughs] you don't know, do you? [laughs] that's quite doom and gloom [laughs] - Ruby

172. [Facilitator: thank you for participating] "I've quite enjoyed it" [laughs] - Karen

Quote Box 29: Humour, PPP1

6.3 Demographics

Demographics, including factors such as age, gender and place of residence, could also be described as orienting dispositions. They are discussed in section 8.5, which presents the results and discussion of regression analyses on various factors, including demographics. Raw demographic data is presented in Appendix L.

6.4 Summary: orienting dispositions for sea-level change perceptions

Results show that orienting dispositions for SLC perceptions include a variety of factors including sources of information and personality variables such as worldviews and emotions. Regarding information sources, PPP2 respondents most trust the Environment Agency and Natural Resources Wales (66%) for information about SLC, with scientists coming a close second (63% of respondents). Individuals tend to place a lot of trust in experience, and learn about SLC through personal and vicarious experiences. Local knowledge is important, accessed by certain groups such as 'old timer families' and through engaging with certain activities such as sailing and farming. Although scientists were highly trusted sources of information about SLC, a significant proportion of respondents do not trust them to tell them the truth about it. Indeed, PPP1 participants had complex relationships with science, which was both revered and challenged.

Respondents tend to express relatively low concern about SLC, with few being very concerned about it. SLC is not something that people think about much, is not something that frightens many people, and is of low concern relative to other issues such as the economy. Flooding is considered to be the highest SLC concern. Generally, physical impacts such as flooding and erosion, and immediate socio-economic impacts such as travel disruption, are more concerning than lagged socio-economic impacts such as decreased house prices. Perceived scientific uncertainty (both founded and unfounded) was a common theme, although scepticism regarding SLC was relatively low.

Some PPP1 participants prescribe to worldviews that place the locus of control for SLC in the hands of external powers, and others have a faith in flood defences that fosters a false sense of security. Interviewees tended to emphasise the role of history in predicting the future, which may lead to a reduced capacity to think about potential extreme events or 'surprises'. Individuals tend to think that SLC is something that will be worse in other places, and affect people in the future more than today; though these views should be taken in context (SLC is indeed likely to be worse in other places and in the future). When people do think about climate change and SLC, they tend to associate them with negative feelings. The relationships between these orienting dispositions and other factors are shown in Chapter 8. First, Chapter 7 considers factors constituting a risk appraisal.

7 PUBLIC RESULTS: RISK APPRAISAL

This chapter addresses the components of a risk appraisal of SLC, including the factors that constitute a threat appraisal and a coping appraisal. The chapter begins with a discussion of the salience and understanding of issues regarding SLC on the Estuary, including public expectations of future SLC magnitudes. A few remarks on public terminology are followed by a discussion of knowledge structures, i.e., the ways in which individuals organise their beliefs about SLC. The chapter then presents findings regarding the factors constituting a coping appraisal: public perceptions of responsibility, efficacy and trust.

7.1 Introduction

A risk appraisal can be conceptualised as consisting of a threat appraisal and a coping appraisal (Bubeck et al., 2012). In this analysis, a threat appraisal consists of the salience and knowledge of a risk, including knowledge about different aspects of that risk. Coping appraisal includes perceptions of self-efficacy, trust and responsibility.

Unlike Chapter 6, much of this chapter compares public perceptions with expert perceptions. As discussed in 2.4.2, a criticism of the mental models approach is that this comparison implies that the expert model is correct or true, while the public model is not; and this is not necessarily the case (Edge, 1995). However, while it is recognised that the expert model is not one of 'truth', it is necessary to somehow compare the two in order to develop risk communications that take into account differences between expert and public perceptions. Therefore, throughout this comparison, for brevity and for consistency with previous mental model studies (Morgan et al., 2002) the terms 'true' and 'false' refer to ideas consistent and inconsistent with the expert model.

7.2 Threat appraisal

7.2.1 Self-reported informedness

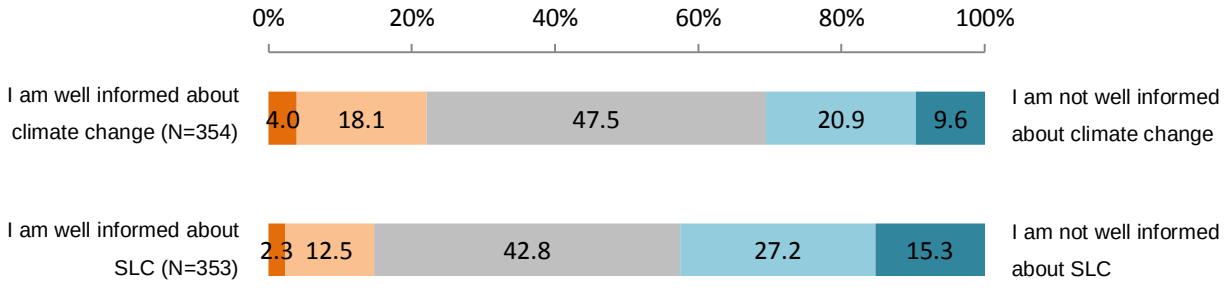


Figure 27: Self-reported informedness of climate change and SLC

Percent responses to Q18: "Please indicate which of these opinions you most agree with..."

Survey results show that in general, people do not feel well informed about SLC. Respondents felt significantly more informed about climate change (Mdn = 3, M = 3.14) than they did about SLC (Mdn = 3, M = 3.41) ($z=-7.02$, $p<.001$), but self-reported informedness was still low (Figure 27). PPP2 respondents feel less informed about climate change and SLC than participants in other

recent studies do[74]. These differences may in part be due to the positioning of the question within the survey. In the current study, the question was placed relatively near the end of the survey, after participants had been asked questions about their knowledge of the issue. The equivalent question did not follow any 'knowledge test' type questions in the Shuckburgh et al. (2012) and CLAMER (2011a) surveys. Question wording and format were also different.

A Spearman's correlation showed no significant relationship between knowledge scores and self-reported informedness (r_s = -.098, ns). In other words, people who felt they were more informed about SLC did not tend to score higher or lower on the summed knowledge scale. This supports previous work in disparate fields (Crosby & Yarber, 2001), but is contrary to climate change research that shows a positive relationship between knowledge scores and perceived understanding (Hamilton, 2008; McCright, 2010).

7.2.2 General salience and understanding of sea-level change on the Severn Estuary

This section presents an overview of results from the qualitative interviews (PPP1) and quantitative survey (PPP2) before each theme in the expert model is examined more closely. Both the *salience* of the themes, and the *understanding* of them are considered, because salience can be high in an individual's mental model without that theme also being understood or 'owned', to return to the terminology of Kearney and Kaplan (1997).

SLC was not immediately salient to PPP1 respondents when asked open questions about the Severn Estuary and the issues that face it. When asked at the start of the PPP1 interviews "what comes to mind when I say 'Severn Estuary'?", participants thought of a number of topics, including the Estuary's geographical form, mud, tides, bridges, a Severn Estuary barrage, sailing, Wales, development, the landscape, the Bristol Channel and the Severn bore; but no interviewee mentioned SLC. The next question, "what are the main issues facing the Severn Estuary?" elicited a similar response, with only one participant mentioning SLC. However, flooding, global warming, a 'huge wave', erosion, and managed realignment were mentioned, all of which are linked with SLC. Other issues included pollution, alternative energy and a barrage, ports, nuclear power, development, shipping, the bridge toll, and the decline in old traditions and industries such as salmon fishing and boat building. However, when PPP2 respondents were presented with a list of potential concerns including SLC, the issue featured relatively highly (see Figure 24, Chapter 6).

[74] Forty-one percent of UK survey respondents know a fair amount or a lot about climate change (Shuckburgh et al., 2012), and 43% of European respondents felt informed about SLR (CLAMER, 2011a)

Figures 32 and 33 show choropleth-style meta-influence diagrams summarising public salience[75] of beliefs (PPP1), mapped onto the expert model. The nodes mentioned by the most people are represented by darker shades of blue, and the nodes that were mentioned least are represented by lighter shades. Nodes not mentioned at all are white. Figure 32 shows the nodes that were discussed during the core dump phase of the mental models interviews, i.e. the issues that required minimal prompting. Figure 33 shows nodes discussed during the *whole* interview process, including the core dump, follow-up questions, picture sorting and cognitive mapping tasks. See section 5.2.2 for methodological details and Appendix G for the salience data tables used to create the maps.

Flooding was the most commonly mentioned theme (dark blue), and was discussed by all respondents without prompting (Figure 32). This was followed by anthropogenic climate change, flood defences and glacio-eustacy (ice melt), each mentioned by 16 participants without prompting. Homes and property damage, tides, storms and natural cycles were mentioned by 14, 13, 12 and 12 people respectively. Topics not mentioned at all during the core dump phase include the North Atlantic Oscillation (NAO), isostatic subsidence and personal sensitivity factors such as age and mobility.

Wisdom of the crowd

When PPP1 participants' data are aggregated in this way, the maps show that the majority of nodes were mentioned by someone at some stage during the interview process: 65% of nodes are covered in the core dump diagram and 78% in the full diagram. Likewise, when PPP2 survey results are averaged, mean answers tend to be in agreement with the expert model. This is illustrated in Figure 31, which shows the means of true/false answers and their standard deviations. Positive means indicate that the consensus amongst respondents is that the statement is true, while negative means indicate that the consensus amongst respondents is that the statement is false. The expert model consensus is shown by colours: red indicates false statements, and green indicates true statements. Where a red bar has a positive mean (i.e. it is on the right of the y-axis) or a green bar has a negative mean (is on the left of the y-axis) this indicates a widely held misconception amongst the public, and is circled in blue. The figure shows that *when averaged*, only five out of 34 topics were answered incorrectly. However, this 'wisdom of the crowds' (Galton, 1907) belies a more nuanced picture. The next sections examine each model theme in turn, discussing topic salience and understanding amongst interviewees and survey respondents. It shows that despite the crowd consensus being highly consistent with the expert model, there is much uncertainty and a number of differences between expert and public perceptions.

[75] As discussed in section 5.2.2, salience is calculated as a percentage, where 100% indicates that everyone mentioned the topic in the core dump phase, and lower percentages indicate that fewer people mentioned the topic or that it was mentioned during the later stages of the interviews.

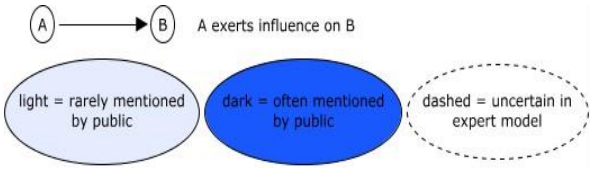


Figure 28: Key for public meta-influence choropleth diagrams (overleaf)

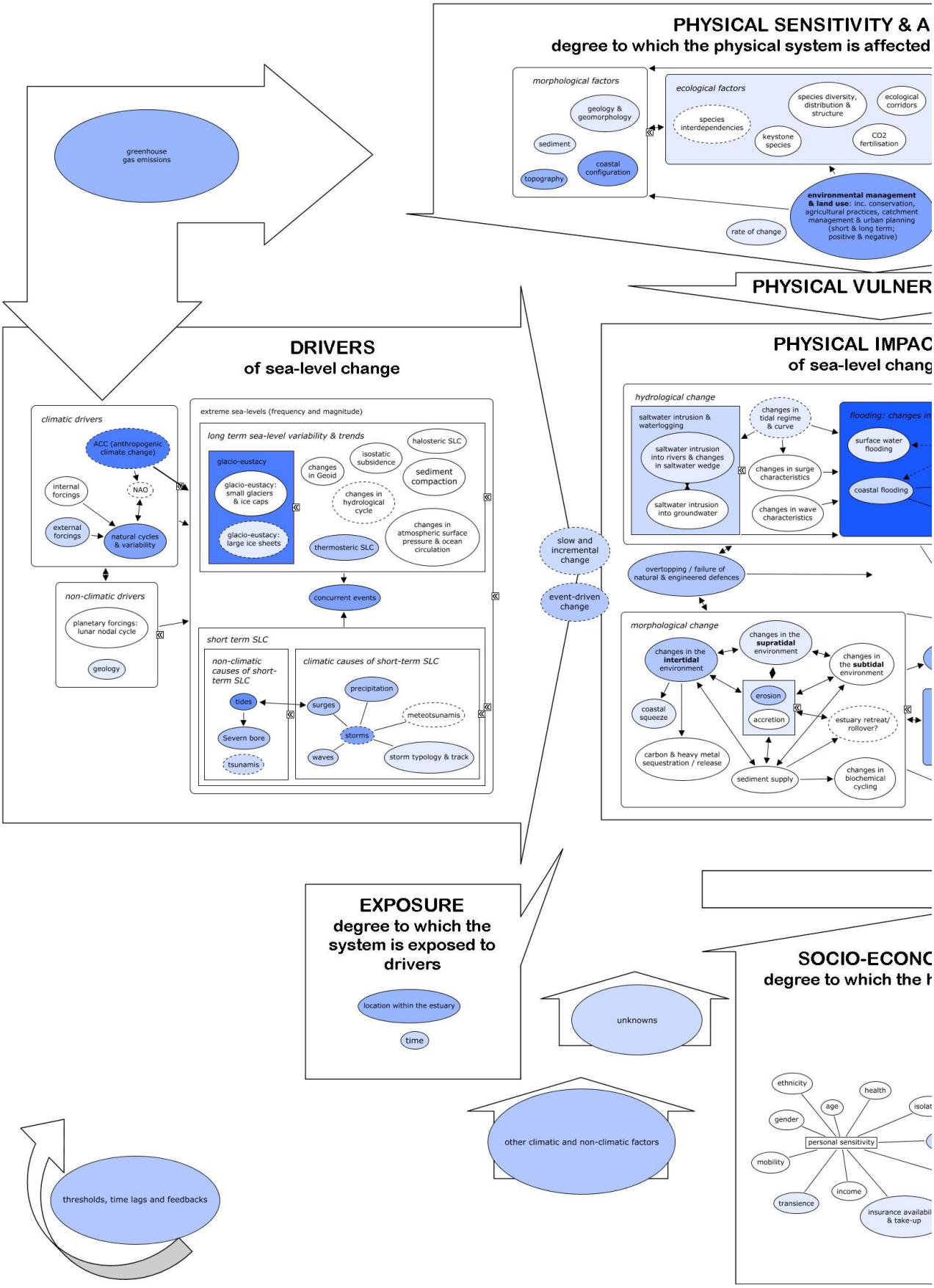
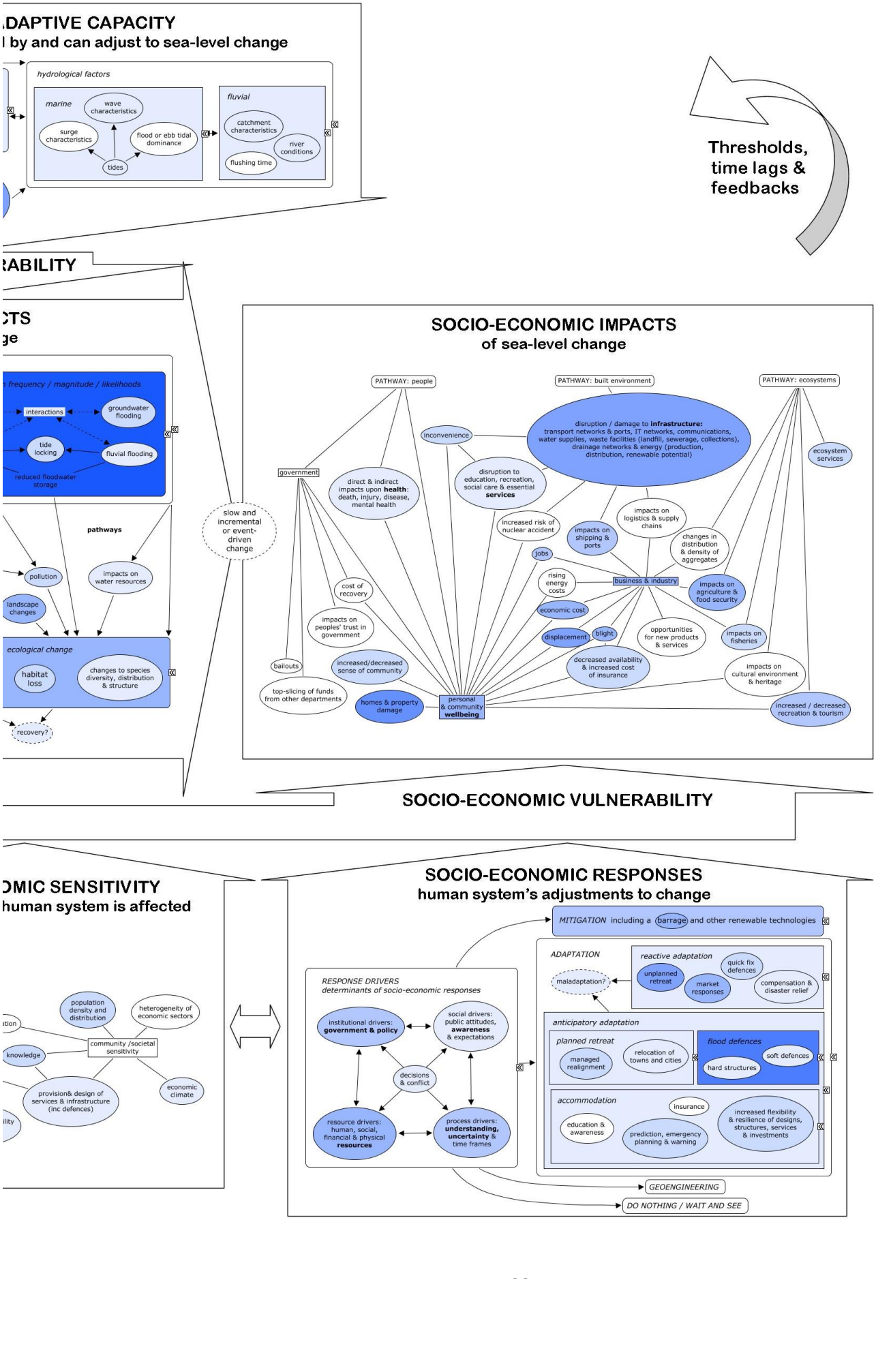


Figure 29: Public mental models 'core dump' themes mapped onto expert model


DAPTIVE CAPACITY
by and can adjust to sea-level change
hydrological factors
marine
wave characteristics
surge characteristics
flood or ebb tidal dominance
tides
fluvial
catchment characteristics
river conditions
flushing time
Thresholds, time lags & feedbacks
RABILITY
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frequency / magnitude / likelihoods
interactions
groundwater flooding
tide locking
fluvial flooding
reduced floodwater storage
pathways
pollution
impacts on water resources
landscape changes
ecological change
habitat loss
changes to species diversity, distribution & structure
recovery?
slow and incremental or event-driven change
SOCIO-ECONOMIC IMPACTS
of sea-level change
PATHWAY: people
PATHWAY: built environment
PATHWAY: ecosystems
government
inconvenience
disruption / damage to infrastructure: transport networks & ports, IT networks, communications, water supplies, waste facilities (landfill, sewerage, collections), drainage networks & energy (production, distribution, renewable potential)
ecosystem services
direct & indirect impacts upon health: death, injury, disease, mental health
disruption to education, recreation, social care & essential services
increased risk of nuclear accident
impacts on logistics & supply chains
impacts on shipping & ports
changes in distribution & density of aggregates
jobs
rising energy costs
business & industry
impacts on agriculture & food security
cost of recovery
economic cost
impacts on peoples' trust in government
displacement
blight
opportunities for new products & services
impacts on fisheries
bailouts
increased/decreased sense of community
decreased availability & increased cost of insurance
impacts on cultural environment & heritage
top-slicing of funds from other departments
homes & property damage
personal & community wellbeing
increased / decreased recreation & tourism
SOCIO-ECONOMIC VULNERABILITY
OMIC SENSITIVITY
human system is affected
population density and distribution
heterogeneity of economic sectors
community /societal sensitivity
knowledge
provision& design of services & infrastructure (inc defences)
economic climate
SOCIO-ECONOMIC RESPONSES
human system's adjustments to change
MITIGATION including a barrage and other renewable technologies
ADAPTATION
reactive adaptation
maladaptation?
unplanned retreat
market responses
quick fix defences
compensation & disaster relief
anticipatory adaptation
planned retreat
managed realignment
relocation of towns and cities
flood defences
soft defences
hard structures
accommodation
insurance
education & awareness
prediction, emergency planning & warning
increased flexibility & resilience of designs, structures, services & investments
RESPONSE DRIVERS
determinants of socio-economic responses
institutional drivers: government & policy
social drivers: public attitudes, awareness & expectations
decisions & conflict
resource drivers: human, social, financial & physical resources
process drivers: understanding, uncertainty & time frames
GEOENGINEERING
DO NOTHING / WAIT AND SEE

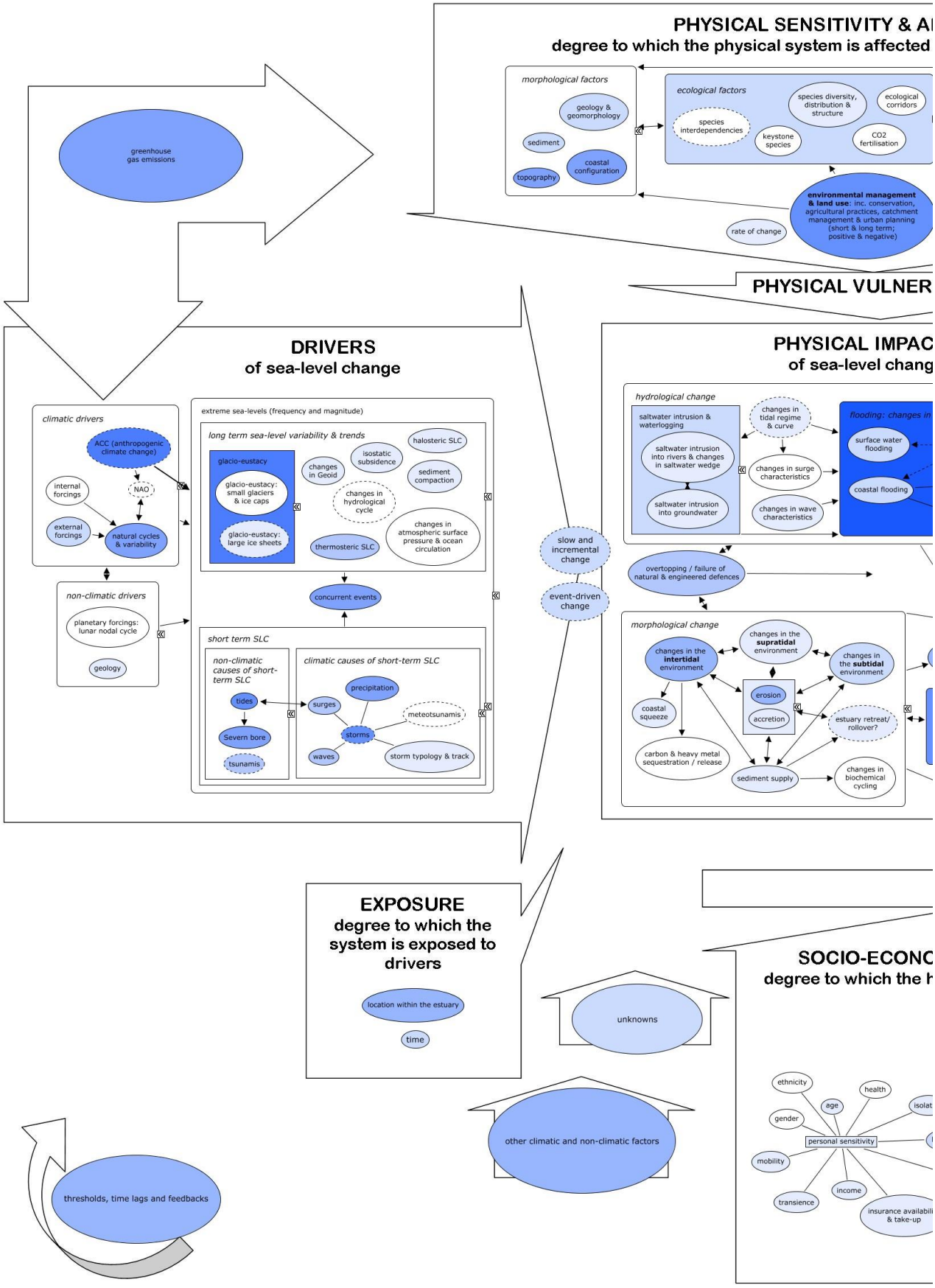
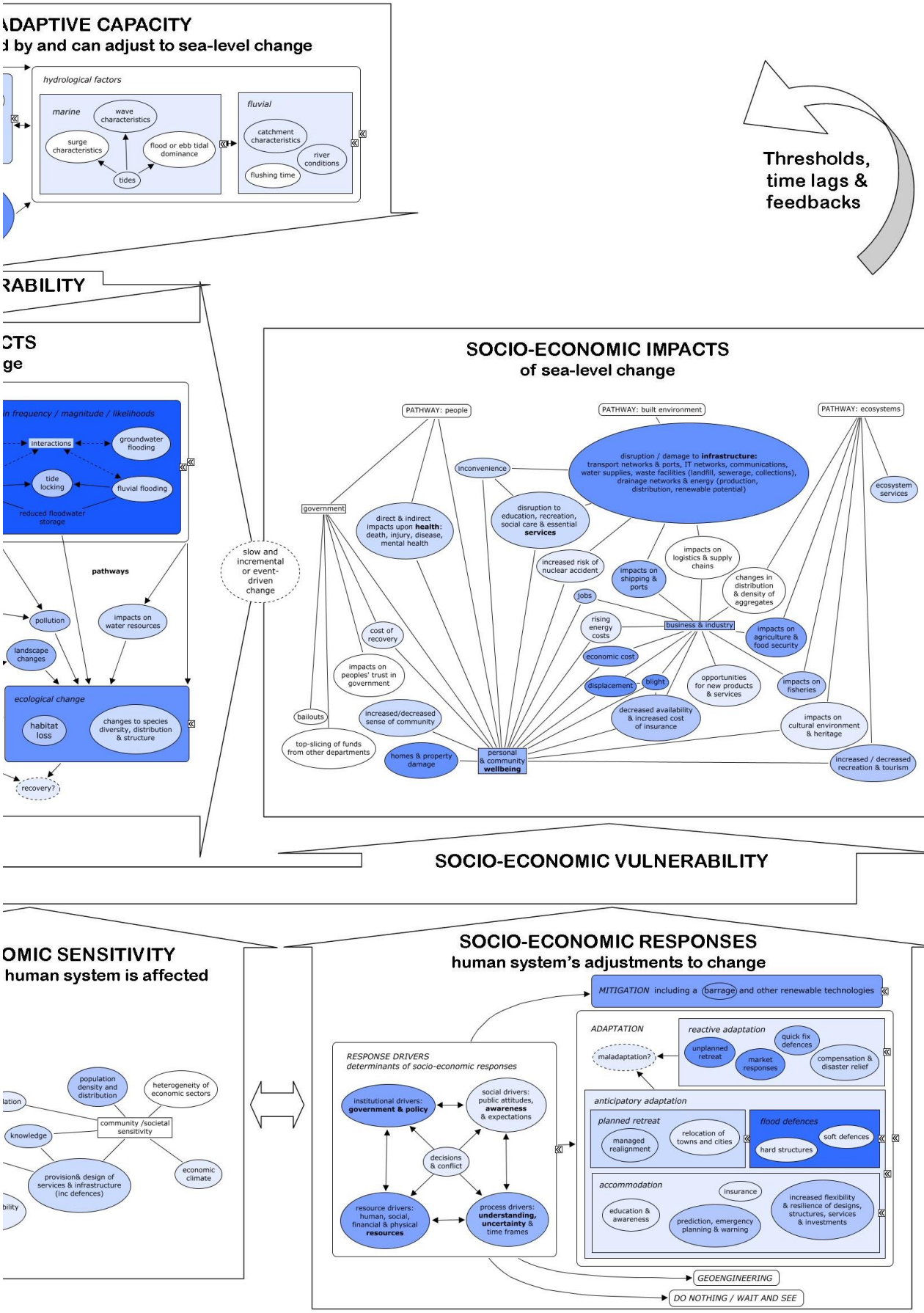


Figure 30: All public themes mapped onto the expert model

Including data from PPP1 mental models interviews, picture sorting task and cognitive mapping task. Dark colours represent themes most commonly coded.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hydrological factors
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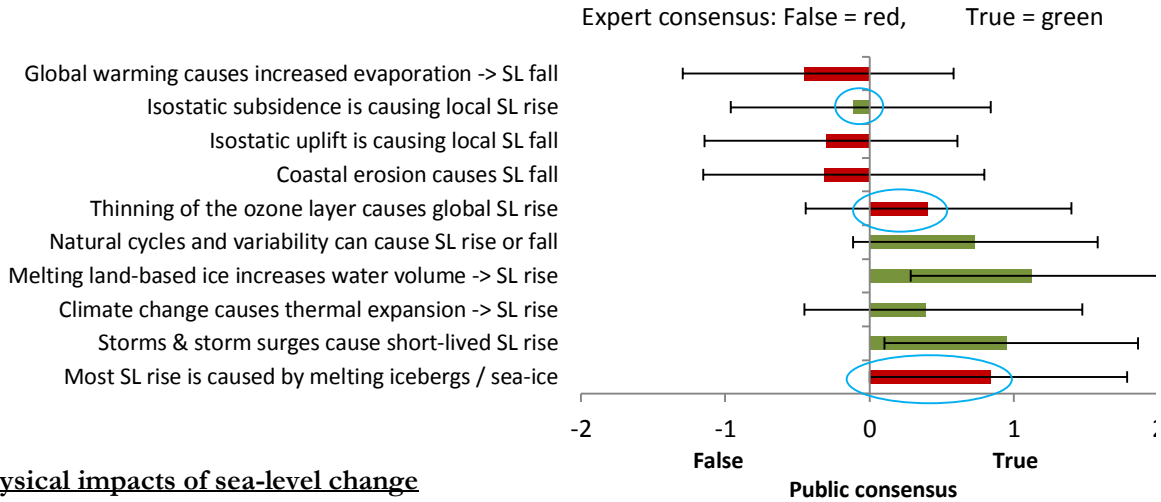
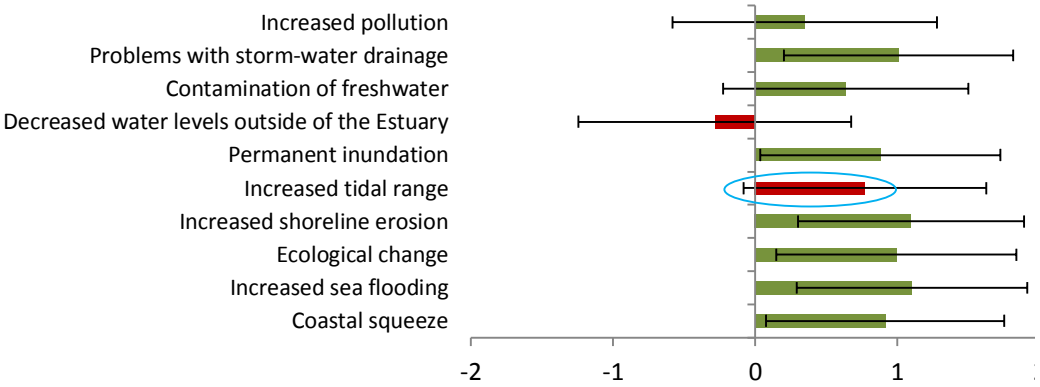
wave characteristics
surge characteristics
flood or ebb tidal dominance
tides
fluvial
catchment characteristics
river conditions
flushing time
Thresholds, time lags & feedbacks
RABILITY
CTS
ge
n frequency / magnitude / likelihoods
interactions
groundwater flooding
tide locking
fluvial flooding
reduced floodwater storage
pathways
pollution
impacts on water resources
landscape changes
ecological change
habitat loss
changes to species diversity, distribution & structure
recovery?
slow and incremental or event-driven change
SOCIO-ECONOMIC IMPACTS
of sea-level change
PATHWAY: people
PATHWAY: built environment
PATHWAY: ecosystems
inconvenience
disruption / damage to infrastructure: transport networks & ports, IT networks, communications, water supplies, waste facilities (landfill, sewerage, collections), drainage networks & energy (production, distribution, renewable potential)
ecosystem services
government
direct & indirect impacts upon health: death, injury, disease, mental health
disruption to education, recreation, social care & essential services
increased risk of nuclear accident
impacts on logistics & supply chains
impacts on shipping & ports
changes in distribution & density of aggregates
jobs
rising energy costs
business & industry
impacts on agriculture & food security
cost of recovery
economic cost
impacts on peoples' trust in government
displacement
blight
opportunities for new products & services
impacts on fisheries
bailouts
increased/decreased sense of community
decreased availability & increased cost of insurance
impacts on cultural environment & heritage
top-slicing of funds from other departments
homes & property damage
personal & community wellbeing
increased / decreased recreation & tourism
SOCIO-ECONOMIC VULNERABILITY
OMIC SENSITIVITY
human system is affected
population density and distribution
heterogeneity of economic sectors
community /societal sensitivity
knowledge
economic climate
provision& design of services & infrastructure (inc defences)
SOCIO-ECONOMIC RESPONSES
human system's adjustments to change
MITIGATION including a barrage and other renewable technologies
ADAPTATION
reactive adaptation
maladaptation?
unplanned retreat
market responses
quick fix defences
compensation & disaster relief
anticipatory adaptation
planned retreat
managed realignment
relocation of towns and cities
flood defences
soft defences
hard structures
accommodation
insurance
education & awareness
prediction, emergency planning & warning
increased flexibility & resilience of designs, structures, services & investments
RESPONSE DRIVERS
determinants of socio-economic responses
institutional drivers: government & policy
social drivers: public attitudes, awareness & expectations
decisions & conflict
resource drivers: human, social, financial & physical resources
process drivers: understanding, uncertainty & time frames
GEOENGINEERING
DO NOTHING / WAIT AND SEE

Drivers of sea-level change



Physical impacts of sea-level change



Socio-economic impacts of sea-level change

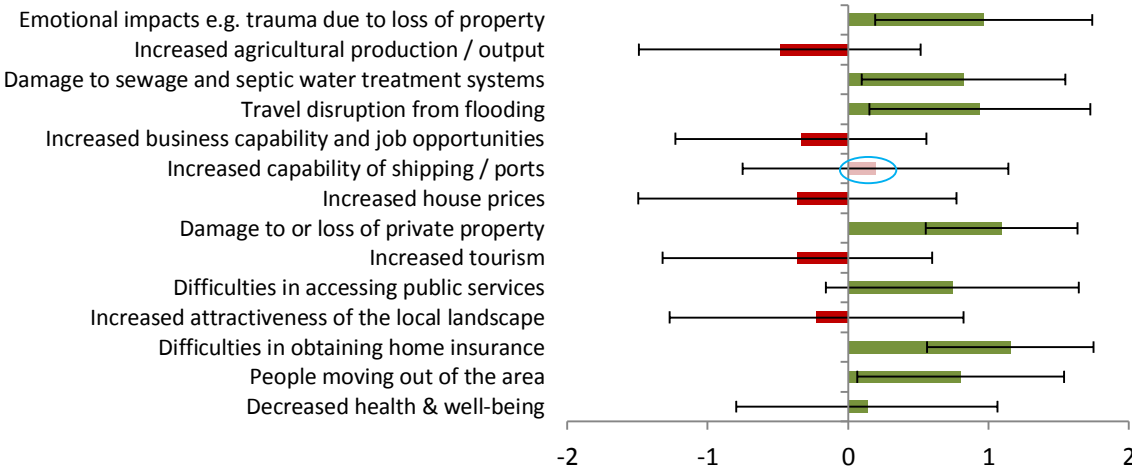


Figure 31: Average PPP2 responses to true/false questions, with standard deviations

Positive means indicate that the consensus amongst respondents is that the statement is true, while negative means indicate that the consensus amongst respondents is that the statement is false. Expert model consensus is shown by colours: red indicates false statements, and green indicates true statements. Question wording has been modified to fit the page. "Increased capability of shipping/ports" (pink) is a particularly uncertain theme in the expert model. Widely held EP differences (differences between expert and public perceptions) are circled in blue.

7.2.3 Salience and understanding by theme

This section shows parts of Figure 33 in more detail[76]. While the maps show if a node is salient, they do not show how well it is understood. Understanding is therefore further explored with reference to PPP1 and PPP2 findings.

Drivers of sea-level change

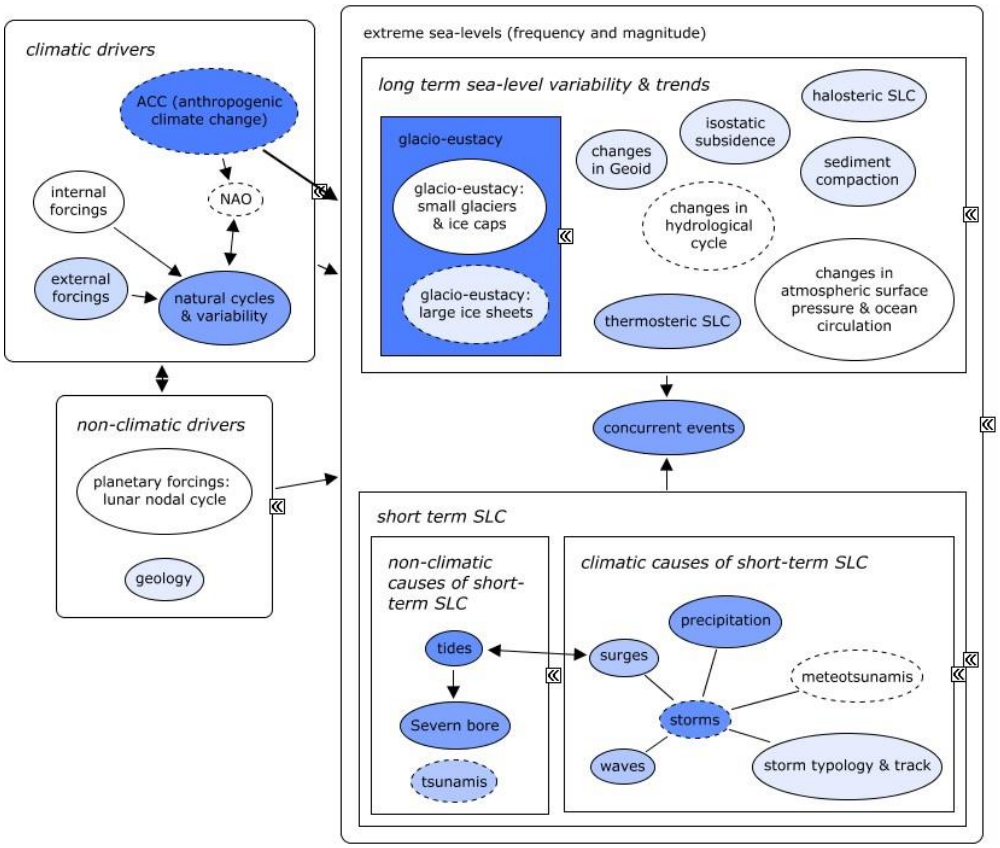


Figure 32: Public salience of drivers mapped onto expert model, PPP1

The most salient drivers amongst PPP1 respondents were ice melt (glacio-eustacy) and anthropogenic climate change (ACC), while the North Atlantic Oscillation (NAO) and lunar cycles were not discussed at all[77]. Sixteen participants talked about ACC without being prompted, indicating that participants closely link ACC and SLC. Christine summed up this link, noting that "you can't divorce rising sea levels from climate change".

[76] Data from the whole PPP1 interviews are presented rather than solely the 'core dump' stage, because the core dump risks overlooking topics.

[77] The NAO is a key driver of storminess on the Severn Estuary, and lunar cycles cause great variations in tidal amplitudes (see Expert Model, Appendix O) so both are important drivers of SLC. It is debateable though whether concepts such as these should be included in risk communications because they do not directly influence behaviour (Lorenzoni & Pidgeon, 2006).

Figure 33 and Figure 34 show survey responses to true/false questions about the drivers of SLC. The graph with the green background shows the percentage of true/false responses to statements for which the expert consensus is that they are true. The graph with the red background shows the percentage of true/false responses to statements for which the expert consensus is that they are false. Large percentages of respondents stating that the statement is false (red bars) on the green background indicate a widely held misconception that a true statement is false. Likewise, large percentages of true answers (green bars) on the red background indicate a widely held misconception that a false statement is true. Widely held differences between expert and public perceptions are circled in blue.

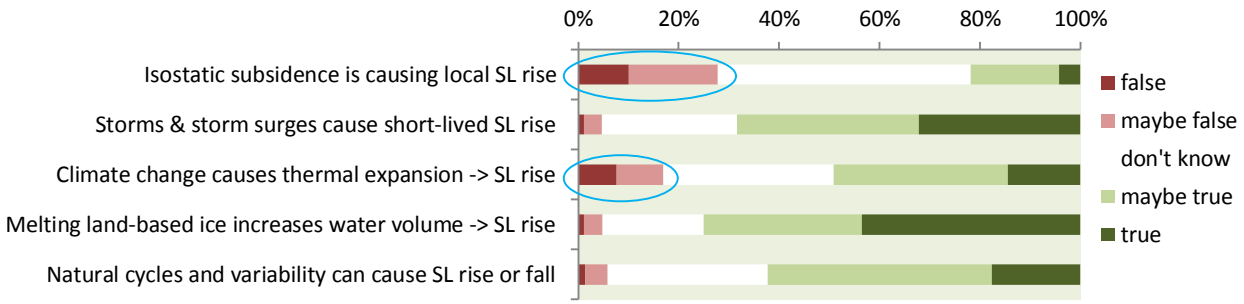


Figure 33: True/false responses (%) to TRUE statements about the causes of SLC, PPP2
Question wording has been modified to fit the page.

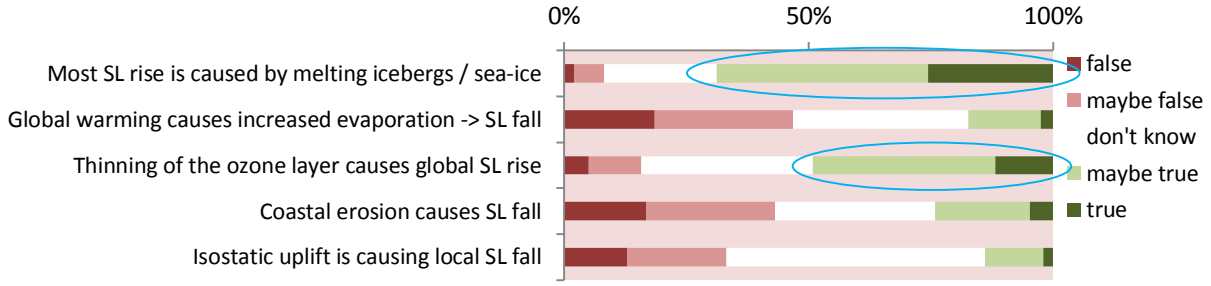


Figure 34: True/false responses (%) to FALSE statements about the causes of SLC, PPP2
Question wording has been modified to fit the page.

Figure 33 and Figure 34 show that while mean public understanding is consistent with the expert model for most of the true statements (i.e. the majority of respondents state that the true statements are true), the graphs show that there is a lot of uncertainty (denoted by the wide white 'don't know' bars), and a number of differences, particularly when framed as false statements. Differences between the public and expert models can be summarised as follows:

- **Most SLR is caused by melting icebergs/sea-ice**. 69% of PPP2 participants thought the (false) statement 'Most global sea-level rise is caused by melting icebergs/sea-ice' is true, while 8% thought it is false.

- **Thinning of the ozone layer causes global SLR**. 49% of respondents thought the (false) statement 'Thinning of the ozone layer causes global sea-level rise' is true, while just 16% thought it is false, echoing previous studies showing misconceptions regarding ozone layer depletion as a cause of climate change (Bord et al., 2000; Bostrom et al., 1994; Tobler et al., 2012).
- **Isostatic subsidence is not causing local SLR**. 28% of respondents thought that the (true) statement 'The land around the Severn Estuary is sinking in response to the last glacial period, and therefore causing local sea levels to rise' is false, while 22% thought it is true. Misconceptions regarding local subsidence were also found by Akerlof (2012).
- **Coastal erosion causes sea levels to fall.** 24% respondents agreed with this (false) statement.
- **Global warming causes increased evaporation, leading to sea-level fall**. 17% respondents agreed with this (false) statement.
- **Climate change does not cause thermal expansion.** 17% respondents *disagree* with the (true) statement that climate change causes thermal expansion, leading to sea-level rise. The low awareness of the importance of thermal expansion has also been found by other researchers (Read et al., 1994; Reynolds et al., 2010; Tobler et al., 2012).
- **Isostatic uplift is causing local sea-level fall.** 14% respondents agreed with this (false) statement.

There is strong public consensus about some drivers of SLC, but more varied opinions about other factors. In the expert model, the two most dominant drivers of long-term mean SLR are glacio-eustacy and thermosteric SLR. Fully 75% of PPP2 respondents agree with the (true) statement that 'as land-based ice melts, the addition of water to the oceans causes global sea-level rise', and just 5% disagree, indicating strong public agreement about this factor. However, there is much more variation in responses to the statement 'Climate change causes the water in the oceans to expand as it gets warmer, and therefore causes global sea-level rise' with 49% agreeing and 17% disagreeing. This is supported by qualitative interviews, whereby SLC caused by thermal expansion had a salience score of 26%, while glacio-eustacy was much more salient with a score of 85%. The high salience of ice-melt has also been found in studies of the images that the public most readily associate with climate change (Lorenzoni et al., 2006).

The high frequency of 'don't know' responses is not insignificant. Although it could show an element of 'flatlining', where respondents just pick the middle option for all questions, or indifference, it is likely to indicate issues that respondents literally do not know about (Durand & Lambert, 1988; Grichting, 1994). The issues with the greatest number of 'don't know' responses are also those with the greatest proportion of misconceived responses. They are: isostacy, evaporation, the ozone layer, coastal erosion and thermal expansion. It should also be noted that

there is likely to be an element of availability bias (Tversky & Kahneman, 1973) in some of the responses, whereby participants associate concepts with others that more easily come to mind. For example, if a person has heard of ozone in relation to the health of the environment, they may be more likely to associate it with SLC when presented with the two topics together. There may also be an element of acquiescence bias (Jackson & Messick, 1958) whereby respondents are more likely to agree with a statement than disagree with it. This may mean that differences on the true chart (Figure 33) are more significant than differences on the false chart (Figure 34), because disagreeing with a true statement such as "The land around the Severn Estuary is sinking in response to the last glacial period and causing local sea levels to rise" may take more cognitive effort than agreeing with a false statement.

Physical impacts of sea-level change

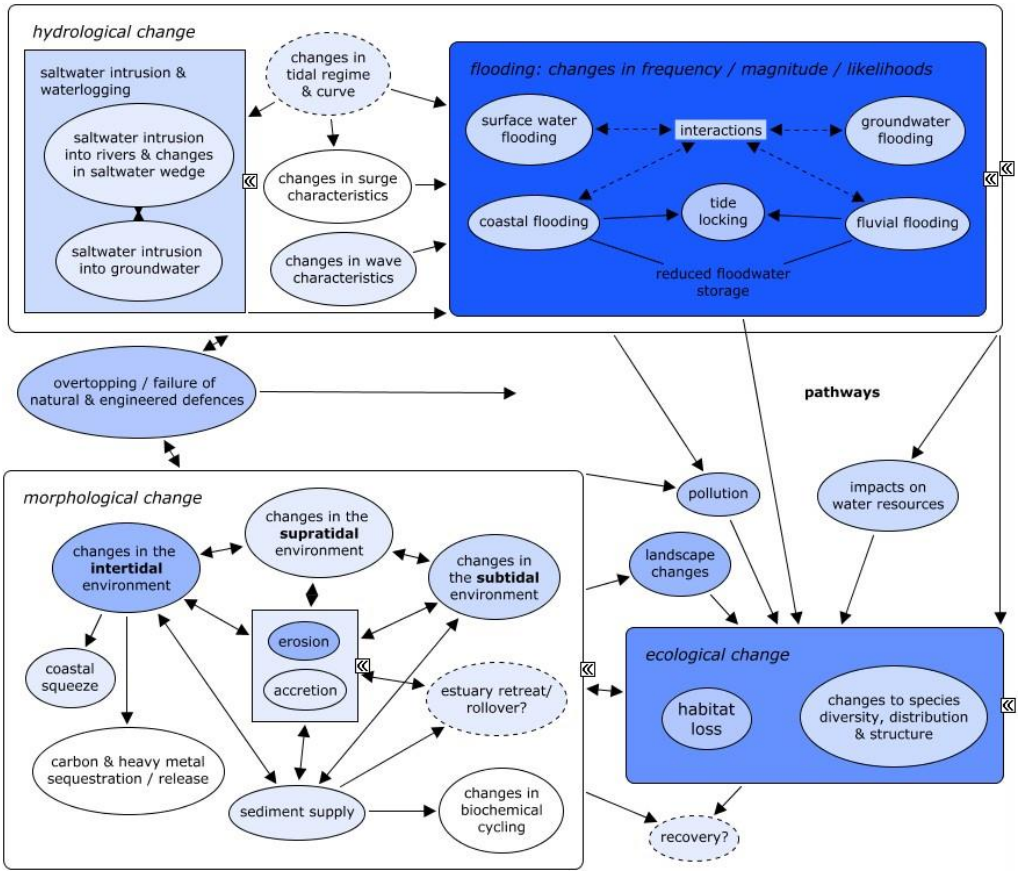


Figure 35: Public salience of physical impacts mapped onto the expert model, PPP1

Figure 35 shows that the most salient physical impacts amongst interviewees were flooding and ecological change. Changes in surge characteristics, biochemical cycling and carbon and heavy metal sequestration/release were not mentioned at all, which is unsurprising as they are arguably

more peripheral topics, and are rarely mentioned in mainstream media sources[78]. The salience of flooding is reassuring from a communications perspective, as this is widely believed amongst experts to be the greatest impact of SLC on the Severn Estuary. This high public salience is also unsurprising considering the historical record of flooding on the Estuary (Haslett & Bryant, 2004; Horsburgh & Horritt, 2006; Proctor & Flather, 1989; Zong & Tooley, 2003).

Interview findings were broadly supported by survey results, which on average showed that public understanding of physical impacts is broadly consistent with expert understanding (Figure 36 and Figure 37). The main exception regarded tidal range, which 62% of PPP2 respondents thought would increase with SLR, in contrast to the expert view that tidal range is more likely to decrease with SLR. It was also the most salient EP difference amongst PPP1 respondents (Appendix I). This is not a surprising finding, because an increase in tidal range is perhaps a more intuitive response. Furthermore, this response may be due to confusion with the term 'tide', which PPP1 participants sometimes used to refer to general sea level (see section 7.2.6).

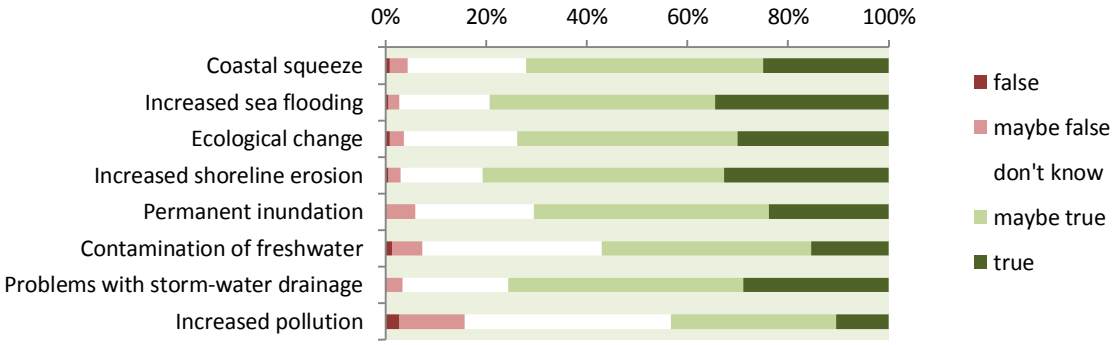


Figure 36: True/false responses (%) to TRUE statements about the physical impacts of SLR, PPP2 Statements have been shortened for clarity.

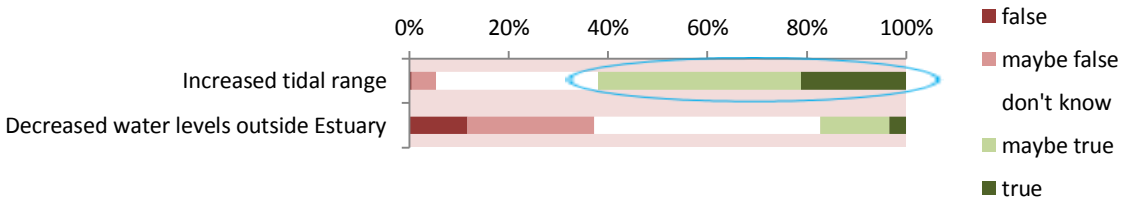


Figure 37: True/false responses (%) to FALSE statements about the physical impacts of SLR, PPP2 Statements have been shortened for clarity.

There was much uncertainty among many survey responses, particularly regarding statements about freshwater contamination, pollution, and decreased water levels outside of the estuary. Survey results indicate the following EP differences regarding the physical impacts of SLC:

[78] Confirmed with a search of these topics on Google News, September 2013.

- **SLR causes an increase in tidal range.** 62% respondents thought that this (false) statement was true.
- **SLR on the Severn Estuary causes sea levels to fall elsewhere**. 37% thought this (false) statement was false, but a significant portion (17%) thought that the statement was true, indicating underlying differences between expert and lay beliefs about the processes of global SLC.

The bias in this survey item should be noted. Physical impacts are wide ranging and were difficult to frame as 'false' statements in the PPP2 survey. Therefore, eight of the ten statements were 'true', meaning acquiescence bias and flatlining may have affected the results differently than with the more equally weighted true/false statements used for drivers and socio-economic impacts themes.

Socio-economic impacts of sea-level change

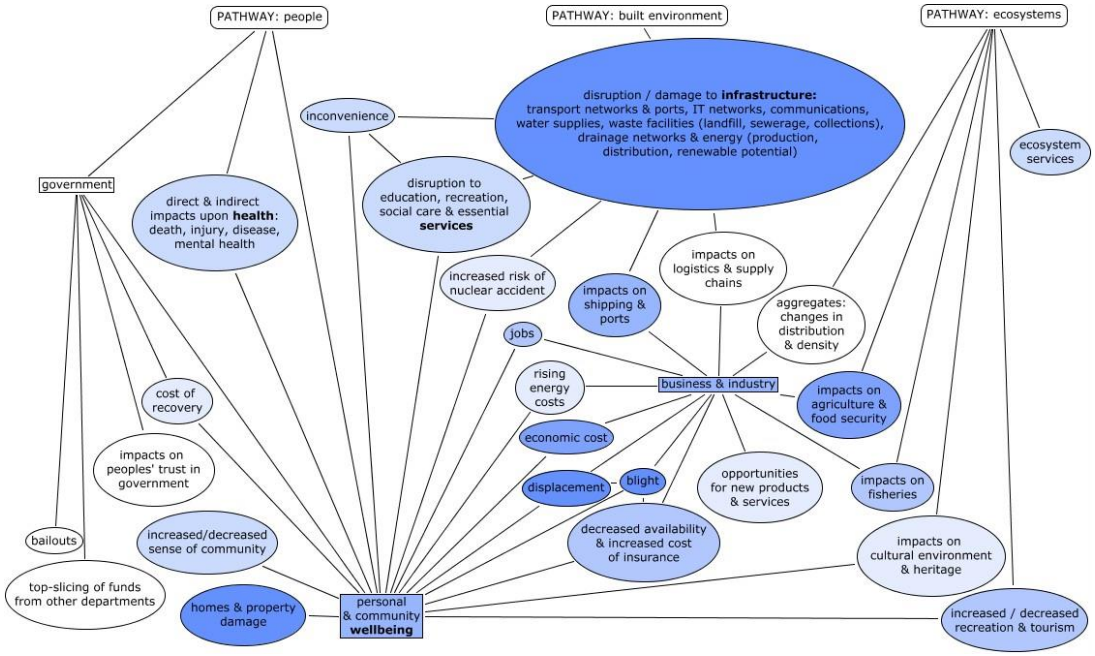


Figure 38: Public salience of socio-economic impacts mapped onto the expert model, PPP1

Damage to homes and property was the most salient socio-economic impact amongst interviewees, scoring 73% salience. Inconvenience scored just 20% salience, and few respondents mentioned health (13%), services (13%), and impacts on the cultural environment and heritage (5%). These findings indicate that indirect impacts such as these are less salient than direct impacts such as damage to homes and property. This is unsurprising as people are perhaps more likely to think about impacts that directly concern them, as discussed earlier. Other studies have also shown that public knowledge of climate change consequences tends to focus on immediate physical impacts

such as flooding rather than more indirect impacts such as social disruption (Capstick et al., 2013; Lorenzoni et al., 2006).

The high salience of home and property damage is echoed by survey results, which show that very few people (2% of respondents) disagree that SLC would cause damage to or loss of private property. The same proportion of survey respondents (2%) disagreed with the statement that SLC would cause difficulties in obtaining home insurance, which achieved a lower salience score of 30% during the public interviews.

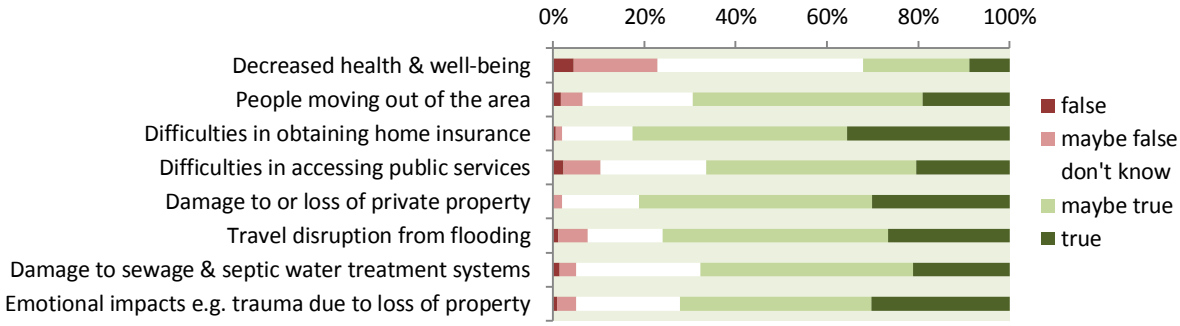


Figure 39: True/false responses (%) to TRUE statements about the socio-economic impacts of SLR, PPP2

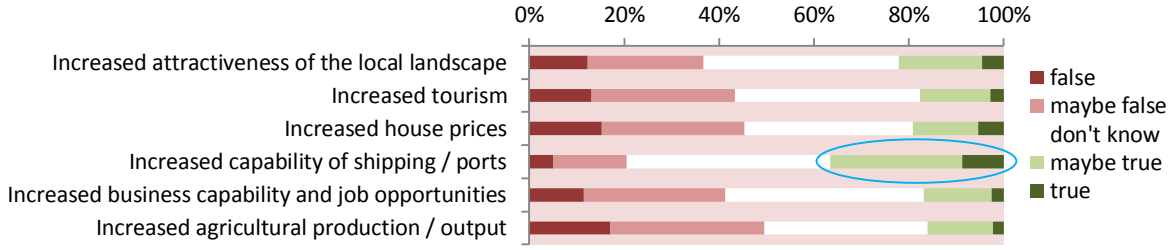


Figure 40: True/false responses (%) to FALSE statements about the socio-economic impacts of SLR, PPP2

On average, survey respondents exhibited an understanding of the socio-economic impacts of SLC broadly consistent with the expert model, as shown in Figure 39 and Figure 40. Also, relatively few survey respondents answered 'don't know' to the socio-economic items, particularly the true statements. This may be for two reasons: a) social impacts may be more salient or better understood than drivers or physical impacts, or b) the statements are perceived as intuitive or obvious. It should be noted that a number of socio-economic impact items are subjective and/or open to interpretation. For instance, who is to say whether someone will find the landscape less attractive after sea-level rise? Furthermore, there may indeed be increased job opportunities for some sectors, e.g. coastal engineers. This reflects an underlying difficulty of this research, whereby a model of 'truth' cannot be definitively constructed. Survey results indicate the following differences between expert and public perceptions:

- The only mean public response in disagreement with the expert model is "**increased capability of shipping/ports**", which is itself a particularly uncertain area in the expert model. This finding was supported during public interviews, where Laura, Lee, Ellen, Steve and Henry thought that the impacts of SLC on shipping and ports might be positive. This is not a surprising result, as raised sea-levels may logically be related to more available water for shipping. The relationship with storminess (leading to decreased viability of shipping/ports) is perhaps less obvious.
- Fully 23% respondents thought that the statement that SLR would cause **decreased health and wellbeing** was false or maybe false. This may indicate a misconception, but it may also be a value judgment or a reaction to a perceived negative framing of the issue, prompting participants to 'look on the bright side' in response to a long list of negative implications.

Vulnerability

Figure 41, Figure 42 and Figure 43 show the salience of vulnerability themes among PPP1 participants, organised into the three relevant themes in the expert model: physical sensitivity & adaptive capacity, socio-economic sensitivity and socio-economic responses. Findings are then discussed in relation to specific vulnerability factors.

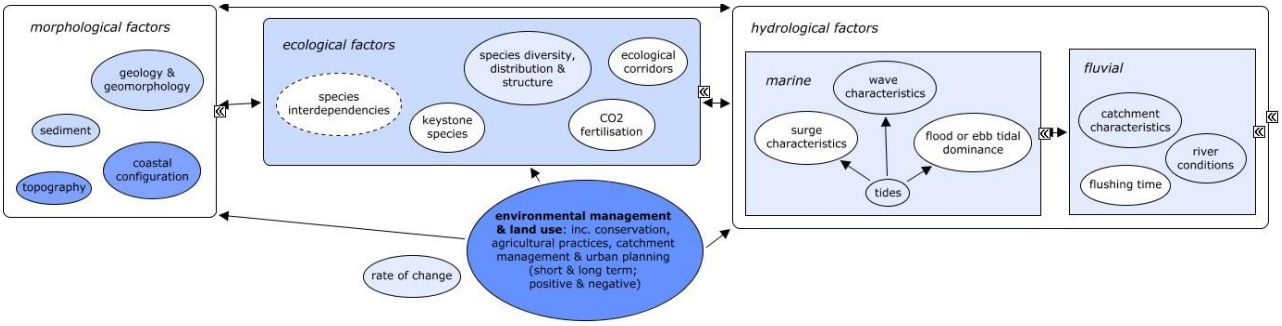


Figure 41: Public salience of physical sensitivity and adaptive capacity, mapped onto the expert model, PPP1

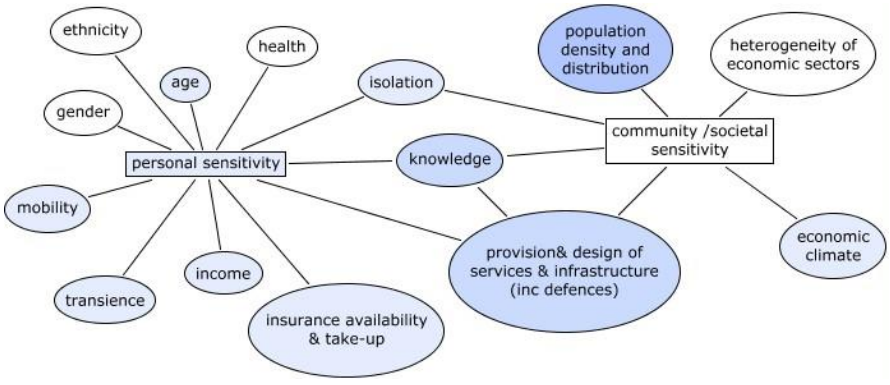


Figure 42: Public salience of socio-economic sensitivity mapped onto the expert model, PPP1

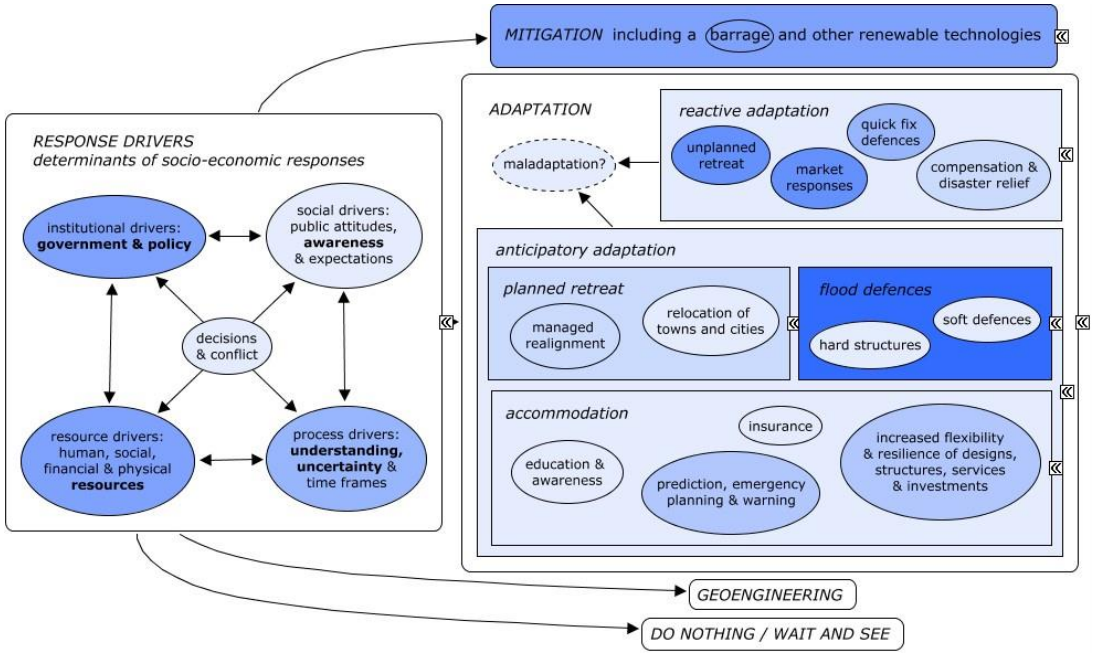


Figure 43: Public salience of socio-economic responses mapped onto expert model, PPP1

Gradual versus sudden impacts of sea-level change

As outlined in the expert model, the drivers and impacts of SLC may be slow and incremental, for example through gradual erosion of salt marsh by 'average' sea conditions, or more sudden through event-driven changes like storm-induced flooding. This is an important part of the model because the vulnerability of the Severn Estuary will depend in part on whether impacts are slow or fast. During interviews, SLC and its effects were generally seen as a distant, 'creeping' problem, which are too gradual to notice, though Ruby and Henry did acknowledge that future change might be fast (Quote Box 30). Indeed, the majority of survey respondents (60%) believe that the impacts of SLC will be gradual rather than sudden (Figure 44).

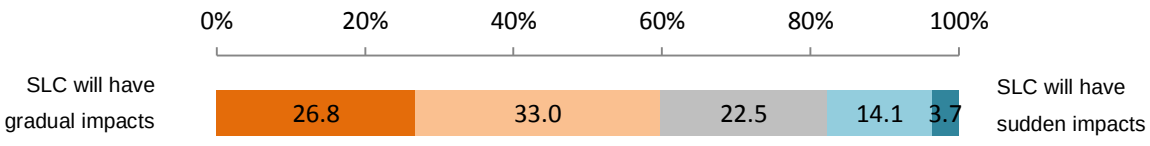


Figure 44: Percent respondents who think that SLC impacts will be gradual versus sudden

173. "It's something that's creeping up isn't it, rather than just happening instantly" – Anthony

174. "It's not noticeable. Not in my lifetime anyway" – Steve

175. "I don't think it's supposed to be enough that it's going to be noticeable in our lifetime" - Yasmine

176. "I don't know how fast it's going to happen. You know, it'll probably take us by surprise won't it I think" – Ruby

177. "I suspect the change won't be gradual. Or it will be gradual if you measure the level of the increase in the seawater will be gradual, but I suspect that will keep going and then there will be some fairly major catastrophic event, so that change won't be gradual" - Henry

178. "I have my own managed retreat policy, sell up before [SLC] materially affects the value of this house" – Fred

Quote Box 30: Perceived gradual versus sudden impacts of SLC, PPP1

Some of the impacts of SLC may be slow and others fast, and experts are not agreed on which will be dominant (see the expert model in Appendix O for more information). However, sudden catastrophic changes through storm events and even tsunamis remain a possibility (Defra, 2005; Horsburgh, 2011). The widely held perception that SLC will be gradual is therefore important; people who hold this view may be unprepared for surprises, as summed up by Fred (Quote 178), who plans to sell his house before SLC affects its value.

Spatial vulnerability

Figure 45 shows that the majority of respondents selected low-lying coastal areas such as Berkeley, Caldicot, Weston and Thornbury as being at greatest risk from SLC. This aligns with the expert model. However, exposure and therefore vulnerability is not straight forward: wave overtopping is a problem in the outer estuary, while the greatest flood risk in the uppermost reaches of the estuary is from high river flows (Environment Agency, 2011b) and tidal currents (Severn Estuary Coastal Group and ATKINS, 2010b). As well as spatial heterogeneity in natural protection, there is variation in the amount and quality of protection provided by flood defences. Due to these nuances and methodological limitations, the main EP differences are tentative. They are as follows:

- 21% of respondents ranked the Vale of Glamorgan amongst the top five areas at risk, when the low lying regions of Newport and Cardiff further are more likely to be affected. Newport and Cardiff are ranked relatively low (12% and 11% of respondents respectively), but this may be due to these regions being represented by smaller areas on the map: larger areas may have been more attractive to survey respondents because they covered more regions deemed to be at risk.

- Although Gloucester was the area most often cited by interview respondents to be at risk, it was only chosen by 23% of survey respondents as amongst the top five areas at risk, despite recent floods there (Prior & Beswick, 2008). This also might have been due to the small size of the section on the map.

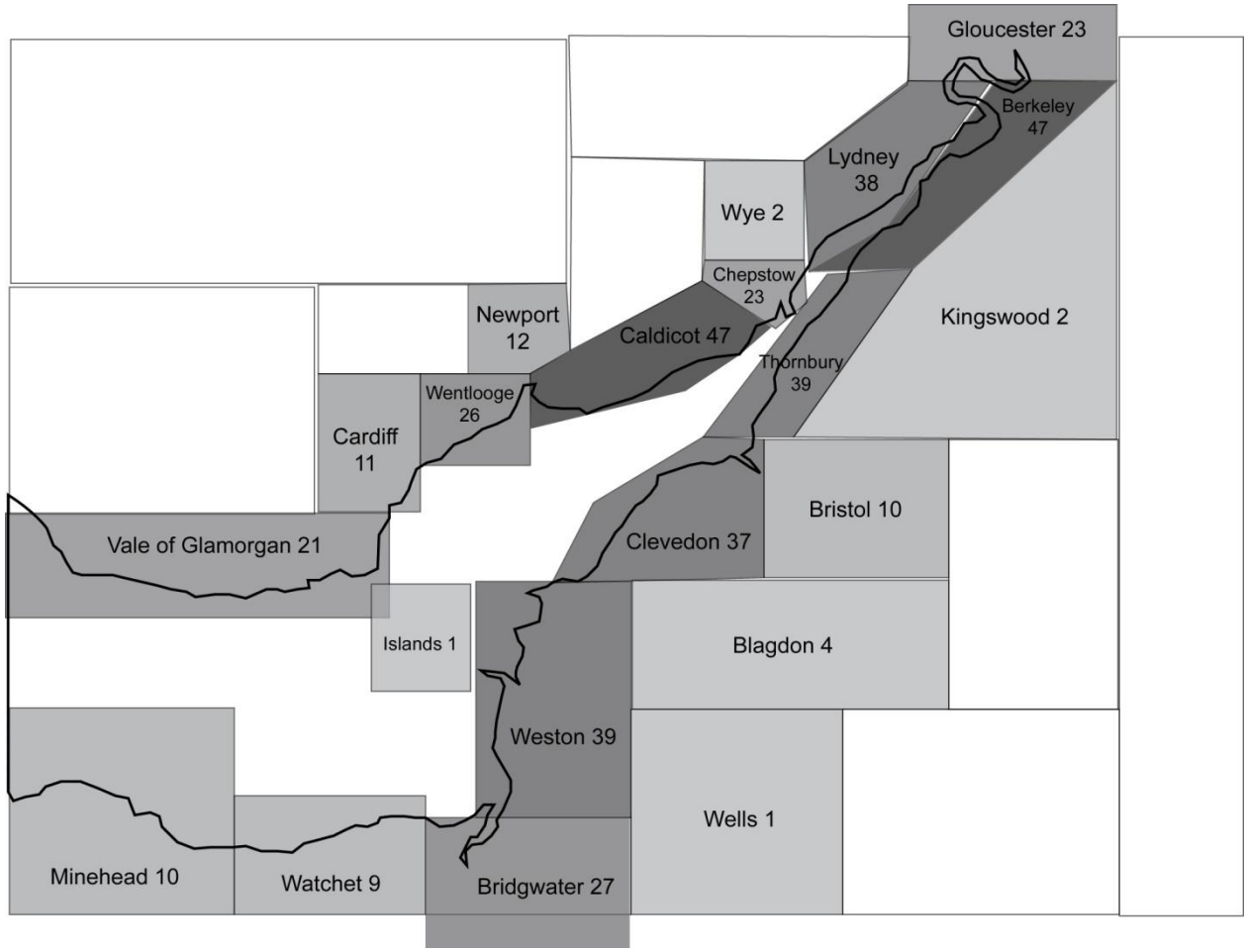


Figure 45: Choropleth showing regions perceived to be most at risk of SLC on the Severn Estuary, PPP2 Numbers show the percent of respondents who think the region is one of up to five areas that would be most affected by sea-level rise by the year 2050 (N=324). Darker greys denote areas perceived by more people to be at risk; white boxes denote regions chosen by less than 1% of respondents.

Socio-economic vulnerability

The interview protocol did not directly address socio-economic vulnerability apart from the inclusion of the following pictures in the picture sorting task: an elderly couple sign, a father and child, an Asian mother and child, and a corner shop. Bearing this in mind, there was a striking low salience of socio-economic sensitivity nodes during PPP1 (Figure 42), which *may* indicate a lack of knowledge about the people who are most at risk from SLC on the Severn Estuary. While some interviewees talked about SLC affecting everyone and being no respecter of age (Quote Box 31), vulnerability was talked about extensively in relation to people in *other* places and at other times, as

discussed in 6.2.5 (Psychological Distance). Darren mentioned elderly people being the first to be moved, a comment indicating that he thinks they may be vulnerable, which is a belief consistent with the expert model.

179. "the impact for people of SLC in the Severn Estuary is that it will affect all age groups and be no respecter of age, disability or how nice they are" – Ellen

180. "It affects everyone though, climate controls [sic], SLC would affect everyone. No one would be immune from it" – Steve

181. "Yes, how other countries will be affected, because well, they will be won't they? Sea levels are global, aren't they" – Christine

182. "If the sea level rises everywhere, then it's going to you know, affect the Severn, as well as everywhere else" [Moderator: same sort of amounts or not?] "Yes. But we don't live quite as close to the water as they do in Bangladesh and people on the coral islands and so on" - Glenda

183. "Old people. A lot of old people in seaside towns. Maybe they'll have to move. [...facilitator: are they more vulnerable or not really?] Oh, they'll be alright. They'll probably be top of the list to be moved" – Darren

Quote Box 31: Perceived vulnerability, PPP1

Vulnerability of rural and urban areas

While PPP1 interviewees expressed mixed views about the relative vulnerability of rural and urban areas (Quote Box 32), PPP2 survey respondents tended to think rural areas would be most affected. Forty-one percent respondents thought that SLC will affect people in rural areas more than people in urban areas, compared to 10% who thought it will affect people in cities most. This view is valid in the current legislative climate, where the cost-benefit analyses of coastal defence planning favours larger, more economically diverse settlements (Fernandez-Bilbao, 2012). There was however much uncertainty regarding this question, with 49% respondents choosing the middle option on the bipolar scale.

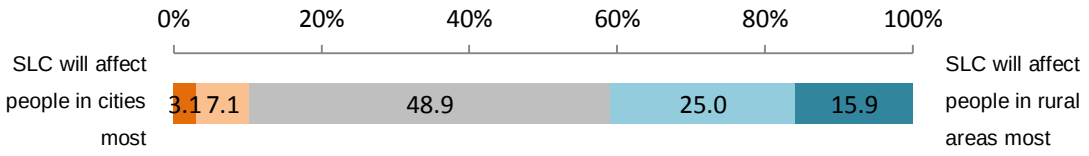


Figure 46: Perceived vulnerability of people in rural and urban areas, PPP2

Percent of respondents who believe that SLC will affect people in cities most vs people in rural areas most

184."I think parts of Bristol are at risk from flooding if we had a major rise in the tides here, because if you think of the Cumberland Basin all up around through there, it's all, round the docks there, it's all at sea level. So cities would flood, probably the same over in Wales as well, Cardiff and Newport probably. A lot of that's round the docks, isn't it. Quite vulnerable from it" – Steve, Kingston Seymour

185."I think cities might find it harder to manage than small villages and towns, to be honest. […] You've got more volumes to deal with. More people, even more properties to renovate. One property affecting another" – Lynne, Coedkernew

186."…rural Britain […] I suppose they're probably the most affected areas, because they're going to be cared about less to prevent issues, and I suppose I think of places like Boscastle that got massive floodings. And they were pretty rural" – Anthony, Bristol

187."I personally feel a bit safer in a city and I feel that if I'm in a city more is being done about it. And I think you're less at risk. I think people are less likely to let stuff happen to a city than they are happen to a little Victorian coastal town." – George, Portishead

Quote Box 32: Perceived rural and urban vulnerability, PPP1

Mitigation and adaptation measures

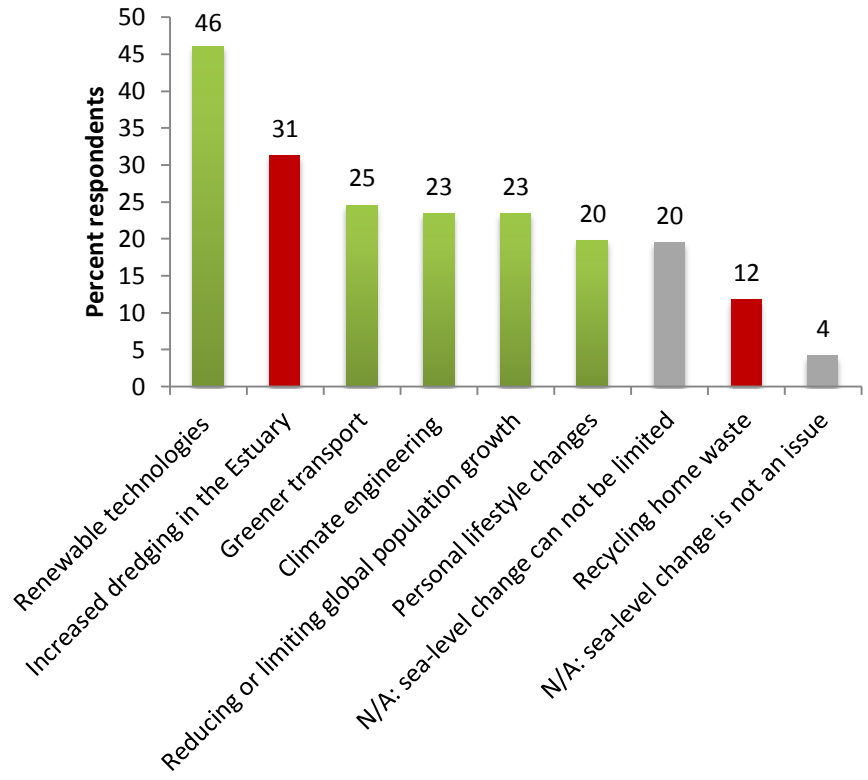


Figure 47: Perceived effectiveness of mitigation measures, PPP2

Percent of respondents selecting item as one of the three most effective ways of limiting the amount of SLR on the Severn Estuary. Red bars indicate measures that are deemed to be the least 2 effective measures (N=358).

The survey item addressing mitigation measures (Q15) was not a true/false item so cannot easily be compared to the expert model. It is also possible that responses contain an element of preference, despite the question being prefaced with "regardless of which you prefer...". However,

some conclusions may be drawn from the responses. Most notably, 31% of respondents thought that increasing dredging in the estuary would be amongst the three most effective measures in limiting the amount of sea-level rise there (Figure 47). Although dredging can affect waves, tidal currents and sediment deposition (Tillin, Houghton, Saunders, Drabble, & Hull, 2011), I am not aware of any direct impacts of dredging on average sea levels. Also, 12% rank recycling home waste amongst the top three, echoing previous research (e.g. Lowe et al., 2006; Read et al., 1994) showing that recycling is consistently cited as a key mitigation measure, when its effect is small compared to other measures.

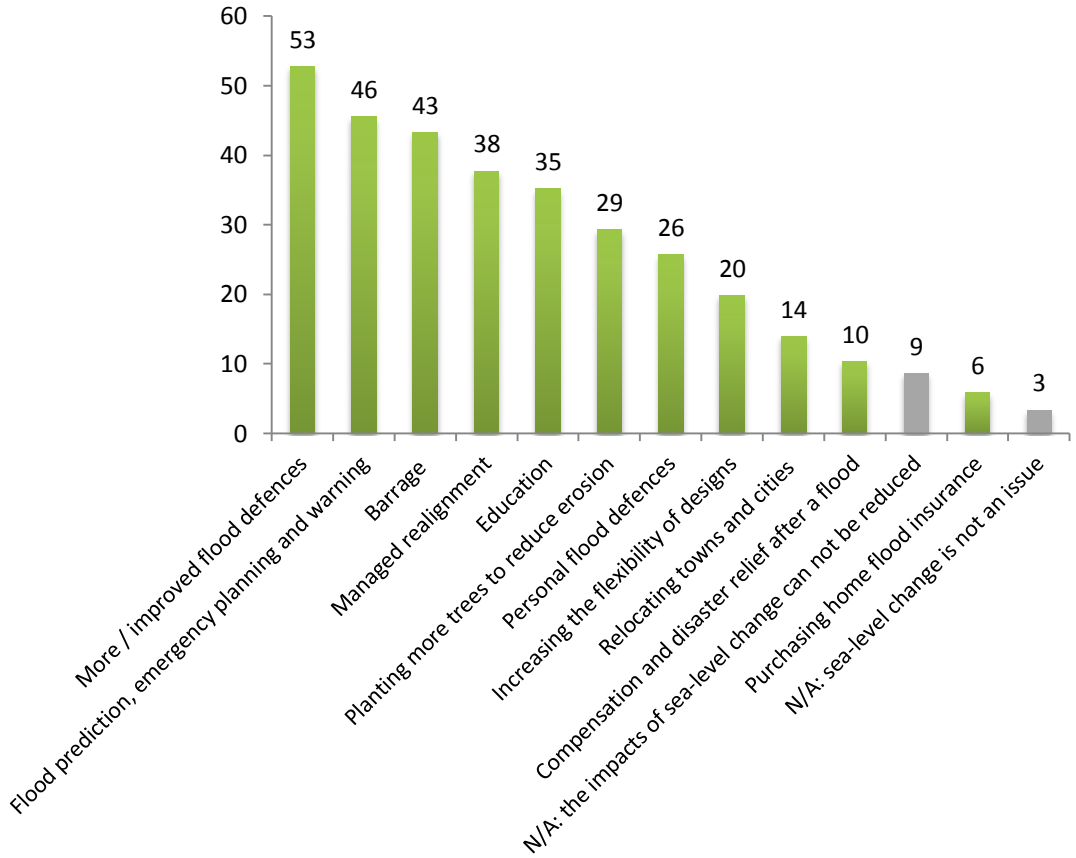


Figure 48: Perceived effectiveness of adaptation measures, PPP2

Percent of respondents selecting item as one of the five most effective ways of reducing the impacts of SLR on the Severn Estuary (N=358).

The survey item addressing adaptation measures (Q16) was also not a true/false item, but instead asked about the effectiveness of different measures (Figure 48). It cannot be directly compared with the expert model because effectiveness was not explicitly included in EPP. PPP2 findings support PPP1 findings, which showed that flood defences were the most salient adaptation measure for interviewees (Figure 43). A barrage (55% salience) and flood warnings (25%) were also discussed during interviews, and were high on the list of most effective measures from survey

respondents (Figure 48). The measure deemed fourth most effective by PPP2 respondents was managed realignment. Overall salience of managed realignment during the PPP1 stage was relatively low at 15%. However, for some interview respondents it was a particularly salient issue, and constituted a large proportion of their interview session. Managed realignment is a controversial issue on the Severn Estuary, and an emotive subject for some interviewees, as discussed in section 7.3.3.

7.2.4 Projections of sea-level change

In line with previous research that shows the public expect sea levels to rise in future, (Akerlof, 2012; CLAMER, 2011a), the majority of PPP2 respondents thought that sea levels on the Severn Estuary will rise between now and 2050, 2100 and 2200 (Figure 49). Having said this, interview and survey results both showed that some participants thought that sea levels might *fall* between now and 2050, 2100 and 2200 (Figure 49, Quote Box 33). PPP1 participants were generally unsure of how *much* SLC is expected in future (Quote Box 33). Some estimates were in the right 'ballpark' range of between a few inches and a few feet (Anthony, Fred), but many were not aware of the broad order of magnitude expected by experts (Christine, Darren, Ellen, Paul).

188."I don't know. Feet, a few feet? Three feet?" – Anthony

189."But its mean levels to rise, is it half a metre in 100 years, or a metre in 100 years. But I certainly know that sea level has gone up and down tens of metres if not one or two hundred metres in geological timescales" – Fred

190."I've no idea [laughs] [...] I mean I mustn't assume its rising, must I. It could be rising, it could be falling" – Christine

191."I wouldn't have a clue" – Darren

192."I've got no idea, and I wouldn't even guess" – Ellen

193."I can't tell. I mean you can't tell without measurement" – Betty

194."I could pluck three feet out of the air out of the air or 30 feet and I have no idea. No idea" – Paul

Quote Box 33: Public uncertainty in SLC projections, PPP1

The uncertainty expressed by PPP1 participants was echoed by PPP2 survey results, which showed a broad range of opinion. Two survey questions, framed in different ways, asked about future SLC. Question 2 consisted of three simple sliders representing sea-level rise and fall (significant, moderate, slight or no change) by 2050, 2100 and 2200. Question 5 listed five amounts of SLC and asked participants to state the likelihood of each on a seven point scale from very unlikely to very

likely. The results from these questions are shown in Figure 49 and Figure 51 (Q2) and Figure 50 (Q5).

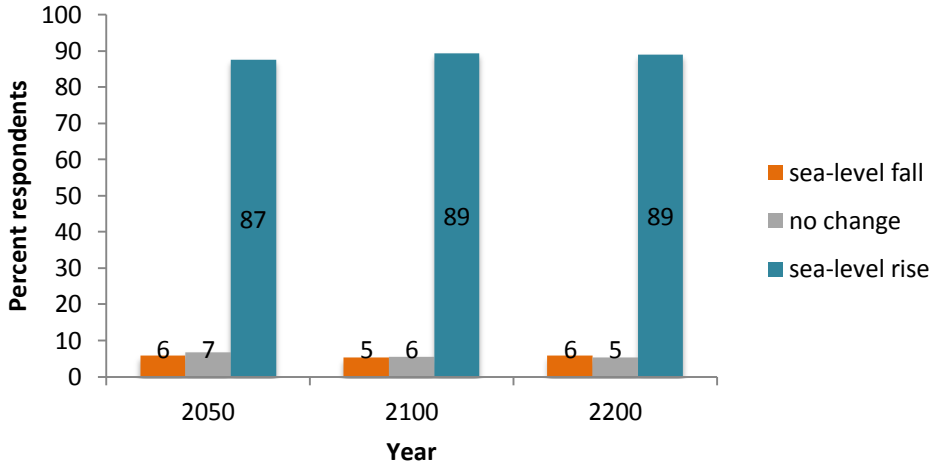


Figure 49: Perceived sea-level rise or fall for 2050, 2100 and 2100, PPP2

Percent respondents who believe sea levels will fall, stay the same, or rise by 2050, 2100 and 2200 (Q2: Move the sliders to show roughly how much you think sea levels are likely to rise or fall by the years shown, compared with today)

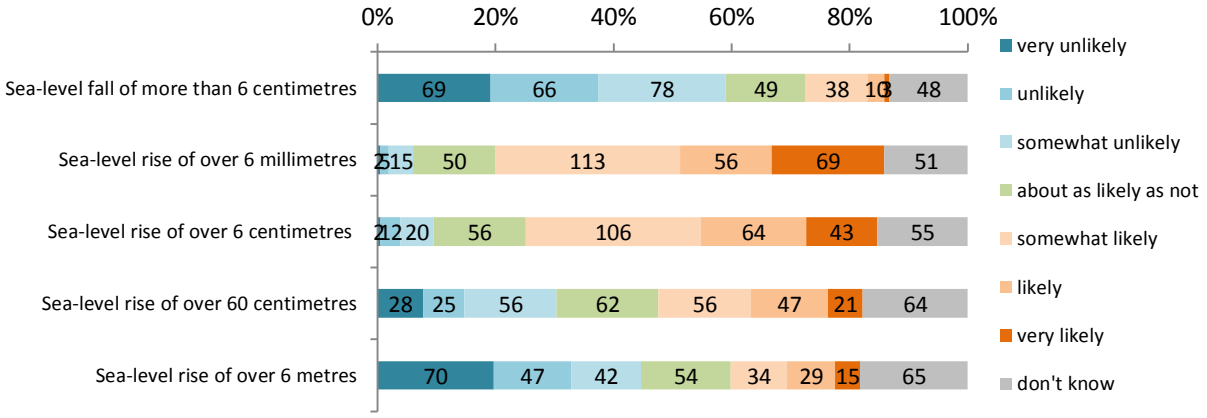


Figure 50: Perceived likelihood of sea-level change magnitudes by 2100, PPP2

By frequency of respondents (Q5: Please indicate whether you think the following amounts of sea-level change on the Severn Estuary are likely or unlikely by the year 2100, relative to today)

Results show that most participants think that sea-level fall is unlikely. The majority think that sea-level rise of more than 6mm is likely by 2100 (Figure 50), but as projections become more extreme, uncertainty increases as shown by the increasing 'don't know' responses (grey). Perceived likelihoods also decrease as the magnitude of SLC increases. Once the suggested SLR reaches

60cm[79] public responses are ambivalent: 35% think that SLR over 60cm is likely (somewhat likely, likely or very likely), while 30% think it is unlikely (somewhat unlikely, unlikely, or very unlikely). When the SLR estimate reaches six metres by 2100 (deemed very unlikely by experts), 22% of PPP2 respondents still think the magnitude is likely (somewhat likely, likely or very likely). This reflects the PPP1 finding that while some participants tend to know there will be a rise, some have "no idea" of its magnitude (Ellen).

Figure 49 shows that just 5% of respondents believe sea levels will fall between now and 2100 when asked to indicate their beliefs on a sliding scale. However, when the question is framed as perceived likelihoods on a Likert scale (Q5, Figure 50), 14% respondents thought that more than 6cm of sea-level fall was likely (somewhat likely, likely or very likely). The way in which questions are structured and worded is known to affect answers (Oppenheim, 1996). In this case, bias may have been due to one format encouraging respondents to express a general trend rather than exact amounts, due to acquiescence bias in question Q5, due to a greater range of attitude expression in Q2, or perhaps due to misreading questions.

Comparison of public and expert sea-level change estimates

The uncertainty expressed by PPP1 and PPP2 participants regarding future SLC is unsurprising considering the expert uncertainty in future projections (Chapter 4). As noted by Expert James, "If we as the scientific community and the engineering community that are involved in looking at these things can't make up our mind what the risk is and how it's going to change, how on earth do we communicate that to the wider public?"

Figure 51 shows the responses to PPP2-Q2 plotted as box plots. As with expert results, the plots show that while mean and median estimates of future SLC are all positive (i.e. on average respondents believed that sea levels will rise), there is a wide variation in estimates for all epochs, with the variability in projections increasing for longer time periods (denoted by wider ranges and variance between percentiles). Unlike expert projections however, the average responses indicate a gradual increase in sea-levels over time (denoted by the stepwise increase in estimates over 2050, 2100 and 2200). Expert's projections, as shown in Figure 52, tended to show a spreading out of estimates over time, indicating that rates of SLR in 2200 will be more extreme. The expert projections unsurprisingly better reflect the scientific literature, which predicts that rates of SLR will increase (Nicholls, 2011). However, it should be remembered that the expert and public questions were framed differently, and explicit values were not obtained from public participants.

[79] IPCC's Fourth Assessment Report (AR4) estimates global mean SLR of 18cm to 59cm (model-based range for six emissions scenarios, compared to 1980-1999) at the end of the 21st Century (IPCC, 2007), but these estimates are thought to be too low (Nicholls et al., 2011b; Rahmstorf et al., 2012). EPP median estimates of sea-level rise (compared to the 2011 level) ranged from 20cm to 100cm in the year 2100.

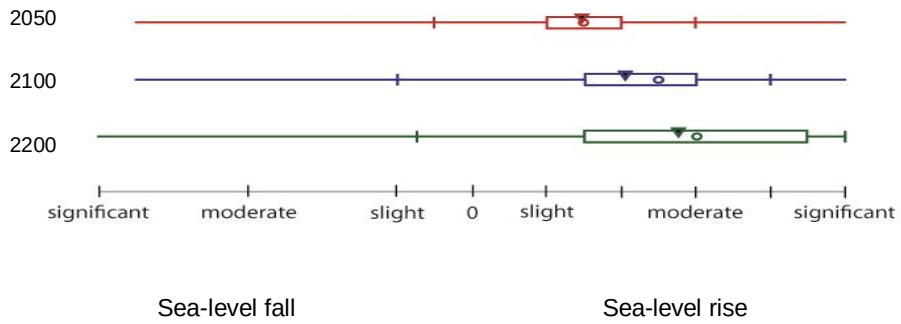


Figure 51: Public SLC projections expressed as box plots, PPP2

The plots summarise public responses to the question "Move the sliders to show roughly how much you think sea-levels are likely to rise or fall by the years shown, compared with today" for 2050 (red), 2100 (blue) and 2200 (green). Vertical tick marks indicate 90% percentiles, and boxes denote 50% percentiles. Open circles indicate medians, solid triangles indicate means.

Figure 52: Example expert SLC projection: box plots, EPP

Sandra's elicited relative SLC on the Severn Estuary in 2050 (red), 2100 (blue) and 2200 (green). Vertical tick marks indicate 90% confidence intervals, and boxes denote 50% confidence intervals. Open circles indicate medians, solid triangles indicate 'best estimates' (value chosen if the expert were to bet money on it). Question marks show where no absolute maximum or minimum was stated, and dashed lines show where no explicit probability or very low probabilities ($1/10^5$ to $1/10^9$) were estimated.

7.2.5 Sea-level change as a threat

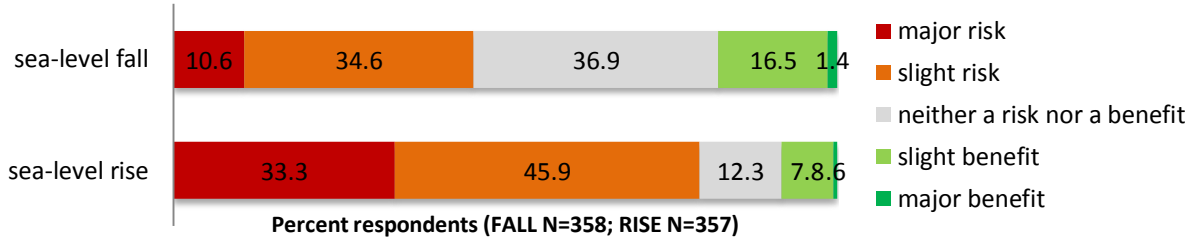


Figure 53: Perception of SLC risk versus benefit, PPP2

Q3&4: Do you think sea-level rise / fall would be an overall risk or an overall benefit to the Severn Estuary?

As shown in Figure 53, SLR is perceived to be an overall risk by most survey respondents (79%), while 8% think SLR poses an overall benefit. As Carolan (2010) laments, survey data do not provide the underlying reasons for such answers. But PPP1 interviewees' responses may shed some light on this. PPP1 respondents alluded to potential benefits of SLR including an increase in habitats, increased fertility of farmland due to flooding, increased viability of shipping and more power from a Severn Estuary barrage. Opinion is more divided over whether sea-level fall would be a risk or

benefit[80]. Quote Box 34 shows that the perception of how *much* SLC constitutes a threat varied among PPP1 participants with some participants believing a few inches would cause problems, and others not.

195. "I can imagine that just a small rise could cause a devastation" – Betty

196. "Well a foot, I don't know whether that's quite a sizable change really, I would have thought" – Jessica

197. "Obviously a foot is quite a lot, and three feet would be an awful lot. A metre would be an awful lot in 100 years [...] Whereas one inch is, you can probably cope with, 18 inches, if it went 18 inches one extreme in 50 years, that's obviously a major problem" – Steve

198. "They do say, having read another article somewhere, but I can't remember all of it, that that would be catastrophic. Even a rise of two or three inches. But for the life of me I can't see why" – Lynne

199. "If someone said to me it's going to rise a metre a year, or its going to rise a metre every 100 years, I'd probably say 'oh right, ok' [laughs]" – George

Quote Box 34: SLC as perceived threat, PPP1

7.2.6 Sea-level change terminology

The terminology used by public interviewees is an important consideration for communication design. Many participants used concepts and terms in ways consistent with the expert model (e.g. see Steve's responses in section 6.1.5), but the terms tides, tidal surge and tsunami were sometimes confused or misused (Table 16).

Term	Description and examples
Tides, tidal surge	Tides, tidal surges and sea levels were conflated by some respondents: *"I suppose if we all rode more places on our bicycle, less CO2, less greenhouse gases, less risk of global warming affecting the tides" – Yasmine* *"I know that the Severn Estuary has got a very big tidal surge, I think the biggest one is somewhere in Canada" – Anthony*
Tsunamis	Tsunamis were sometimes confused with weather events (perhaps typhoons): *"I can't imagine us having bad enough weather to have a tsunami" – Yasmine* *"I thought [tsunamis] were a south sort of Asian phenomena, to do with very intense cyclonic weather, the sort of we wouldn't get here. You never know I suppose" – Jessica* This association between the climate and tsunamis was also made by 2% of respondents in the European CLAMER survey (CLAMER, 2011b).

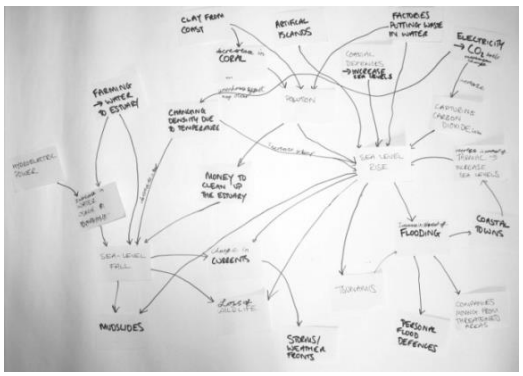
Table 16: Confused terminology, PPP1

[80] The utility of these data is limited because risks such as SLC can be perceived as being both high risk *and* high benefit, and this question did not allow for expression of this.

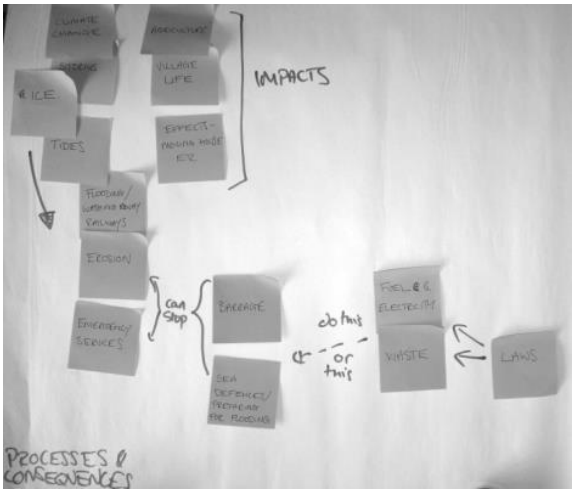
7.2.7 The structure of public beliefs about sea-level change

This section discusses the ways in which the public might structure a threat appraisal. Participants' cognitive maps are shown below, apart from Fred's because he did not have time to draw one. It should be noted that maps bear an imprint of the interview process, reflecting the structured approach to map creation[81].

Henry



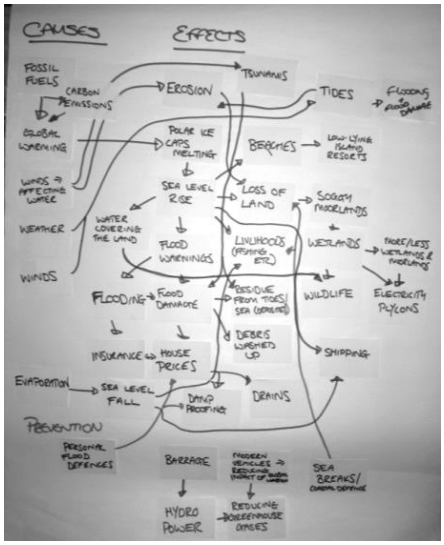
Owain



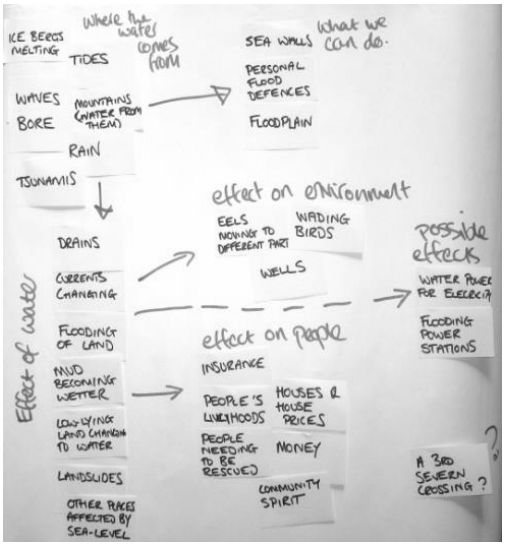
Paul

Glenda

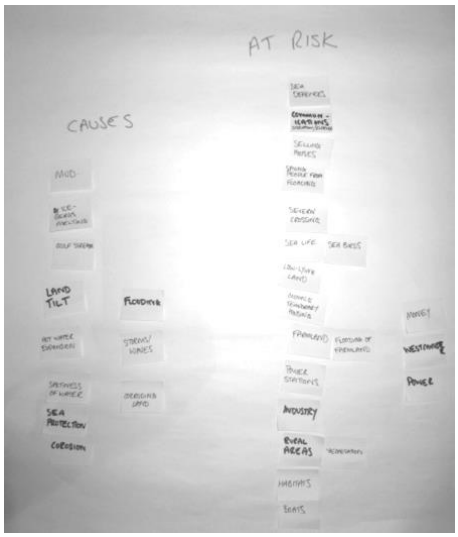
[81] Maps were influenced by the following instructions and suggestions during the mapping task. Participants were asked to put the post-its on a large piece of paper in a way that shows how they come together in their mind. It was suggested that they might want to group them or draw lines between those that are most related to each other, and participants were provided with a set of post-its (consisting of their own comments) as an aid. They were also shown an example of a map illustrating the factors that I think influence whether I get sunburnt.



Yasmine

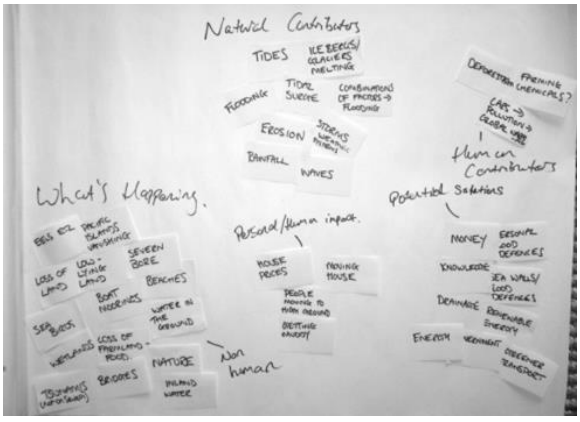


Karen



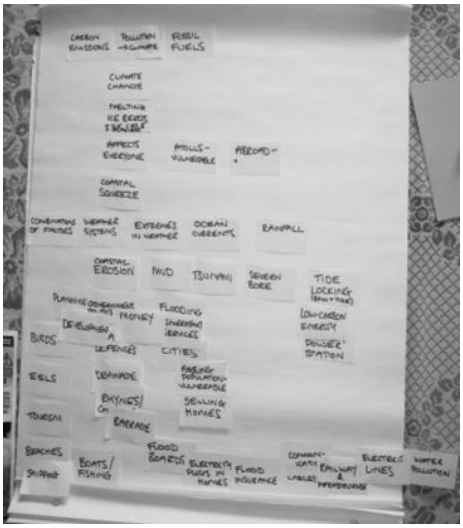
Anthony

Ellen

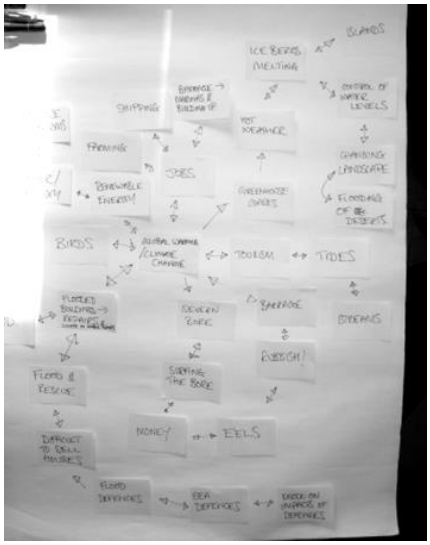


George

Jessica

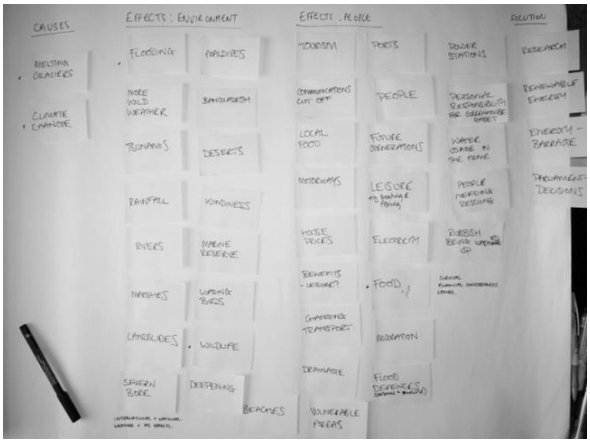


Steve

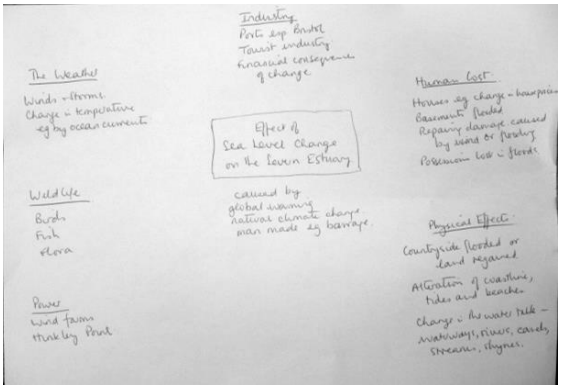


Lee

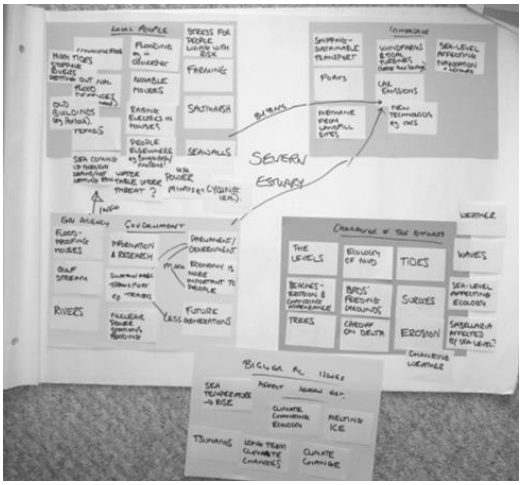
Lynne



Ruby



Christine



Laura

Terry

Betty

Darren

Figure 54: Cognitive maps, PPP1.

The cognitive maps illustrate that participants structure themes in different ways. While Glenda, Anthony, George, Ruby, Christine, Darren and Terry solely grouped items, Paul, Karen, Ellen, Jessica, Lynne, Laura, Betty and Steve[82] grouped them and drew arrows between the groups. Owain, Yasmine, Lee and Henry drew arrows between the themes themselves, creating intricate webs of ideas. The ways in which themes were grouped varied. Delineations included 'impacts and processes', 'big impacts and lesser impacts', and the most common, 'cause and effect' (also referred to as contributors and impacts). This common way of thinking about the issue was probably in part due to the structure of the earlier mental models interview, which asked about causes and effects. But it may point to a potential way of communicating the risks in future. During pilot interviews, one participant noted that he was only interested in impacts, *not* causes, implying that a clear distinction between the two is important (Quote Box 35).

[82] Steve talked through his links rather than drawing them.

200. "Who cares why it is happening? What is happening. [...] I don't care if the tides change; only if it affects me. So that's what is most important" – Victor, pilot interviews.

Quote Box 35: Preferences for cause and effect information, PPP1 pilot participant Victor

Induction

Quote 201 below shows that to create his 'pseudo-attitude' (Terpstra et al., 2009), Owain pieced together his fragmentary beliefs into a 'theory' of how SLC works. This is induction; a 'bottom-up' approach to reasoning whereby specific observations are generalised into broader theories: I've only seen white swans, and therefore I reason that all swans are white[83]. Induction is a valid mode of reasoning, but can cause problems when the premises are wrong, as shown in Quote Box 36. Yasmine's prior perception of moorland as being on high ground, and having heard the levels referred to as moors, led her to induce that sea-levels are falling. Having seen glaciers melting in Norway and not having heard of thermal expansion, Glenda inferred that because glaciers are 'relatively small', sea-level rise 'wouldn't be more than an inch or so'.

201. "I've taken my knowledge and applied it to this, and then just gone 'well if that's going to happen, I know this will happen because I know this, therefore such and such will happen or could happen if we expand it and take it on in exactly the same line its going'" – Owain

202. "Has it risen much in the past 20 years, does anyone know? because I don't know" [Moderator: do you think it would have done?] probably, if they say the ice caps are going then you'd imagine so, but I don't know by how much. It's got a lot of place to fill up, hasn't it?" - Darren

203. "Well I know there's quite a lot of moorland and stuff under the bridges, so presumably historically, the sea levels would have been a lot higher. Which kind of implies they're going down and out. A little bit, which is funny because when they say about global warming, and everyone goes on about sea levels rising" – Yasmine

204. "It's a very large world, and the glaciers are relatively small. So I would expect it wouldn't be more than an inch or so. It wouldn't be feet, I don't think" – Glenda

Quote Box 36: Inducing erroneous inferences, PPP1

Reflection

Quote Box 37 illustrates the importance of reflection and deliberation in thinking about SLC. As discussed in section 2.4.1, the degree of deliberation in decision making can vary due to the familiarity of the subject, the ease at which beliefs and ideas come to mind, and the time available

[83] Deduction, on the other hand works from the more general to the specific: All swans are white; there is a swan next door; therefore the swan next door is white.

for reflection. For example, even on a timescale of a minute or two, allowing Henry to reflect on his initial comments about tsunamis meant he could search his mental contents for more information and to retract his initial statement (Quote 207).

205. "I hadn't really thought about the whole thing before" – Christine

206. "I don't think about this very often, if ever. To be honest" – Darren

207. "Tsunami's the result of weather change caused by global warming, which is the reason why the sea level's going to rise in the Severn Estuary. So- is that ok?" [Moderator: That's fine. So it is linked but not really in the Severn Estuary. Is that right?] "It's linked- I mean- the sea-level rise in the Severn Estuary is caused by global effects, as are tsunamis. So global warming's- actually, I say tsunamis, I suppose technically they're not really. They're caused by earthquakes really. [...] I've talked myself out of that one" – Henry

208. "What's that, is that the nuclear thing at- [Facilitator: yes]. That's the worry about sea change, thinking about it" - Lynne

Quote Box 37: Reflective mental models, PPP1

7.3 Coping appraisal

7.3.1 Responsibility for sea-level change

Responsibility for the causes and impacts of SLC

Consistent with previous studies, participants located the responsibility for causing and mitigating climate change with others (Darier & Schüle, 1999; Lorenzoni et al., 2007). While nature could not be blamed because "when the sea comes to get you it doesn't mean anything by it" (Ellen), PPP1 participants laid the blame for SLC with a variety of actors including corporations, rich people, city people, ignorant people, fat Americans, mindless behaviour, government, aristocracy, wasteful people, western greed, China, short-termism and other countries (Quote Box 38). More specific factors such as badgers (Terry, Quote 214) were also cited for specific risks (flooding), echoing previous research that shows factors such as blocked drains, local development and road resurfacing are seen as primary causes of flooding (Harvatt et al., 2011; Whitmarsh, 2008). Such factors might indeed be to blame; indeed, local knowledge of such issues should not be underestimated, as discussed in earlier.

209. "People will forgive the river because it's there, it does its thing, we choose to live here, if it comes to join us occasionally, well you just have to learn to live with it. But what people DON'T like around here, [...] is **fresh water flooding runoff from Thornbury**" – Fred

210. "I feel fairly easy about more natural events, aware that SLC is not a natural- there is a bigger issue around that, but when the sea comes to get you, it doesn't mean anything by it"- Ellen

211. "**Giant international conglomerate**, contributing greatly to all sorts of dreadful things, including no-doubt, sea level, because they're just evil" – Betty

212. "I could tell you about methane from cattle that are being put on the land that's being chopped down by **people wanting more hamburgers in America** to make them fatter and fatter when they don't need it" [...] "I'm going to put that in the middle" [Facilitator, reading from cognitive map: **western greed unsustainable**] "that's my key driver" – Henry

213. "I don't see our country necessarily as one of the worst polluters in the world. [...] I don't really blame our country. [...] **Other countries** are far worse than us. So I blame them [laughs] before I blame us" – Lee

214. "The tide came in where you're sat, what was it '82, 3? [...] the bank breached down here. But that only breached because of **badgers.** Because they were in the second bank, the outer bank, which is only when the tide comes over once in a blue moon, it saves it, and where these badgers had their hole, pshw" – Terry

Quote Box 38: Perceived responsibility for causing SLC and flooding, PPP1

Responsibility for responding to SLC

As shown above, the responsibility for the *causes* of SLC lay with a number of actors, but notably not with individuals. Results indicate that the responsibility for responding to the *impacts* of SLC follows a similar theme. Figure 55 shows PPP2 responses to the question "regardless of which you prefer, which of the following measures do you feel would be most effective in reducing the impacts of sea-level rise on the Severn Estuary?" The graph has been colour coded to reflect those measures for which the main responsibilities lie with the government (blue), the individual (orange) or have mixed responsibility (green). It shows that adaptation measures deemed to be most effective tend to be those for which the government is responsible. This may be because these measures are indeed perceived to be most effective on account of being on a larger scale. But this may again reflect an externalisation of responsibility, as shown in Quote Box 39.

215. [Facilitator: if there are problems around the Severn Estuary, do you think the government will help people?] "Yes I think it will. It's quite a rich area, isn't it? Gloucester and all these places. So yes, I think so, because I think the government generally does" – Betty

216. "You could call that on the parliament, and cause them to change it that way [sic]. Decrees and stuff like that"- Owain

217. "You'd go on to the government, who would then have their contingency plans" – Lynne

218. "Are they going to harness it [build a barrage] - you know, somehow protect us?" [...] "I would hope that they're putting something in place, [...] They must be doing something, I assume" - Ruby

Quote Box 39: Perceived governmental responsibility, PPP1

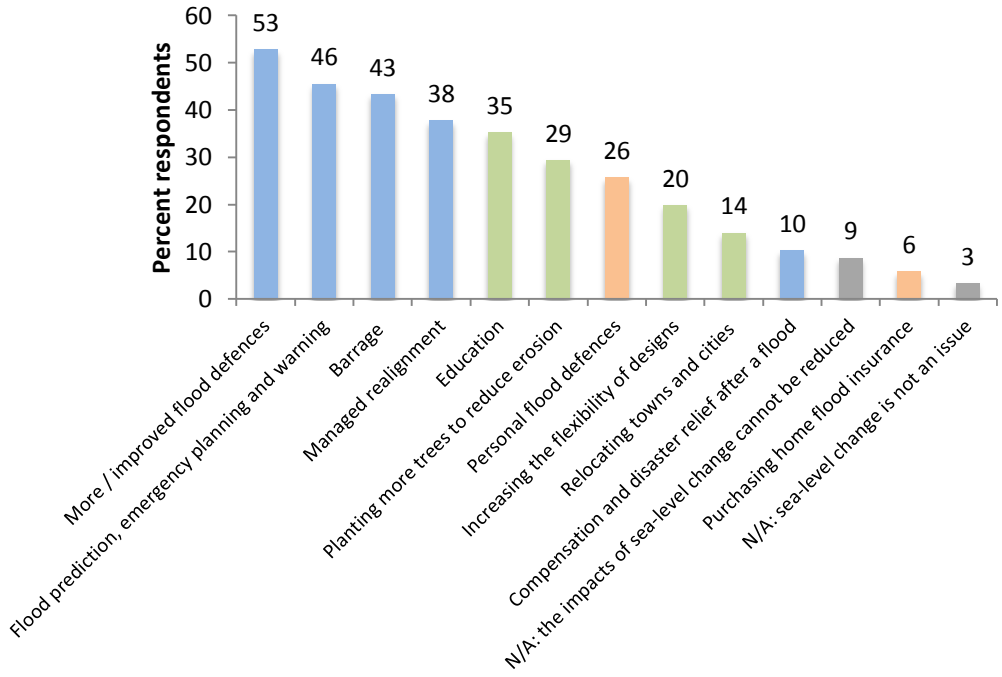


Figure 55: Perceived effectiveness of adaptation measures, PPP2

Percent respondents selecting item as one of the five most effective ways of reducing the impacts of SLR on the Severn Estuary (N=358). Colour coded: blue = governmental responsibility, green = mixed responsibility, orange = personal responsibility

PPP2 results lend support to PPP1 responses. While 37% and 32% of survey respondents thought that it is their responsibility to act to reduce the causes of SLC and the impacts of SLC respectively, a higher percentage of respondents (61%) thought it is the government's responsibility to protect residents from flooding (Figure 56). Findings are consistent with previous research that shows that responsibility for climate change, SLR and flooding tends to be ascribed to powerful external

actors[84]. One reason for placing the responsibility with other parties might be to reduce cognitive dissonance (Festinger, 1962). Another might be that the public does not feel that they are personally *able* to make a difference. It is to this lack of self-efficacy that we now turn.

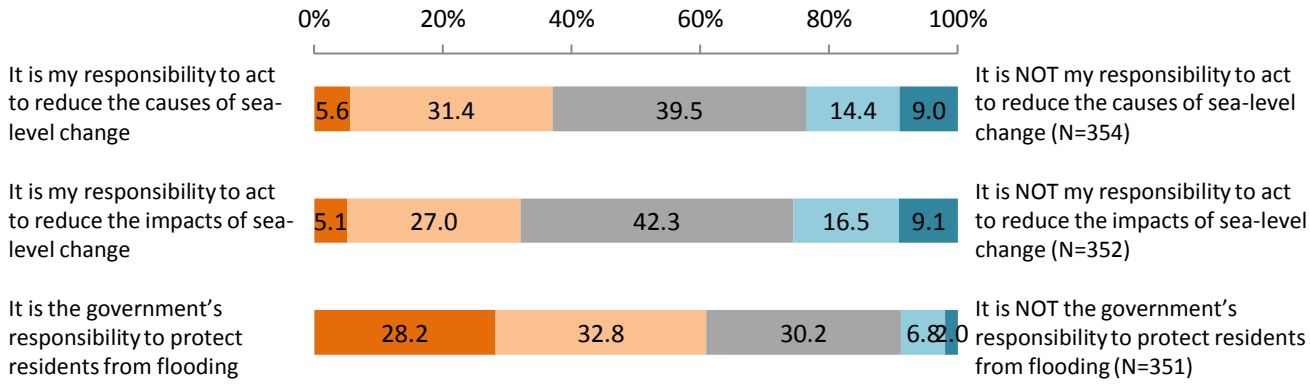


Figure 56: Perceived responsibility for action on causes and impacts of SLC, PPP2

7.3.2 Self-efficacy

A common theme among PPP1 participants was that SLR is happening and we cannot do much about it, that power is in the hands of few, and most of us are helpless, as shown in Quote Box 40. This indicates feelings of low self-efficacy in relation to SLC, a finding supported by PPP2 results (Figure 57), which show that on average, people feel unable to do much about the causes and consequences of SLC.

219. "The two issues of SLC are either global warming, which **we can't do much about**; or man-made, because there is talk that the Severn barrage, [which] would alter the sea level at Weston" - Christine

220. "I do find this kind of stuff quite frightening, and I do- it makes you feel **powerless** as well, doesn't it" [...]"I think 'well what can I really do, myself?' as you know, one human being" - Ruby

221. "There's certainly **nothing I can do personally**, it's happening" – Fred

222. "There's no point in worrying about the big picture, is there. Because there's **not a lot you can do about the big picture**" – Glenda

223. "As for the sea level rising, **there's not a lot we can do about it**" – Lee

Quote Box 40: Perceived efficacy, PPP1

[84] Transferral of responsibility for climate change has been found in the UK and Australia (Poortinga et al., 2006) (Capstick et al., 2013; Pidgeon, 2012; Ryan et al., 2012; Spence et al., 2010b). It has also be found for groundwater flooding (Kreibich et al., 2009) and for SLR (Harvatt et al., 2011).

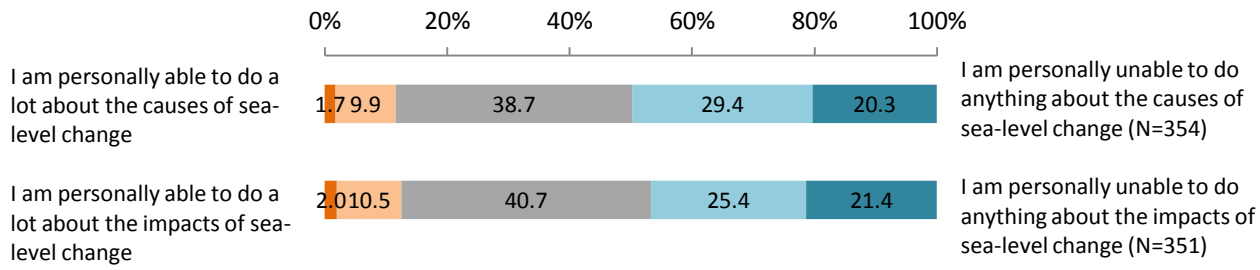


Figure 57: Perceived personal efficacy for causes and impacts of SLC, PPP2

7.3.3 Trust

Although the responsibility of responding to SLC is generally transferred to powerful external actors, at the same time, these actors are not fully trusted to carry out these responsibilities effectively, as shown in Figure 58 and Quote Box 41. PPP1 interviewees particularly voiced distrust in the government and the Environment Agency, consistent with other research that shows low levels of trust in the agencies perceived to be responsible for flood and SLR protection and information dissemination (Evans et al., 2012; Fernandez-Bilbao, 2012).

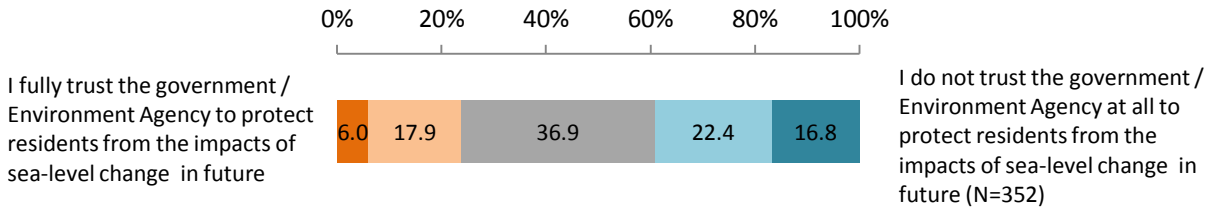


Figure 58: Public trust in the government / Environment Agency, PPP2

224. "This is not going to end well for South Gloucestershire. And even less well if the Environment Agency don't do their thing with their locks, which they sometimes do fail to do" – Ellen

225. "I can't believe that no one's working on a solution. But they probably aren't. But, you know, at the end of the day, they're telling people to get in a supply of sand bags. Well I'm sorry, that was pre first war. And that is still the solution to people who might have floods coming through. Move your furniture to the top floor, and put a load of sand bags on your doorstep. Well, I mean. It's just ridiculous really" [...]"Parliament, I don't know. I don't think it's up to much really. We're relying on people who don't know what they're doing" - Lynne

226. "Management retreat [sic] [is an] absolute disgrace, it is abysmal what they've done over there. [...] It's the way it's all been done behind our backs, and not up front. I just, I can't put it into words. It's an absolute disgrace. [...] absolutely annoys me, the way that people can come and just walk all over you" – Terry

227. "The time it took to build that small [local] bridge, [...] I mean, you know, are we ever going to get a [Severn Estuary] barrage built? [laughs]" – Ruby

Quote Box 41: Distrust in government and agencies, PPP1

Distrust in agencies was accompanied by a perceived unfairness of these agencies' decisions and scepticism over their intentions (Quote Box 42). Some PPP1 participants voiced dissatisfaction with the Environment Agency, whom they felt had not been upfront with regard to managed realignment and had been acting with a lack of evidence for SLC to justify their actions. There was also dissatisfaction surrounding perceived double standards regarding floodplain planning (Steve, Terry, Fred) and flood mapping (Lynne). These results suggest that the public has a 'critical trust' (Poortinga & Pidgeon, 2003; Walls, Pidgeon, Weyman, & Horlick-Jones, 2004) in the agencies perceived to be responsible for acting on SLC, whereby they do not distrust the agencies outright, but do not uncritically accept their decisions either; instead viewing them with an amount of scepticism.

228. "It seems to me that there's this plan, that if you're a big developer and you argue your case, you can get away with it, but they try and stop the small people trying to make a living, actually making it very difficult for us" - Steve

229. "Weston were going to do all the air field, which is on a floodplain, so it's alright in Weston. But if one little bloke wants to build a house out Kingston for his son, he got to have it right in the neck" – Terry

230. "When we built the garage, we were initially refused planning permission, [by the Environment Agency...] because they complained, said we were consuming the floodplain.[...] well what was interesting was when it comes to build a new nuclear power station, three buildings of 6 reactors, the fact that that will consume 100 acres of floodplain doesn't matter. Hence come back to my point about there's rules for us little people, but when it comes to big businesses like that 'oh no this is judged by different criteria'" - Fred

231. "I don't think this publishing of the flood map or anything has helped me. Because they've actually crystallised my fears and put it in writing so somebody else can actually pick up on it. And you know, it could stop us selling our house if something happened [...] I don't think they've helped anybody except the insurance companies" – Lynne

Quote Box 42: Perceived unfairness and scepticism regarding responsible agencies' decisions, PPP1

A degree of critical (dis)trust in government agencies can be a good thing, and studies show that trust in public flood defences is negatively related to flood preparedness and mitigation (Kellens et al., 2013), and flood defence improvements contribute to low concern (Harvatt et al., 2011). This is important when we consider that these defences sometimes fail; famously during Hurricane Katrina in 2005 (Jonkman, Maaskant, Boyd, & Levitan, 2009) and more locally in Weston-super-Mare. The following story recently ran on the Guardian newspaper website 'There were protests in Weston-super-Mare on the Somerset coast after flooding hit shops and restaurants following a tidal surge. Warnings did not reach the area in time for the storm gates to be closed on a new £29m protection system' (Wainwright, 2012). Having said this, there was also recognition amongst PPP1 interviewees that big events like tsunamis could overpower coastal defences. Indeed, PPP2 survey results showed that respondents tend to think people are *not* well protected by flood defences

around the Estuary. Only 7% of respondents agree that people are currently well protected by flood defences around the Severn Estuary, compared to 50% who do not. (Figure 59). A large proportion (43%) do not know if they are well protected; an unawareness also voiced by Ruby during PPP1 interviews.

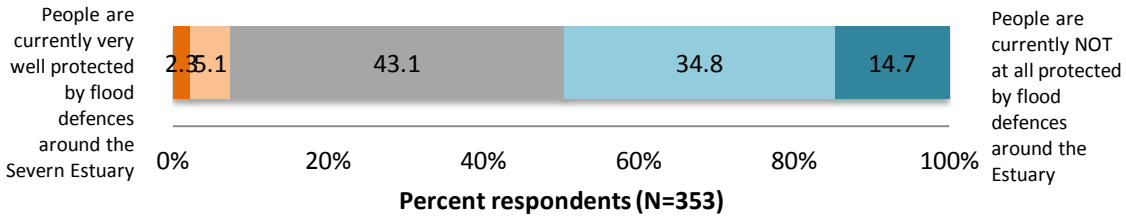


Figure 59: Perceptions of the protection afforded by flood defences, PPP2

(Q18: Please indicate which of these opinions you most agree with...)

7.4 Summary: public risk appraisal of sea-level change

The Severn Estuary public does not feel well informed about SLC, but their perception of how informed they are does not correlate with how much they actually know. SLC is not a highly salient issue, and while mean public understanding of drivers is well aligned with expert perceptions, there is much uncertainty and a number of differences between expert and lay models. Particularly, a number of lay participants believe that most SLR is caused by melting icebergs/sea-ice, that isostatic subsidence is not causing local SLR, that the thinning of the ozone layer causes global SLR, that coastal erosion causes sea levels to fall, that global warming causes increased evaporation, and that isostatic uplift is causing local sea-level fall. Importantly, the salience of thermosteric SLC is low compared to glacio-eustatic SLC.

The most salient physical impacts amongst interviewees are flooding and ecological change. Generally, the public's understanding of physical impacts is well aligned with expert perceptions. There was however much uncertainty regarding freshwater contamination, pollution, and decreased water levels outside of the estuary. The most salient socio-economic impact was damage to homes and property, while indirect impacts such as inconvenience and impacts on health and services were less salient. Individuals expressed few beliefs inconsistent with the expert model regarding socio-economic impacts, but there was some disagreement between experts and the public about potential changes in the viability of shipping and ports, and the impact of SLC on health and wellbeing.

The majority of survey respondents believe that the impacts of SLC will be gradual rather than sudden, perhaps rendering them less prepared for surprises. Generally, public and expert

respondents agree about the areas of the Severn Estuary that are most at risk, but the Vale of Glamorgan was perceived to be at disproportionately high risk by PPP2 respondents. Factors that affect socio-economic sensitivity, such as age and transience, were of low salience (PPP1). Individuals tended to think that rural areas would be worse affected than urban areas, but views were mixed. The main EP differences regarding mitigation responses were that recycling home waste and increasing dredging in the estuary would limit the amount of sea-level rise. Flood defences were the most salient adaptation measures, and were perceived to be the most efficient, followed by flood prediction, emergency planning and warning. Compensation and flood insurance were perceived to be the least effective measures.

Most individuals think that sea levels will rise on the Severn Estuary in future, though some believe that they will fall. Respondents are generally unsure of how much SLC there will be, with many not knowing the broad magnitude of expected change. Like with expert projections, uncertainty increases when public respondents are asked about longer timescales. The perception of how much SLC constitutes a threat varies, but sea-level rise *per se* is generally perceived to be a risk to the Estuary. Participants structure their beliefs about SLC in different ways, but a 'cause and effect' model is common. Induction is used to reason about unfamiliar topics, but can be problematic when the initial premises are wrong. Time to reflect on the issues is shown to be important, raising the possibility that deliberation might be a valuable communications tool.

Respondents tend to place the blame for causing SLC with external parties, and place the responsibility for responding to SLC elsewhere. The transferral of responsibility to others may be related to feelings of low self-efficacy, which are common amongst PPP1 and PPP2 respondents, who tend to feel unable to do anything about the causes or impacts of SLC. However, this transferral or responsibility to other agencies is accompanied by a critical (dis)trust in these agencies: participants do not tend to feel well protected by flood defences, and in some cases agencies are deemed to be acting unfairly in their response to SLC.

8 PUBLIC RESULTS: RESPONSES and RELATIONSHIPS

This chapter has two parts. First, it discusses active responses to SLC such as actions currently being taken to adapt to the risks, and inactive responses such as denial. The chapter then presents and discusses the results of statistical regression analyses (PPP2) on factors influencing SLC risk perceptions, exploring the relationships between various factors pertaining to public perceptions of SLC.

8.1 Introduction

As discussed earlier, the investigation of public perceptions was exploratory and not designed to test any particular model of risk perceptions or behaviour. Individual responses to SLC were not discussed unless they were raised by participants; and this was rare. Thus, analysis of responses is short, consisting of a brief discussion of active responses, followed by a discussion of the inactive responses that emerged during PPP1 interviews (optimism and avoidance). The second part of this chapter investigates the relationships between factors by way of five hierarchical linear regressions carried out on PPP2 data.

8.2 Active responses

Although mention of responses was rare during PPP1, some participants talked about their current active engagement by way of mitigation and adaptation responses (Quote Box 43). Regarding mitigation measures, Ellen and Fred Smith spoke of never using a tumble drier, and Betty talked about her solar water heater, while Lynne and Paul both recycle but recognise that it may not be very effective in reducing climate change. As landowners bordering the Estuary, Steve and Terry are currently involved in adapting to SLC through potentially surrendering their land for managed realignment, though they are opposed to the scale and nature of these measures. Henry has considered moving away from the area but has not, while Christine and Fred may consider moving if and when they perceive the threat to be great enough, which they currently do not.

Quote Box 43: Active responses to SLC, PPP1

232. "I lived in a mobile home with three children under the age of 6, and I still didn't have a tumble drier. It's quite possible for everybody else to live without a tumble drier. They use up masses of electricity" - Fred

233. "I have a water heater on my roof - a solar water thing" – Betty

234. "One tries to do all the recycling and all things like that, I mean, you think 'what difference does this make' but, I don't know, but it must make some" - Paul

235. "Putting out the recycling. I don't really believe it's going to make a blind bit of difference, but I'm neurotic about it. You know, I separate it all. And I don't have a problem with doing it, although I'd like a few less bins, but deep down, I don't think we're going to achieve anything by doing all that" - Lynne

236. "It seems a bit unfair in some ways that they needed the extra land here [for managed realignment] rather than spread out along the whole length of the estuary" – Steve

Continued…

Continued…

237. "I've agreed to let them have some management retreat [on my land, sic]" [...] "Over Kingston, what they've done management retreat, a small bit, it's an absolute disgrace, it is abysmal what they've done over there" – Terry

238. "My wife and I have given reasonably serious thought to whether we should move" - Henry

239. "I have done the calculation and the answer is don't panic yet. [...] at the moment I think it's a gamble worth taking. Because this ticks so many other boxes of you know, living here and bringing up the family and stuff like that, but it's far too big for my wife and I once the kids have gone, so as long as you know, we can sell up, and- so, and to be honest I will certainly give more than a passing thought to where my next house is located with regard to flooding, but not just sea-level rise" - Fred

240. "If sea levels were definitely rising, like if they rose an inch last year and were forecast to rise another inch this year, I suppose we might think about selling our house and moving a bit higher up" - Christine

Quote Box 43: Active responses to SLC, PPP1

8.3 Inactive responses

8.3.1 Optimism

In Quote Box 21 (worldviews, section 6.2.3), PPP1 participants alluded to the belief that 'technology will save us': Owain thought that we'll soon be able to 'intervene' with climate change, and Jessica felt that engineers 'can deal with' SLC. This is technological optimism: the belief that technological improvements will sustain life as human populations soar (Basiago, 1994). Indeed, optimism was explicit and implied throughout PPP1 interviews, and was also noted during expert interviews (Quote Box 5). While Ellen was not optimistic, other PPP1 participants talked both implicitly and explicitly about being optimistic (Quote Box 44).

241. "Do you think we might have pulled ourselves together by then and done something about it? Because there are things that people can do, aren't there?" [Facilitator: do you think we might have done?] "What, given a few hundred years? Oh please, yes. Yes, **you do hope so**" [...] "I'm an **optimistic** sort of person" – Glenda

242. "I think there is warming happening, but I don't know if it's- I'm hoping it's going to be cancelled out by the next little ice age. Possibility, maybe. **Trying to think positively**" - Jessica

243. "I don't see it being a big permanent rise, not really. I have to say. I'm probably **a bit half full person** really" – Lynne

244. "**I don't think it will just all be alright**" – Ellen

Quote Box 44: Optimism, PPP1

8.3.2 Avoidance

A number of interviewees talked about trying not to think about the issues of SLC and climate change because they find them depressing, frightening, worrying, too big to deal with or because they make them angry (Quote Box 45). Ruby and Ellen talked about deliberately not watching films and programmes about climate change. This 'active silencing of risk' has also been noted in relation to nuclear risks (Bickerstaff & Simmons, 2009). While such avoidance may provide a way of coping with SLR and flood risks (Harvatt et al., 2011), the implications are that they will not be ameliorated by mitigation and adaptation.

245. "I do think [SLC] is a worry. The more I talk about it the more I start thinking- because I do try and put it to the back of my mind" – Lynne

246. "I deliberately didn't watch [Inconvenient Truth] because I do find this kind of stuff quite frightening. It makes you feel powerless as well" – Ruby

247. "I do find the whole environmental thing a bit- well more than a bit depressing. I do try not to think about it too much. I avoid watching television programs about it. It makes me angry, I think it's a bit hopeless to be honest. Um the broader issue, you know" [...] "most people know but they shut their eyes and stick their fingers in their ears and it's too big for people to deal with" – Ellen

248. "The whole thing fills me with horror when I think of people living in Thailand and these very low places where they are living just up off the sea [...] and how devastating that's going to be. I almost can't think about that" – Betty

Quote Box 45: Avoidance, PPP1

8.4 Summary: public responses to sea-level change

While public responses to SLC were not actively investigated during this study, some participants were already engaging with the issue (voluntarily or involuntarily) or were thinking about doing so. However, participants also exhibited inactive responses with optimistic biases and avoidance, both of which may act as barrier to active engagement (Lorenzoni et al., 2007). Indeed, the relationships between factors discussed in the next section indicate that these inactive responses may affect risk appraisals.

8.5 Relationships between factors

8.5.1 Introduction

This thesis has shown that knowledge is only one aspect of SLC perceptions on the Severn Estuary. This section presents the results of five regression analyses on PPP2 survey results that investigate how some of the many factors might influence perceptions. The first regressions investigate the factors that might influence knowledge about SLC on the Severn Estuary: the regression presented in section 8.5.2 investigates predictors of knowledge about expected magnitudes, causes, impacts and mitigation measures of SLC on the Estuary; the three regressions presented in 8.5.3 further investigate one aspect of this knowledge, that is, the factors that predict how much future SLC is expected. The fifth regression investigates concern, which has been shown to be one of many factors that might influence SLC perceptions (section 8.5.4). The main rationale for including variables in these regressions was that they emerged from the PPP1 interviews as potentially important factors in public SLC perceptions. However, it was not possible to include all of the factors because statistical power is lost when too many independent variables are included relative to the sample size (Field, 2009). Therefore variables had to be selected based on the literature and specific ideas emerging from the findings. The hypotheses and rationales for including each variable are provided for each regression, before regression results are presented and discussed.

Each regression table includes the individual contribution of the variable if all other effects are held constant (B), the standard error (Std. Error), the standardised importance of each predictor (Beta), and the variance inflation statistic (VIF). The VIF is a measure of multicollinearity, indicating whether an independent variable has a strong linear relationship with any of the other independent variables[85]. VIF > 10 indicates high collinearity (Myers, 1990). The VIF statistics reported in the regression tables indicate that multicollinearity is not of concern in the models (the largest VIF is 3.374). Furthermore, when the regression results are compared with independent correlations (Appendix N), we find that the direction of the relationships and relative importance of the independent variables are consistent, indicating that multicollinearity has not affected the relative importance of the predictors in the regression model.

[85] Multicollinearity occurs where there is a strong linear relationship between two or more independent variables. While low levels of collinearity pose little threat to model estimates, high levels make it difficult to assess the individual importance of predictors, limit the size of the variance explained by the model (because two predictors are accounting for much of the same variance in the dependent variable), and affect the models ability to make 'trustworthy' predictions (Field, 2009; Myers, 1990).

8.5.2 Predictors of sea-level change knowledge

Table 17 lists the independent variables entered into a hierarchical linear regression on total knowledge scores (the summed knowledge scores for magnitudes, causes, physical impacts, social impacts and mitigation measures). The table shows the variable, why it was included, the hypothesis, and an indication of whether the hypothesis is supported (S), partially supported (~S) or unsupported (US) by regression results (Sup. column).

Table 17: Independent variables included in regression analysis on knowledge scores

Variable	Rationale	Hypothesis	Sup.
Education and science education	PPP1 results (6.1.5) indicated that perceptions of SLC are strongly influenced by experience and cannot be expected to arise from education alone. Indeed, other research indicates that higher educational levels do not necessarily mean higher scientific literacy (Hargreaves et al., 2003).	Education level does not predict knowledge about SLC.	S
SLC Scepticism	Although in general scepticism about SLC was shown to be quite low around the Severn Estuary, a number of PPP1 and PPP2 respondents expressed sceptical beliefs, which have been shown in previous research to be a barrier towards climate change engagement (Lorenzoni et al., 2007). While knowledge has been found to be a poor predictor of scepticism (Whitmarsh, 2011), I was interested if there was a relationship in the other direction (i.e. if scepticism could predict knowledge). I expected scepticism to predict lower knowledge scores due to lower information seeking behaviour among sceptical individuals.	SLC scepticism predicts lower knowledge scores.	S
Concern	Concern was found to vary amongst PPP1 and PPP2 respondents. It is hypothesised that concerned individuals may engage in more information seeking behaviour, or that greater knowledge could lead to increased concern.	Higher concern predicts higher knowledge scores.	S
Efficacy	Kahlor and Rosenthal (2009) found that worry did not correlate with knowledge, but suggest that this may be the result of suppressor effects of self-efficacy. Efficacy was therefore included as a potential moderator.	Efficacy interacts with other variables to affect knowledge scores.	S
Age	Of PPP1 interviewees, those with the highest mental model completeness scores tended to be older (Steve 53, Ellen 45, and Laura 63), while those with the lowest scores tended to be younger (Yasmine 30, Owain 18, and Darren 28), perhaps because they have had more time to learn about SLC from experience.	Older groups are more knowledgeable.	~S
Gender	Research indicates that women may have greater scientific knowledge of climate change than men do (McCright, 2010).	Women have higher knowledge scores.	US

Continued…

Table 17 continued

Variable	Rationale	Hypothesis	Sup.
Experience of flooding or erosion	Section 6.1.5 discussed the importance of direct experience in SLC perceptions around the Estuary. Previous research indicates that experience of a risk may predict greater awareness or knowledge of the risk (Wagner, 2007; Zsamboky et al., 2011).	Experience of flooding or erosion predicts higher knowledge scores.	US
Time lived around estuary	PPP1 results indicate the importance of direct experience in SLC perceptions (6.1.5), and research suggests that individuals with greater risk experience know more about that risk (Wagner, 2007; Zsamboky et al., 2011). It is hypothesised that people who have had more time to experience SLC around the estuary may know more about it.	People who have lived around the Estuary for longer have higher knowledge scores	US
Rurality	PPP1 interviewees living in rural areas (e.g. Steve, Ellen, Fred) tended to talk more knowledgably about SLC than those living in more urban areas, drawing on their local knowledge of the issues (section 6.1.5).	People living in rural environments have higher knowledge scores	US
Distance from estuary	PPP1 interviewees indicated that local knowledge was an important factor influencing risk perceptions (6.1.5). It is hypothesised that this local knowledge might be related to how far an individual lives from the Estuary.	People living closer to the Severn Estuary know more about SLC	S
Relationship with local community	Section 6.1.5 discussed the importance of vicarious experience and local knowledge in SLC perceptions. It is hypothesised that such influences may be greater in individuals with close links to the local community.	Individuals with a close relationship with the local community have higher knowledge scores	US
Relationship with the Severn Estuary	Section 6.1.5 discussed the importance of experience, which may be expected to be greater amongst those with a closer relationship with the Severn Estuary. For example, some PPP1 participants gained local knowledge through working as part of or alongside organisations such as the drainage board or the Environment Agency.	Individuals with a close relationship with the Severn Estuary have higher knowledge scores	US

Table 17: Independent variables included in regression analysis on knowledge scores

Sup. column shows whether hypothesis is supported (S), partially supported (~S) or unsupported (US) by regression results.

	B	Std. Error	Beta	VIF
Step 1				
(Constant)	23.988	3.180		
Education (no formal quals/GCSE)				
A-Level or higher	-.535	.926	**-.035n.s.**	1.159
Science education (no formal quals/GCSE)				
A-Level or higher	-.278	.838	**-.020n.s.**	1.147
SLC Scepticism	-.449	.136	**-.319****	2.929
Concern scale (5 items)	.412	.186	**.221***	3.109
Efficacy (causes)	-.867	.416	**-.130***	1.208
Step 2: age & gender				
(Constant)	23.587	3.251		
Education (no formal quals/GCSE)				
A-Level or higher	-.213	.913	**-.014 n.s.**	1.191
Science education (no formal quals/GCSE)				
A-Level or higher	-.398	.831	**-.029 n.s.**	1.188
SLC Scepticism	-.413	.135	**-.293****	3.014
Concern (5 items)	.410	.184	**.220***	3.209
Efficacy (causes)	-.463	.418	**-.069 n.s.**	1.286
Age (45-54)				
17-24	-3.449	1.920	**-.108 n.s.**	1.194
25-34	-2.698	1.192	**-.151***	1.465
35-44	-1.876	1.109	**-.112 n.s.**	1.440
55-64	1.518	1.068	**.096 n.s.**	1.500
65-74	-.352	1.363	**-.016 n.s.**	1.285
75+	-2.122	2.994	**-.041 n.s.**	1.087
Gender (men)				
women	-.750	.763	**-.057 n.s.**	1.094
Step 3: local knowledge factors				
(Constant)	24.762	3.616		
Education (no formal quals/GCSE)				
A-Level or higher	-.351	.912	**-.023 n.s.**	1.267
Science education (no formal quals/GCSE)				
A-Level or higher	-.552	.814	**-.040 n.s.**	1.216
SLC Scepticism	-.415	.132	**-.294****	3.107
Concern (5 items)	.365	.183	**.196***	3.374
Efficacy (causes)	-.571	.429	**-.085 n.s.**	0.446
Age (45-54)				
17-24	-2.227	2.014	**-.070 n.s.**	1.401
25-34	-2.110	1.243	**-.118 n.s.**	1.700
35-44	-1.581	1.140	**-.094 n.s.**	1.623
55-64	1.181	1.059	**.074 n.s.**	1.571
65-74	-.207	1.354	**-.009 n.s.**	1.353
75+	-3.038	2.981	**-.058 n.s.**	1.149
Gender (men)				
women	-.623	.762	**-.047 n.s.**	1.164
Experience of flooding or erosion				
property damage	.888	2.573	**.021 n.s.**	1.273
disruption	1.128	1.083	**.065 n.s.**	1.391
Affected others	1.552	.802	**.117 n.s.**	1.277
Time lived around estuary (0-10yrs)				
>10yrs	.720	.960	**.046 n.s.**	1.324
Rurality (urban)				
Rural	.782	.964	**.046 n.s.**	1.140
Distance from estuary	-1.049	.423	**-.150***	1.280
Relationship with local community	.210	.273	**.049 n.s.**	1.417
Relationship with the Severn Estuary	.052	.293	**.012 n.s.**	1.669
R^2 = .24 for Step 1 (p<.001), ΔR^2 = .06 for Step 2 (p<.01), ΔR^2 = .07 for Step 3 (p<.01), n.s. non-significant , *p<.05, **p<.01, ***p<.001				

Table 18: Hierarchical linear regression for factors predicting knowledge of SLC on the Estuary, PPP2

Table 18 shows the results of the hierarchical linear regression on total knowledge scores, with significant predictors shown in red. The model predicts 36% of the variance in knowledge scores (R^2 =.36). The greatest proportion of variance is predicted by SLC scepticism, with lower levels of scepticism predicting higher knowledge scores. We cannot draw conclusions about the causality of relationships, but there are a few potential interpretations. Firstly, we could speculate that knowing more about SLC leads to less scepticism. Alternatively, less sceptical individuals could engage in more information seeking behaviour, thus increasing their knowledge of the issue. Or people who have higher knowledge about SLC could also happen to have less scepticism due to a third variable such as the media sources they use. Finally, the relationship could be due to the ways in which sceptical people answer knowledge questions: they might *know* as much about the science as less sceptical individuals do, but be less inclined to *agree* with it. This final suggestion is supported by research by (Tobler et al., 2012), which shows that while greater knowledge of climate change causes, consequences and actions predict lower scepticism, higher physical knowledge (e.g. about methane, the ozone layer and plant respiration) predicts *higher* scepticism. In contrast to Tobler et al's (2012) research however, educational level does not predict knowledge scores.

After scepticism, concern is the next largest predictor of knowledge scores, with those who are more concerned scoring higher on the knowledge scale. This finding supports previous work that shows that individuals with better knowledge of Alpine flash floods and landslides express greater fear about the hazards (Wagner, 2007). Again, we cannot infer causality, but more knowledge about SLC *could* lead to more concern, or more concerned individuals *could* engage in more information seeking behaviour. Or again, the relationship could be due to some other factor that correlates with both.

Efficacy is a significant predictor in Step 1, but becomes insignificant when age and gender are added to the model. When efficacy was omitted from earlier analyses (not reported here) concern was not a significant predictor of knowledge scores. This indicates an interaction effect where concern only predicts higher knowledge scores when efficacy is included in the regression (low efficacy + high concern predicts higher knowledge scores). This supports findings by Kahlor and Rosenthal (2009) who suggested that their finding that worry did not correlate with knowledge may have been the result of suppressor effects of self-efficacy. Again, we cannot infer causality, but one explanation may be that individuals who know more about SLC also believe that they cannot do much about it and feel more concerned.

In Step 2, age and gender improve the model, increasing the R^2 value to .30 (i.e. predicting 30% of variance). However, gender is not a significant predictor of knowledge. Middle-aged groups are most knowledgeable, but the only significant effect is for 25-34 year olds, who have lower knowledge scores than the reference group (45-54 year olds) in step 2 – but this effect is made insignificant when local knowledge factors are included in Step 3. This may be due to an interaction

effect regarding the demographics of those living closest to/farthest from the estuary. 'Local knowledge factors' (experience of flooding/erosion, time lived around estuary, rurality, distance from estuary, relationship with the local community and relationship with the Severn Estuary) improve the model, increasing the R^2 value to .36. Distance from the estuary is a significant predictor, with increased distance from the estuary predicting lower knowledge scores. While this could be interpreted as a function of having increased experience of SLC or flooding in the past, and therefore knowing more about it, this does not seem to be the case as flood experience does not predict knowledge. It may be that distance from the estuary increases knowledge through other means, perhaps through increasing general knowledge of the estuary and its processes, facilitating a better reflective and inductive understanding of SLC (section 7.2.7). Or perhaps people who know more about the Estuary (and the sea in general) have a fondness for sea views and are more likely to live close to it.

8.5.3 Predictors of sea-level change magnitude estimates

Table 19 shows the independent variables included in three hierarchical linear regressions on PPP2 Question 2 responses. For this question, participants were asked to move the sliders to show roughly how much they think sea levels are likely to rise or fall by 2050, 2100 and 2200, compared with today. The sliders marked a scale from 'significant sea-level fall' to 'significant sea-level rise'. Each position on the slider was assigned an integer between -10 (significant sea-level fall) and 10 (significant sea-level rise), but these numbers were not visible to participants (see Appendix J for survey layout). Results therefore provide a general gauge of expected SLC magnitudes rather than numerical estimates. Regression analyses for three dependent variables (DVs) are presented. The first is SLC magnitudes in 2050, and the second is SLC magnitudes in 2200. The third DV is the *difference* between 2050 and 2200 estimates. The purpose of this third DV is to investigate what might predict larger perceived increases in SLC over this time period. EPP qualitative analyses indicated that the ways in which experts thought about the future (e.g. futuristic repertoires and optimism) may affect the extremity of their estimates (Section 4.2.3), so this regression model was designed to investigate whether this might be the case for PPP2 participants.

As mentioned in 8.5.1, statistical power is jeopardised if too many independent variables are included in a regression (Field, 2009). It is therefore necessary to select variables for an analyses rather than including all of the variables that might possibly be related to the dependent variable. The independent variables in this regression were different from those used in the knowledge regression above because EPP and PPP1 analyses indicated that additional variables (optimism and futuristic difference) might be important for perceptions of the magnitude of future SLC. It was therefore necessary to remove some of the other variables from the first analyses. I chose to remove 'local knowledge factors' (experience of flooding/erosion, time lived around estuary,

rurality, distance from estuary, relationship with the local community and relationship with the Severn Estuary) because I had no theoretical reason to include them.

Variable	Rationale	Hypothesis	Sup.
Knowledge	Those with greater knowledge of the causes of SLC will have a greater understanding of processes, time lags and so on, meaning they will predict greater rises over longer time periods.	Knowledge, particularly of SLC causes, predicts greater differences in SLC estimates (2050-2200)	S
Gender	Gender has been found to influence interpretations of climate change and SLC risks (CLAMER, 2011a; Hamilton, 2008; Shuckburgh et al., 2012). This variable was included to see if gender would predict SLC magnitude estimates.	This variable was included for exploratory reasons. There was no hypothesis.	-
Optimism	EPP qualitative analyses indicated that optimism may affect expert probability judgements, and PPP1 results suggested that optimism may also be a factor in public responses.	Higher optimism predicts lower SLR estimates.	S
SLC scepticism	Although scepticism about SLC was shown to be generally low around the Severn Estuary, a number of PPP1 and PPP2 respondents expressed sceptical beliefs. It is hypothesised that sceptical individuals are less likely to believe that SLC will occur in future, or that the amount of SLC has been exaggerated, thus leading to lower SLC estimates.	Sceptics predict lower SLR.	S
Concern	PPP1 interviews showed that concern varied amongst individuals. This variable was included to investigate whether this level of concern may be related with the amounts of SLC that people expect.	Those who are more concerned about SLC predict greater SLC.	US
Futuristic Difference	EPP qualitative analyses indicated that the ways in which experts thought about the future may affect the extremity of their estimates (Section 4.2.3). PPP1 results indicate that members of the public may also subscribe to varying future repertoires, and it is hypothesised that these repertoires may affect how much SLC they think may occur.	People who subscribe to futuristic difference think greater amounts of SLC are possible.	US
Efficacy	A number of PPP1 participants felt that people could not do much to stop SLR. It is hypothesised that such beliefs may lead to higher levels of expected SLC.	Higher perceived self efficacy predicts more extreme SLC estimates	US

Table 19: Independent variables included in regression analysis on SLC estimates
Sup. column shows whether the hypothesis is supported (S), partially supported (~S) or unsupported (US) by regression results.

Table 20 shows the results of the three hierarchical linear regressions on public SLC estimates[86]. The analyses suggest that knowledge, optimism and scepticism explain some variance in public SLC projections, but the explained variance is small. The low explained variance could be partly a function of the survey question, which allowed for attitudinal ambiguity, or could be simply

[86] Note that the results may not be generalisable to the wider population because post-hoc tests suggest that the models may violate the assumptions of heteroscedasiticity and non-linearity.

because the dependent variables are noisy (contain a lot of error). The predictive power of the model for 2050 estimates is particularly low, with an R2 of .06 for Step 1 ($p<.01$) and an insignificant increase of just .03 (n.s.) for Step 2. Step 2 of the 2050 model had no significant predictors at all, with knowledge of social impacts and mitigation measures predicting greater SLC estimates in Step 1 only.

More variance was explained for 2200 estimates, with the model predicting 14% of variance in Step 1 (knowledge factors), increasing by a further 7% when gender, optimism, scepticism, concern, futuristic difference and efficacy are included. Knowledge of causes and social impacts predict greater SLC estimates for 2200. Optimism and scepticism both predict lower SLC magnitude estimates. This is consistent with the hypotheses that more optimistic people expect lower SLR, and that more sceptical people predict lower SLR.

Optimism and scepticism also predict smaller differences in SLC magnitude estimates between 2050 and 2200. In other words, those people who are more optimistic expect the difference in SLC between 2050 and 2200 to be less extreme than those who are less optimistic. The most significant predictor for this regression is scepticism (*standardised* $\beta = -.26$), with higher scepticism about SLC predicting smaller differences in SLC magnitude estimates between 2050 and 2200. Knowledge of causes and social impacts predict a greater difference in SLC estimates between 2050 and 2200. The relationship between causal knowledge and predictions could feasibly be because people who know more about the causes of SLC are more equipped to construct an attitude about the extremity of SLC through inducing from their mental model. For example, if an individual knew about thermal expansion of SLC, they might predict higher amounts of SLC than someone whose mental model is restricted to the melting of ice-caps, as Glenda's was: "it's a very large world, and the glaciers are relatively small. So I would expect it wouldn't be more than an inch or so. It wouldn't be feet, I don't think". Indeed, though the effect size is small, there is a significant positive correlation between believing the comment 'climate change causes the water in the oceans to expand as it gets warmer and therefore causes global SLR' is true, and predicting a higher magnitude of SLC in 2200 ($r_s = .13$, $p<.05$). This reiterates the importance of getting the basic premises of inductive reasoning right (section 7.2.7). The relationship between social impacts knowledge and magnitudes of expected SLC *could* be because individuals who expect more SLR expect more social impacts, so have beliefs more consistent with the expert model (and thus a higher social impacts knowledge score). Gender and age are not significant predictors of SLC magnitude estimates.

Independent Variable (predictor)	Dependent Variable: SLC by 2050 (N=312) **R^2 = .06 for Step 1 (p<.01), ΔR^2 = .03 for Step 2 (n.s.)**				Dependent Variable: SLC by 2200 (N=314) **R^2 = .14 for Step 1 (p<.001), ΔR^2 = .07 for Step 2 (p<.01)**				Dependent Variable: difference in SLC (2200-2050) (N=307) **R^2 = .12 for Step 1 (p<.001), ΔR^2 = .06 for Step 2 (p<.01)**			
	B	Std. Error	**Beta**	VIF	B	Std. Error	**Beta**	VIF	B	Std. Error	**Beta**	VIF
Step 1												
(Constant)	1.649	.425			1.253	.678			-.372	.495		
Knowledge												
Causes	.011	.008	**.092**	1.439	.032	.013	**.156***	1.421	.021	.009	**.147***	1.442
Physical impacts	-.009	.007	**-.093**	1.769	-.003	.012	**-.020**	1.771	.007	.008	**.061**	1.790
Social impacts	.013	.006	**.137***	1.512	.037	.010	**.236*****	1.536	.022	.007	**.202****	1.532
Mitigation	.012	.004	**.178****	1.045	.016	.006	**.140***	1.049	.004	.004	**.046**	1.047
Step 2												
(Constant)	.833	1.457			3.224	2.254			2.466	1.667		
Knowledge												
Causes	.012	.008	**.097**	1.589	.031	.013	**.153***	1.554	.019	.010	**.135***	1.588
Physical impacts	-.011	.007	**-.108**	1.814	-.006	.011	**-.035**	1.822	.006	.008	**.048**	1.833
Social impacts	.010	.007	**.106**	1.641	.026	.010	**.167***	1.671	.015	.007	**.139***	1.666
Mitigation	.007	.004	**.111**	1.208	.006	.006	**.051**	1.208	-.002	.005	**-.025**	1.204
Gender (male)												
Female	-.142	.283	**-.029**	1.099	.421	.443	**.051**	1.097	.465	.325	**.079**	1.098
Optimism	-.001	.032	**-.002**	1.060	-.099	.050	**-.104#**	1.073	-.090	.037	**-.133***	1.063
SLC Scepticism	-.009	.051	**-.017**	3.119	-.163	.080	**-.187***	3.181	-.160	.058	**-.256****	3.143
Concern (5 items)	.098	.068	**.141**	3.149	.046	.106	**.040**	3.237	-.054	.078	**-.065**	3.169
Futuristic Difference	-.036	.078	**-.027**	1.170	.034	.121	**.016**	1.173	.063	.089	**.040**	1.174
Efficacy												
Causes	.130	.227	**.052**	2.745	.161	.342	**.039**	2.594	.012	.261	**.004**	2.767
Impacts	.130	.221	**.053**	2.665	.240	.334	**.059**	2.573	.137	.256	**.046**	2.713
n.s. non-significant , *p<.05, **p<.01, ***p<.001, #p=.05												

Table 20: Hierarchical linear regression for factors predicting SLC estimates, PPP2

For 2050, 2200 and for the difference between 2050 and 2200 estimate (data from Q2, sliding scale from 'significant sea-level fall' to 'significant sea-level rise')

8.5.4 Predictors of concern about sea-level change

The final regression was carried out to further investigate the findings of section 6.2.1, which showed that concern about SLC varies amongst individuals, is a multifaceted issue, and is potentially related with other factors. Table 21 explains why each independent variable was included and whether the hypotheses were supported or unsupported (Sup. column). The dependent variable was a 5-item concern scale, consisting of the following items from the PPP2 survey: Q3 SLR as an overall risk; Q6 self-reported concern about SLC; Q9 SLC as a problem; Q9 too much fuss made about SLC (reversed); and Q18 SLC is frightening. See Appendix M for more details of scale construction and reliability.

Table 21: Independent variables included in regression analysis on SLC concern

Variable	Rationale	Hypothesis	Sup.
SLC scepticism	Although scepticism about SLC is generally low around the Severn Estuary, a number of PPP1 and PPP2 participants expressed sceptical beliefs. Investigating how scepticism about SLC relates with other factors is important because it has been shown to be a barrier towards engagement with climate change (Lorenzoni et al., 2007). It is hypothesised that low scepticism predicts low concern.	SLC 'sceptics' are less concerned about SLC.	S
Knowledge	Some research suggests that individuals who know more about particular aspects of climate change are more concerned about climate change and/or SLR (Bord et al., 2000; Hamilton, Cutler, & Schaefer, 2012; Tobler et al., 2012).	Individuals with greater SLC knowledge are more concerned.	~S
Experience of flooding or erosion	Research shows that experiences of specific local risks such as flooding are influential in determining perceptions of these risks (Baumann & Sims, 1978; Harvatt et al., 2011; Siegrist & Gutscher, 2006; Spence et al., 2011; Wagner, 2007).	Experience of flooding or erosion predicts greater concern.	US
Relationship with nature	Values and worldviews have been shown to be important predictors of climate change concern (e.g. Bellamy & Hulme, 2011; Brulle, Carmichael, & Jenkins, 2012; Tansey & O'Riordan, 1999). Worldviews volunteered during PPP1 interviews indicated that such views were important factors in SLC risk perceptions. While space constraints in the PPP2 survey rendered a detailed investigation of values unfeasible, a simple diagrammatic 'relationship with nature scale' was included to investigate this relationship.	People who feel close to nature are more concerned about SLC.	S
Education	Research indicates that education level may predict views about marine resource use and ocean-related environmental issues in Maine, USA (Safford & Hamilton, 2012), so this variable was included to see whether it might also predict concern about SLC on the Severn Estuary.	Exploratory only; no hypothesis	-

Continued…

Table 21 continued

Variable	Rationale	Hypothesis	Sup.
Age	Some research finds that older people are less concerned about or perceive a lower threat from climate change (Kellstedt et al., 2008; Whitmarsh, 2008) and SLR (Hamilton, 2008) than young people. However, other research indicates that concern about climate change *per se* and marine climate change issues in particular is lowest among younger people (CLAMER, 2011a; Shuckburgh et al., 2012). Capstick et al. (2013) found that it is the oldest and youngest groups who are least concerned about climate change.	The oldest and youngest groups are least concerned about SLC	~S
Gender	Women have been found to be more concerned than men about climate change (McCright, 2010; Shuckburgh et al., 2012), marine climate change issues (CLAMER, 2011a) and SLR (Hamilton, 2008).	Women are more concerned about SLC	US
Expected SLC by 2200	This variable was included to investigate whether levels of concern may be related with the amounts of SLC that people expect.	Those who predict greater amounts of SLC by 2200 are more concerned	US
Perception of SLC having sudden impacts	Interviews indicated that PPP1 participants perceive SLC and its impacts to be gradual rather than sudden; a finding which was supported by PPP2 results. It was included in this regression because it was hypothesised that the perception of slow and gradual processes would lead to lower concern.	Those who think SLC will have sudden impacts are more concerned	S
Optimism	Some PPP1 participants expressed their level of concern as being a function of their character. The optimism bias causes people to believe that they are less likely to experience negative events, and more likely to experience positive events than other people are (Weinstein, 1980); thus optimistic individuals may be less likely to think SLC will be of a concern to them.	Optimistic individuals are less concerned about SLC	US
Futuristic difference	PPP1 respondents expressed views aligned both with futuristic difference and historic determinist repertoires. It is hypothesised that those who subscribe to a futuristic difference repertoire may be more likely to think about extreme scenarios and thus have a greater concern about SLC.	Those who subscribe to futuristic difference are more concerned about SLC.	US

Table 21: Independent variables included in regression analysis on SLC concern

Sup. column shows whether hypothesis is supported (S), partially supported (~S) or unsupported (US) by regression results.

The model predicts 70% of variance in concern levels. Most of this variance is explained by SLC scepticism (*standardised* β = -.71), with more sceptical individuals expressing less concern. This is unsurprising (why be concerned about something that you are not sure exists?) and is supported

by other research that shows sceptical people perceive lower risks from climate change than non-sceptical people (Poortinga et al., 2011).

The effect of knowledge about SLC on concern is small, with higher knowledge of social impacts predicting higher concern. Results from other surveys pertaining to the relationship between knowledge and concern are mixed. Increased knowledge about climate change has been shown to predict higher concern about climate change consequences in polar regions (Hamilton, 2008; Hamilton et al., 2012), but survey research from the USA shows that more informed respondents show less concern for global warming (Kellstedt et al., 2008)[87]. Survey results from Switzerland showed that of all their knowledge subscales, it was knowledge about climate change and its *causes* that were most strongly related to concern, but people who were aware of the possible negative outcomes of climate change did also tend to worry more about it (Tobler et al., 2012). The effects of knowledge may not be straight forward. In studies of public concern about polar issues, ideology was found to polarise responses, with education positively affecting concern amongst liberals and moderates, and negatively affecting concern amongst conservatives (Hamilton, 2008; Hamilton et al., 2012).

A close relationship with nature predicts higher concern. This finding is consistent with research around climate change *per se*, which shows strong environmental values predict increased concern about and engagement with climate change (Kellstedt et al., 2008; Leiserowitz, 2006). This relationship has also been found in studies of energy choices and nuclear power (Corner et al., 2011; Spence, Poortinga, Pidgeon, & Lorenzoni, 2010a), which suggest that concern about climate change is symbolic of more general environmental concern. In this study, there may be interaction effects between 'closeness with nature' and other variables because this variable only becomes a significant predictor in step 2 of the regression. There may also be an interaction effect between age and other variables, as the significance of the relationship associated with different age groups changes in the second step of the regression.

[87] As mentioned earlier, this study investigated the relationship between concern and *self-reported information*, not objectively measured knowledge. This is important considering that in the present study, self-reported informedness and knowledge scores were not related (Section 7.2.1).

	B	SE	Beta	VIF
Step 1				
Constant	14.878	.875		
SLC scepticism	-.569	.033	**-.748*** **	1.469
Knowledge				
magnitude knowledge	.000	.005	**.002n.s.**	1.389
causes knowledge	-.015	.008	**-.084n.s.**	1.668
physical impacts knowledge	.006	.007	**.041n.s.**	2.104
social impacts knowledge	.015	.006	**.110***	1.683
mitigation knowledge	.004	.004	**.040n.s.**	1.221
Experience of flooding or erosion				
Property damage	-.228	.806	**-.011n.s.**	1.231
Disruption	-.362	.388	**-.039n.s.**	1.346
Affected others	.269	.282	**.038n.s.**	1.240
Relationship with nature	.138	.090	**.061n.s.**	1.274
Age (45-54)				
17-24	-.370	.635	**-.024n.s.**	1.394
25-34	-.238	.408	**-.026n.s.**	1.594
35-44	-.073	.397	**-.008n.s.**	1.557
55-64	-.740	.383	**-.086n.s.**	1.551
65-74	-1.046	.505	**-.084***	1.310
75+	-2.095	1.094	**-.073n.s.**	1.153
Education (no formal quals/GCSE)				
A-Level or higher	.269	.307	**.033n.s.**	1.097
Gender (men)				
Women	.214	.272	**.030n.s.**	1.150
Step 2				
Constant	13.590	1.161		
SLC scepticism	-.536	.034	**-.705*** **	1.637
Knowledge				
magnitude knowledge	.000	.005	**.004n.s.**	1.436
causes knowledge	-.013	.008	**-.075n.s.**	1.735
physical impacts knowledge	.006	.007	**.041n.s.**	2.129
social impacts knowledge	.013	.006	**.097***	1.728
mitigation knowledge	.003	.004	**.028n.s.**	1.241
Experience of flooding or erosion				
property damage	-.134	.795	**-.007n.s.**	1.236
disruption	-.362	.383	**-.039n.s.**	1.352
affected others	.254	.279	**.036n.s.**	1.253
Relationship with nature	.198	.092	**.088***	1.376
Age (45-54)				
17-24 age	-.580	.629	**-.038n.s.**	1.411
25-34 age	-.313	.403	**-.035n.s.**	1.606
35-44 age	-.126	.393	**-.014n.s.**	1.572
55-64 age	-.814	.377	**-.094***	1.557
65-74 age	-.884	.501	**-.071n.s.**	1.329
75+ age	-1.940	1.083	**-.068n.s.**	1.166
Education (no formal quals/GCSE)				
A-Level or higher	.343	.306	**.042n.s.**	1.127
Gender (men)				
women	.277	.272	**.039n.s.**	1.188
Expected sea-level change by 2200	.027	.034	**.031n.s.**	1.276
Perception of SLC having sudden impacts	.367	.122	**.115****	1.193
Optimism	-.037	.032	**-.044n.s.**	1.165
Futuristic difference	.031	.074	**.016n.s.**	1.219
R^2 = .696 for Step 1 (p<.001), ΔR^2 = .014 for Step 2 (p<.05)				
n.s. non-significant , *p<.05, **p<.01, ***p<.001				

Table 22: Hierarchical linear regression for factors predicting concern about SLC on the Severn Estuary

All age groups are less concerned than 45-54 year olds (the reference group), but the only significant differences are between this reference group and older age groups, with older age groups being significantly less concerned. This would support research that finds older people to be less concerned about or perceive a lower threat from climate change (Kellstedt et al., 2008; Whitmarsh, 2008) and SLR (Hamilton, 2008) than young people. This relationship may reflect the assumption that climate change is a future risk (Whitmarsh, 2008). However, other research indicates that concern about climate change *per se* and marine climate change issues in particular is lowest among younger people[88] (CLAMER, 2011a; Shuckburgh et al., 2012). This discrepancy might be explained by recent research that indicates the relationship between age and concern about SLC is not a linear one, with middle-aged people showing the highest levels of concern (Capstick et al., 2013).

The perception of sudden impacts predicted increased concern levels. This is an important finding, because as discussed in section 7.2.3, the perception that SLC impacts will be gradual is predominant amongst PPP1 and PPP2 participants. Finally, flood experience did *not* predict concern about SLC (Table 22) or knowledge of SLC (Table 18) on the Severn Estuary. This may be in part due to the nature of flood events here, which although sometimes extreme, are currently quite rare. Terpstra (2011) suggests that emotions after a flood, and the influence that these emotions have on adaptive behaviours, fade over time, which could explain the lack of correlation between flood experience and perceptions on the Severn Estuary.

8.6 Summary: predictors of sea-level change knowledge and concern

Regression analyses show that the greatest proportion of variance in SLC knowledge is predicted by SLC scepticism, with lower levels of scepticism predicting higher knowledge scores. Those who are more concerned, middle-aged people and those living closer to the estuary also tend to have a greater knowledge of SLC. Knowledge of causes and social impacts predict greater SLC estimates for 2200, and a greater difference in SLC estimates between 2050 and 2200. Optimism and scepticism both predict lower 2200 SLC estimates and smaller differences in estimates between 2050 and 2200. More sceptical people and older people (over 65) tend to be less concerned, while those with higher knowledge of social impacts, a close relationship with nature and a perception that SLC might have sudden impacts, tend to be more concerned.

[88] Shuckburgh et al. (2012) found that young people in the UK (16-24 year olds) expressed less concern than older people (35-64) about climate change. (CLAMER, 2011a) found that older people expressed more than younger people, especially those in the 55-64 age bracket compared to 18-34 year olds.

9 **CONCLUSIONS**

This chapter draws together and discusses the findings of this study. It first summarises how experts and the public perceive the risks of SLC on the Severn Estuary, before discussing the applied and theoretical implications of the research and suggesting avenues for further work.

9.1 Addressing the research questions

This study has explored public perceptions of SLC using a mental models approach, comparing expert perceptions with those of members of the public living around the estuary. The thesis sought to answer three questions: 1) how do 'experts' perceive the risks of SLC on the Severn Estuary? 2) how does 'the public' perceive the risks? and 3) what implications do these perceptions have for risk communications? The answers to these questions are summarised here.

9.1.1 How do experts perceive the risks of sea-level change on the Severn Estuary?

It was hypothesised that experts would present a complicated picture of SLC on the Estuary, fraught with uncertainties. The conceptual model shows that this is indeed the case. It shows that there are countless interactions, feedbacks and thresholds, many of which are unknown or uncertain; and that there are both epistemic and aleatory uncertainties in the drivers of and responses to SLC. While it was hypothesised that experts would expect sea levels to rise on the Severn Estuary, the sheer range of projections was considerable. While all expert participants projected a high likelihood of future SLR, there was wide variation in judgements and much disagreement regarding how much SLC is *possible* there. While median estimates of SLR were of the same order of magnitude as the IPCC's Fourth and Fifth Assessment Reports (IPCC, 2007, 2013)[89], the experts in this study typically made high estimates that were much greater than IPCC ranges. Thematic analyses of expert interviews indicated that the methods and information that experts used, common heuristics and the ways in they think about the future may have affected their judgements.

9.1.2 How does the public perceive the risks of sea-level change on the Severn Estuary?

In general, the public does not feel well informed about SLC. As expected however, results show areas of public understanding that are consistent with the expert model. Notably, most respondents think that sea levels will rise between now and 2050, 2100 and 2200, and tend to relate these rising sea-levels with increased flooding, leading to home and property damage. However, there is much uncertainty regarding the magnitudes of future SLC, and perceptions vary as to how *much* SLC constitutes a threat. Indirect impacts such as inconvenience and impacts on health and services are

[89] Global average relative sea-level rise estimates in IPCC's Fifth Assessment Report (AR5) are 26cm to 98cm by the year 2100 (model based likely range for four RCP scenarios, compared to 1986-2005) (IPCC, 2013). Global average relative sea-level rise estimates in the IPCC's Fourth Assessment Report (AR4) are 18cm to 59cm by 2100 (model-based range for six emissions scenarios, compared to 1980-1999) (IPCC, 2007).

of low salience, and there are differences between expert and lay perceptions in each theme of the expert model. For example, many lay participants believe that most SLR is caused by melting icebergs/sea-ice, do not understand that isostatic subsidence causes local SLR, and do not appreciate the importance of thermal expansion. The majority of survey respondents believe that the impacts of SLC will be gradual, whereas experts recognise that change might be sudden.

The research shows that in addition to formal knowledge, a number of factors influence public perceptions of SLC risks. For example, the public tend to place a lot of trust in experience and local knowledge. They tend to express low concern about SLC, particularly in relation to other concerns such as the economy. They feel detached from the issue, seeing it as something that will happen in the future, to other people, and perceive that neither the causes of nor responses to SLC are their responsibility. While some participants are already engaging with SLC (voluntarily or involuntarily) or are thinking about doing so, a number respond with optimism or avoidance. Regression analyses show that many of the factors are related. For example, low scepticism and high concern predict a greater knowledge of SLC, while optimism and scepticism predict lower estimates of future SLC. As well as the similarities in what experts and the public 'know' about SLC, there are also similarities in contextual themes. Analyses indicated that both groups found it difficult to think about the future, varied in their emphasis on historic determinist and futuristic difference repertoires, and may have been influenced by optimistic biases when assessing risk.

9.2 Applied implications of study findings

9.2.1 Applied implications of EPP findings

> *'The policymaker needs to learn about the full range of outcomes, with probabilities attached and disagreements among experts revealed'- (Socolow, 2011, p. 786)*

Probability elicitation results show much greater uncertainty and a greater diversity of opinion than is cited in reports such as the IPCC and UKCP09, and show that elicitations are influenced by a great many factors. If expert probability judgements are to remain a 'key metric for communicating uncertainty', notably in the IPCC 5th Assessment Report (Mastrandrea et al., 2010)[90], the findings of this study endorse previous recommendations (Frame & Stone, 2012; Morgan, 2011; Oppenheimer et al., 2007) to make explicit the contexts in which such judgements are made. 'For

[90] At the time of thesis submission, the full AR5 was not available for referencing. While the AR5 Summary for Policy Makers (IPCC, 2013) acknowledges the use of expert judgment, it does not provide details of how these judgments were made.

post-normal science, the decision making process is as important as the research product' (Dessai & Hulme, 2004, p. 120). While it is clearly not feasible to design adaptation strategies that are robust to any point on the experts' distributions, it is important to consider the plural nature of such projections. As stated by Zickfeld et al (2007, p. 239) 'the route to scientific truth is not a matter of voting. One of the outliers among the respondents may be correct, and those who appear to be in close agreement may all be wrong'. Robust adaptation planning for SLC must therefore be flexible (Hulme, Pielke, & Dessai, 2009).

The complexity of the expert model indicates that communications about SLC will not be straight forward, and must be selective. 'An enormous amount of sheer *effort* [is] needed for members of the public to monitor sources of scientific information, judge between them, keep up with shifting scientific understandings, distinguish consensus from isolated scientific opinion, and decide how expert knowledge needs qualifying for use in *their* particular situation' (Wynne, 1991, p. 117). Furthermore, if communications include irrelevant information then it wastes peoples' time and diverts their attention from the most important aspects (Morgan et al., 2002). The findings from PPP1 and PPP2 suggest ways in which communications may be streamlined.

9.2.2 Applied implications of PPP1 and PPP2 findings

A number of PPP1 participants expressed a desire to know more about SLC, and results indicate there may be a moral responsibility to inform people of SLC risks (the 'right to know' function of communications discussed by Renn & Levine, 1991). For example, Christine (PPP1) did not know whether the sea level on the Severn Estuary was rising or falling and stated that "if sea levels were definitely rising, like if they rose an inch last year and were forecast to rise another inch this year, I suppose we might think about selling our house and moving a bit higher up". Although sea levels are not rising by as much as an inch per year, this quote indicates that there may be a moral responsibility to inform residents of the potential risks they face. Thus, communications are needed to raise awareness and understanding of SLC so that individuals can make informed decisions such as whether to engage in adaptation and mitigation actions. The following recommendations are drawn directly from perceptions elicited during the course of this research.

Firstly, results show a number of differences between how the public and experts understand the basic processes of SLC, indicating that communications should **raise awareness of basic SLC processes**. Indeed, interview participants tended to talk about SLC in terms of causes and effects (section 7.2.7), and as PPP1 participant George said during his interview, "without knowing the causes of [SLC], people can't directly attribute what they can do about it". Gaining a deeper appreciation of processes also 'allows people to follow debates and grasp the rationale for alternative policies' (Pidgeon & Fischhoff, 2011, p. 38). Particularly, raising awareness of thermal

expansion and isostatic subsidence may facilitate the construction of attitudes from valid premises (section 7.2.7).

PPP1 and PPP2 respondents tended to express relatively little concern for lagged socio-economic impacts such as decreased house prices and people moving out of the area. But those PPP2 respondents who had a better understanding of the social impacts of SLC were also more concerned about it, and predicted greater magnitudes of SLC (section 8.5), indicating that communications could usefully **raise awareness of the social impacts of SLC**. Other research has shown that an emphasis on social aspects of climate change is also linked with more positive attitudes towards climate change mitigation (Spence & Pidgeon, 2010).

Severn Estuary residents feel powerless to act on both the causes and impacts of SLC (section 7.3), indicating that risk communications could usefully include **information about the most effective actions that individuals can take** (Bubeck et al., 2012; Pidgeon, 2010). This could include raising the salience of personal adaptation measures such as installing flood boards, which are currently less salient than large scale measures such as flood defences (7.2.3).

Although the majority of participants thought that sea levels are rising on the Severn Estuary, some thought that they are falling, and many were unsure about how *much* SLC was expected to occur in future. Communications could therefore **include estimates of future local SLC**. They should also transparently communicate the uncertainties involved in such projections; uncertainties that are recognised by the public to exist (6.2.2). As Expert participant Jack points out, people make decisions under uncertainty all the time: "think about buying a house, getting married, all these big decisions that you make in your life". Providing the public with more detailed estimates will equip them with the probabilistic information that they might need to employ their "own managed retreat policy" (PPP1 participant Fred, section 7.2.3), and may increase trust in communications (Johnson & Slovic, 1995). As well as providing such estimates, results show that communications might benefit from providing information about what these numbers actually mean (7.2.5). There is no use in knowing that sea levels are going to rise by a foot if individuals do not know what a foot means in terms of impacts.

Communications could benefit from **using trusted information sources**, with whom the public can identify (Campbell, 2011; Istre et al., 2002; Renn & Levine, 1991). Amongst PPP2 respondents, the most trusted sources of information about SLC are the Environment Agency / Natural Resources Wales, although distrust in these agencies was voiced by some PPP1 participants (7.3.3). **Technical jargon should be minimised** (Shuckburgh et al., 2012) and terms such as 'tides', 'surges' and 'tsunamis' should be defined where it is necessary to use them.

Finally, as discussed in 2.3.1, public involvement can add substance to communications, providing valuable insights and knowledge that may be missed or overlooked by experts (Fiorino, 1990).

Results of this study indicate that **deliberative approaches[91] may prove valuable** on the Estuary. First, section 6.1.5 shows the importance of and depth of local knowledge that could add substance to future communications. Second, survey results show that participants rarely think about SLC (6.2.1), and third, interview results indicate that reflection is an important part of understanding the issue (7.2.7).

Although this study has provided a number of recommendations for how communications on the Severn Estuary may proceed, the limitations of such communications should be recognised. This research has shown that knowledge is not the only factor influencing perceptions of SLC, and while communication campaigns can target public knowledge, some of the other things that have been shown to influence risk perceptions (e.g. optimistic biases and worldviews) may prove more difficult to change. Whitmarsh (2011, p. 699) has shown that '*more information will not engage the most sceptical groups*, since information will tend to be interpreted in relation to existing views, and entrenched views are very hard to change'. Besides, would it be ethical to target some such factors? While optimism may reduce peoples' capacity for realistic and accurate decision making (Dunning et al., 2004; Taylor & Gollwitzer, 1995) and contribute to a false sense of security (section 7.3.3), it would likely be unethical and maladaptive to change![92] Furthermore, there are drawbacks of communicating risks (Section 2.3.2), which should also be considered. For example, PPP1 participant Lynne felt that Environment Agency flood maps, which show the likelihood of flooding from rivers or the sea (Environment Agency, 2012), may stigmatise her locale and make it difficult to sell her house. Such problems can be lessened by educating the media and the government about stigma (Kunreuther & Slovic, 2001), elucidating the role of including such actors in the communication process. Indeed, regardless of personal perceptions of SLC, there remain external barriers (and facilitators) to action (Lorenzoni et al., 2007; Zsamboky et al., 2011). For these reasons, it is not just members of the public who need to be communicated with, but also the media, governing bodies and their agencies.

9.3 Theoretical and methodological implications

9.3.1 The mental models approach

This thesis shows that the mental models approach to risk communications (Morgan et al., 2002) provides a coherent and structured approach for exploring public perceptions and grounding

[91] Deliberative approaches seek to facilitate a two-way debate, information transfer and reflection on issues, and have been endorsed as communication strategies in recent studies (e.g. Shuckburgh et al., 2012).

[92] As discussed in section 2.6.3, optimism has been linked to higher levels of engagement coping and lower levels of avoidance (Carver et al., 2010; Taylor & Gollwitzer, 1995), better health, mood and achievement (Peterson, 2000).

future communications in empirical findings. The study also demonstrates that the mental models approach can be extended to explore contextual factors as well as knowledge related themes (as per Cox et al., 2003; Cox et al., 2005), and can be complemented by diverse methodologies such as subjective probability elicitations and lay cognitive mapping methods.

9.3.2 Mixed-methods approaches and internal consistency

Overall, the qualitative interviews and quantitative survey used in the public phases of this thesis complemented each other well. Firstly, the PPP1 interviews provided the basis of the PPP2 survey, including some beliefs that were not anticipated before the interviews were carried out (for example that sea-level is falling, and that dredging may cause sea-levels to fall). This supports the rationale for the mental models approach (Morgan et al., 2002), whereby the interview is a key part in scoping public beliefs. The interviews also provided context for some of the survey findings. For example, the PPP2 finding that 8% of participants think SLR would be an overall benefit makes sense when PPP1 transcripts are interrogated, finding that respondents think SLR may increase habitats, the fertility of farmland, the viability of shipping and power generation from a barrage. Furthermore, the use of a mixed quantitative-qualitative approach provided triangulation for many of the findings, showing internal consistencies within the data. Examples include the high trust placed in personal experience by both PPP1 and PPP2 respondents, and the externalisation of responsibility for SLC by respondents in both groups. Finally, the findings show the merits of integrating qualitative and quantitative methods to contextualise uncertainty judgements, as recommended by Stirling (2010).

Although in general the quantitative and qualitative approaches generated consistent results, there were some inconsistencies. While PPP2 respondents ranked friends and family as the joint least trusted source of information about SLC on the Severn Estuary, PPP1 respondents often cited information provided by friends and family. As discussed in 6.1.5, this difference might be due to social desirability bias. Another inconsistency regarded the high level of concern amongst PPP2 respondents about travel disruption from flooding, which contrasted with PPP1 findings where inconvenience was of low salience. This may have been due to the semi-structured nature of the PPP1 interviews, whereby participants were not asked about specific impacts unless they mentioned them. In addition, PPP1 respondents who had lived around the estuary for longer had more complete mental models of SLC (6.1.5), but there was no significant relationship between time lived around the estuary and knowledge scores amongst PPP2 respondents (8.5.2). This discrepancy could have been due to the different independent variables (knowledge about a finite set of specific SLC factors in PPP2 versus and mental model completeness scores relating to a greater number of factors during PPP1 interview sessions, which themselves varied in length).

Also, the PPP1 sample was very small (N=20), decreasing the statistical power for such comparisons.

9.3.3 External consistency

The majority of SLC findings in this thesis are consistent with wider climate change research. This is illustrated in Table 23, which summarises the main findings and indicates whether they are supported by previous research (S), partially supported (~S) or unsupported (US). The consistency with previous research is unsurprising considering that PPP1 and PPP2 respondents tended to closely link the two issues of climate change and SLC (section 7.2.3). This consistency has implications for the communication of SLC, and in understanding public engagement with the issue. For example, many of the characteristics of climate change that make it hard to communicate - its complexity, long-term and distant nature, and difficult-to-detect signals - also apply to SLC; as do many of the factors that are perceived to be barriers to engaging with climate change, such as self-efficacy, optimism and scepticism (Lorenzoni et al., 2007).

Table 23: Consistency of PPP1 and PPP2 findings with previous research

Factor	Climate change, SLC and flood risk findings (previous research)	SLC findings (this study)	Sup.
Orienting dispositions			
Sources of information	TV is one of the most common sources of information on **marine climate change** issues (CLAMER, 2011a).	TV is a popular source of SLC information (PPP1).	S
Trust in information sources	The most trusted source of information for **marine climate change** issues is scientific publications; while broadsheets, books and TV are the most trusted media sources (CLAMER, 2011a). High trust is placed in personal observation in the context of **flood** risks (Whitmarsh, 2008).	The most trusted sources of information about SLC are the Environment Agency / Natural Resources Wales and scientists (PPP2). TV is the most trusted media source. Personal experience is highly trusted (PPP1 and PPP2).	S
Education	Educational level predicts knowledge of **climate change** (Tobler et al., 2012).	PPP2 participants' educational level does not predict knowledge scores (a finding also supported by PPP1 interviews (6.1.5)).	US
Local knowledge and experience	Experiences of **flooding** are influential in determining perceptions of flood risks (Baumann & Sims, 1978; Harvatt et al., 2011; Siegrist & Gutscher, 2006; Spence et al., 2011; Wagner, 2007). Individuals with less experience of Alpine flash **flood** and landslide tend to have less complete mental models of the risk (Wagner, 2007).	PPP1 respondents who had lived around the estuary for longer had more complete mental models of SLC. However, there was no significant relationship between time lived around the estuary and knowledge scores (PPP2), and flood experience did not predict concern about SLC or knowledge of SLC (PPP2).	~S

Continued…

Table 23 Continued: Consistency of PPP1 and PPP2 findings with previous research

Factor	Climate change, SLC and flood risk findings (previous research)	SLC findings (this study)	Sup.
Concern	Widespread concern about **climate change** is commonly reported. E.g. among Welsh respondents 36% are very concerned about climate change and 48% are fairly concerned (Capstick et al., 2013). 70% of European respondents reported being concerned about **SLR** (CLAMER, 2011a).	PPP2 respondents were evenly split, with 51% being fairly/very concerned and 49% being not at all/not very concerned. PPP1 responses were also mixed.	US
Concern relative to other issues	**Climate change** ranks low relative to other concerns, particularly day to day issues like personal economic security (Lorenzoni et al., 2007; Zsamboky et al., 2011).	SLC was of low concern relative to other issues (PPP1). But in relation to other risks *specific to the Severn Estuary*, PPP2 respondents factored SLC relatively highly.	S
Scepticism	63% of Americans (Leiserowitz, Smith, & Marlon, 2010) and 80% of UK citizens (Shuckburgh et al., 2012) believe **climate change**/ global warming is happening.	The majority of PPP2 respondents agree that climate change (66%) and SLC (69%) is really happening.	S
Values and worldviews	Values and worldviews have been found to be important in the context of **climate change** (e.g. Kahan et al., 2011; Leiserowitz, 2006; Poortinga et al., 2011).	PPP1 results indicate that values and worldviews are important factors in the perception of SLC and responses to it.	S
Future thinking	Experts think about the future using two temporal repertoires: historic determinism and futuristic difference (van Asselt et al., 2010). To my knowledge, no work has investigated whether the lay public also utilise such repertoires in the context of climate change, SLC or flooding.	EPP and PPP1 respondents placed varying emphasis on historic determinism and futuristic difference. More work is required to see if this affects risk perceptions, though there was no significant relationship between the future scale and SLC perceptions (PPP2).	-
Psychological distance	The UK public associates **climate change** with impacts that are distant in both time and space (Shuckburgh et al., 2012; Spence et al., 2012). Psychological distance also applies to **SLC** (Evans et al., 2012).	PPP1 participants tended to view SLC as something that would affect other places worse than it would affect their local area, and PPP2 respondents tended to believe that SLC would affect the rest of the world more than it would affect them personally. However, more PPP2 respondents thought SLC would affect the Severn Estuary than thought it would affect the rest of the world. There was a widespread belief among PPP1 participants that the SLC impacts would be felt by future generations rather than themselves, while PPP2 responses were ambivalent. Social distancing was uncommon (PPP2).	~S

Continued…

Table 23 Continued: Consistency of PPP1 and PPP2 findings with previous research

Factor	Climate change, SLC and flood risk findings (previous research)	SLC findings (this study)	Sup.
Emotions	**Climate change** risk perceptions and policy support have been shown to be influenced by affect (Leiserowitz, 2006). People who have experienced **flooding** associate it with negative emotions (Siegrist & Gutscher, 2008).	SLC, climate change and particularly flooding were overwhelmingly associated with negative feelings, though some participants spoke of SLC as being exciting (PPP1).	~S
Demographics	Women tend to be more concerned than men about **climate change** (Shuckburgh et al., 2012), marine climate change issues (CLAMER, 2011a) and **SLR** (Hamilton, 2008). Women may have a greater scientific knowledge of climate change than men (McCright, 2010). Capstick et al. (2013) find that the oldest and youngest groups are least concerned about **climate change.**	Gender and age are poor predictors of SLC knowledge (PPP2). Middle aged people are the most concerned about SLC, and older people are the least concerned (PPP2). Gender does not predict concern about SLC.	~S
Risk Appraisal			
Knowledge	There is limited understanding of the causes of and solutions to **climate change** amongst the UK and US public (Bord et al., 2000; Leiserowitz et al., 2010; Lorenzoni & Pidgeon, 2006).	There is limited understanding of the causes of and solutions to SLC (PPP1 and PPP2). However, there are some areas of agreement between experts and publics.	S
Responsibility	Individuals locate responsibility for causing and mitigating **climate change** with others (Capstick et al., 2013; Lorenzoni et al., 2007; Pidgeon, 2012; Poortinga et al., 2006; Ryan et al., 2012; Spence et al., 2010b). The transferral of responsibility has also been shown to exist in contexts of groundwater **flooding** (Kreibich et al., 2009) and **SLR** (Harvatt et al., 2011).	Individuals locate the responsibility for causing and mitigating SLC with others (PPP1 and PPP2).	S
Efficacy	Individual action against **climate change** is seen as difficult (Capstick et al., 2013; Spence et al., 2010b).	PPP1 and PPP2 findings indicate perceptions of low self-efficacy regarding SLC.	S
Trust	Research notes moderate to low levels of trust in the agencies perceived to be responsible for **flood** and **SLR** (Evans et al., 2012; Fernandez-Bilbao, 2012).	PPP1 and PPP2 findings indicate moderate to low levels of trust in the government and its agencies to protect people from SLR.	S
Responses (inactive)			
Optimism	Optimistic beliefs have been cited as potential barriers towards public engagement with climate change (Lorenzoni et al., 2007).	Many PPP1 participants expressed optimism about SLC, and optimism was found to predict lower SLC estimates amongst PPP2 respondents. It is not clear whether these beliefs act as a barrier towards engagement.	~S

Continued…

Table 23 Continued

Factor	Climate change, SLC and flood risk findings (previous research)	SLC findings (this study)	Sup.
Avoidance	Bickerstaff and Simmons (2009) have noted an 'active silencing of risk' in relation to living with nuclear facilities. This is related with denial, which has been described as a potential coping mechanism for **SLR** and **flood** risks (Harvatt et al., 2011).	Analyses suggest some PPP1 participants may be actively avoiding the issue of SLC.	S

Table 23: Consistency of PPP1 and PPP2 findings with previous research

Sup. column: findings supported (S), partially supported (~S) or unsupported (US) by previous research

9.4 Avenues for future research

This research has raised a number of issues worthy of further exploration, either through modifying the methodology, further analyses of the existing dataset, or related studies. If I were to repeat this research, the main addition would be to include PPP2 survey questions about public decisions regarding SLC, particularly current active responses to SLC and intentions to mitigate or adapt, as suggested by de Bruin and Bostrom (2013). This is because although the study provides insights into perceptions of SLC, it does not tell us how these perceptions relate with actions and intentions[93]. I would also improve survey questions to reduce acquiescence bias (section 7.2.3). Regarding specific items, a more consistent question format for PPP2 vulnerability questions would facilitate an investigation into whether vulnerability is really less salient than other factors, as the current format does not allow a direct comparison. Also, the risk/benefit questions (Q3 and Q4) would ask respondents to indicate their level of agreement on two different scales, one for risk and one for benefit. The current single scale reduces the utility of the results because risks such as SLC can be perceived as being both high risk *and* high benefit. If I had more time to interrogate the current data set, further statistical analyses could investigate whether city dwellers feel less at risk than rural dwellers, and whether there is a relationship between where an individual lives and where they think is most at risk from SLC. These analyses could provide another layer to findings pertaining to psychological distance.

[93] Such items were not included in the survey due to time and space constraints, and are currently being investigated in relation to climate change on the Severn Estuary by Robert Sposato in the Understanding Risk Group at Cardiff University.

The thesis has raised a number of avenues for further research through new studies. First, further research should investigate whether these findings are replicated in other low lying areas or whether different themes arise. Such research could focus on similar and disparate environments such as other estuaries, island environments, and coastal cities. Second, while the prospect of a Severn Estuary barrage is currently small (House of Commons, 2013), such a structure would have wide-ranging impacts on the Severn Estuary and alter so many of the processes operating in the expert model as to warrant the development of a whole new model. Third, as discussed in section 8.1, this thesis does not explore in any depth the actions that are being taken or that may be taken by members of the public in response to SLC on the Severn Estuary. Fourth, the final stages of the mental models approach (communication design) have only been touched upon in this study. Further work should develop and test such risk communications.

The final avenue for future research involves the investigation of other risks. Johnson (1999) remarks that the decision over what issues should be communicated with the public is an ethical one; why should some be selected over others? Indeed, SLC is one of a number of impacts of climate change. Others, such as food security and water resources, may have as great or greater impacts on Severn Estuary residents and people around the world. Expert participant Bob stated that on the Estuary, "habitats will adapt and communities will adapt... I think we have bigger things to worry about". Perhaps the main avenue for further research is therefore to use similar extended, contextualised mental models approaches to explore other specific climate change risks.

9.5 Concluding remarks

> *With climate change, the 'stakes are too high for ad hoc communication' (Fischhoff, 2011).*

PPP1 participant Lynne stated that "all the knowledge in the world isn't going to stop [SLC] happening". She's right. If everyone on Earth stopped emitting carbon dioxide today, sea levels may still rise by around 1m (Nicholls & Lowe, 2004). But while knowledge may not stop SLC, it can perhaps empower people to make their own informed decisions about how to respond to it. This thesis has provided the first step towards the provision of such information, by filling the research gap in how the public perceives SLC on the Severn Estuary and by providing insights into how the risks might best be communicated. But it has also highlighted the importance of contextual factors of SLC perceptions, endorsing recommendations that communicators should not only listen to the 'facts' that people know, but to other aspects as well.

References

Adaptation Sub-Committee of the Committee on Climate Change. (2010). How well prepared is the UK for climate change? London: Committee on Climate Change Adaptation.

Akerlof, K. (2012). Public Opinion and Policy Preferences on Coastal Flooding and Sea-Level Rise: Survey report: George Mason University.

Alam, S. M. N. (1990). Perceptions of flood among Bangladeshi villagers. *Disasters, 14*(4), 354-357.

Allen, J. R. L. (1991). Salt-marsh accretion and sea-level movement in the inner Severn Estuary, southwest Britain: archaeological and historical contribution. *Journal of the Geological Society, 148*(3), 485-494.

Anderegg, W. R. L., Prall, J. W., Harold, J., & Schneider, S. H. (2010). Expert credibility in climate change. *Proceedings of the National Academy of Sciences, 107*(27), 12107–12109

Aoyagi, M. (2012, December.). *A study of risk perception in different methods: comparing internet survey and face to face survey*. Paper presented at the Society for Risk Analysis, San Francisco, USA.

Arnell, N. W., Tompkins, E. L., & Adger, W. N. (2005). Eliciting information from experts on the likelihood of rapid climate change. *Risk Analysis, 25*(6), 1419-1431.

Aron, A., Aron, E. N., & Smollan, D. (1992). Inclusion of Other in the Self Scale and the structure of interpersonal closeness. *Journal of personality and social psychology, 63*(4), 596.

Arrhenius, S. (1896). On the influence of carbonic acid in the air upon the temperature of the ground. *Philosophical Magazine and Journal of Science, Series 5., 41*, 39.

ATKINS. (2009). Severn Estuary Shoreline Management Plan Review (SMP2) and Flood Risk Management Strategy (FRMS): SEA Scoping Report (Draft Report). In Severn Estuary Coastal Group (Ed.), (pp. 142). UK: ATKINS

Austin, L. C., & Fischhoff, B. (2011). Injury prevention and risk communication: a mental models approach. *Injury Prevention, 18*, 124-129

Bainbridge, A. (2009). Survey Data Cleansing: Five Steps for Cleaning Up Your Data. *Allegiance Blog*. Retrieved 20 March, 2013, from http://www.allegiance.com/blog/survey-data-cleansing-five-steps-for-cleaning-up-your-data/74

Ballinger, R., & Stojanovic, T. (2010). Policy development and the estuary environment: A Severn Estuary case study. *Marine Pollution Bulletin, 61*(1-3), 132-145.

Bamber, J. L., & Aspinall, W. P. (2013). An expert judgement assessment of future sea level rise from the ice sheets. *Nature Climate Change, 3*, 424-427.

Basiago, A. D. (1994). The limits of technological optimism. *Environmentalist, 14*(1), 17-22.

Baumann, D. D., & Sims, J. H. (1978). Flood insurance: Some determinants of adoption. *Economic Geography*, 189-196.

Bellamy, R., & Hulme, M. (2011). Beyond the Tipping Point: Understanding perceptions of abrupt climate change and their implications. *Weather, Climate, and Society, 3*(1), 48-60.

Bickerstaff, K., Lorenzoni, I., Pidgeon, N. F., Poortinga, W., & Simmons, P. (2008). Reframing nuclear power in the UK energy debate: nuclear power, climate change mitigation and radioactive waste. *Public understanding of science, 17*(2), 145-169.

Bickerstaff, K., & Simmons, P. (2009). Absencing/presencing risk: Rethinking proximity and the experience of living with major technological hazards. *Geoforum, 40*(5), 864-872.

Bickerstaff, K., Simmons, P., & Pidgeon, N. (2006a). Public perceptions of risk, science and governance: main findings of a qualitative study of six risk cases (Technical Report 06-03): Norwich: Centre for Environmental Risk.

Bickerstaff, K., Simmons, P., & Pidgeon, N. (2006b). Situating local experience of risk: Peripherality, marginality and place identity in the UK foot and mouth disease crisis. *Geoforum, 37*(5), 844-858.

Bord, R. J., O'Connor, R. E., & Fisher, A. (2000). In what sense does the public need to understand global climate change? *Public Understanding of Science, 9*(3), 205-218.

Bostrom, A., Morgan, M. G., Fischhoff, B., & Read, D. (1994). What do people know about global climate change? 1. Mental models. *Risk Analysis, 14*(6), 959-970.

Boyle, D. G. (1969). *A students' guide to Piaget*: Pergamon Press Great Britain.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology, 3*(2), 77-101.

Breakwell, G. (2007). *The Psychology of Risk*. New York: Cambridge University Press.

Brooks, N. (2003). Vulnerability, risk and adaptation: A conceptual framework *Tyndall Centre for Climate Change Research Working Paper* (Vol. 38, pp. 1-16).

Brulle, R. J., Carmichael, J., & Jenkins, J. C. (2012). Shifting public opinion on climate change: an empirical assessment of factors influencing concern over climate change in the US, 2002–2010. *Climatic Change*, 1-20.

Bryant, E. A., & Haslett, S. K. (2007). Catastrophic wave erosion, Bristol Channel, United Kingdom: Impact of tsunami? *Journal of Geology, 115*(3), 253-269.

Bubeck, P., Botzen, W. J. W., & Aerts, J. (2012). A Review of Risk Perceptions and Other Factors that Influence Flood Mitigation Behavior. *Risk Analysis, 32*(9), 1481-1495.

Bulkeley, H. (2000). Common knowledge? Public understanding of climate change in Newcastle, Australia. *Public understanding of Science, 9*(3), 313-334.

Burroughs, W. J. (2007). *Climate Change: A Multidisciplinary Approach* (2nd ed.). New York: Cambridge University Press.

Butler, C., & Pidgeon, N. (2009). Media communications and public understanding of climate change: reporting scientific consensus on anthropogenic warming. In T. Boyce & J. Lewis (Eds.), *Climate Change and the Media.* (pp. 43-58). New York: Peter Lang.

Campbell, P. (2011). Understanding the receivers and the reception of science's uncertain messages. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 369*(1956), 4891-4912.

Capstick, S. B., Pidgeon, N., & Whitehead, M. (2013). Public perceptions of climate change in Wales: Summary findings of a survey of the Welsh public conducted during November and December 2012. : Climate Change Consortium of Wales.

Carolan, M. (2010). Sociological ambivalence and climate change. *Local environment, 15*(4), 309-321.

Carver, C. S., Scheier, M. F., & Segerstrom, S. C. (2010). Optimism. *Clinical psychology review, 30*(7), 879-889.

Christensen, J. H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Kolli, R. K., Kwon, W.-T., Laprise, R., Rueda, V. M., Mearns, L., Menéndez, C. G., Räisänen, J., Rinke, A., Sarr, A., & Whetton, P. (2007). Regional Climate Projections. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor & H. L. Miller (Eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.

CLAMER. (2011a). Report on European public awareness and perception of marine climate change risks and impacts (pp. 65): Climate Change & Eiropean Marine Ecosystem Research.

CLAMER. (2011b). Sea Change: Public views on marine climate change impacts in Europe. In P. Buckley, J. K. Pinnegar, G. Terry, J. Chilvers, I. Lorenzoni, S. Gelcich, D. Dudek & A. Arquati (Eds.), *WP2 Summary Report, Climate Change and Marine Ecosystem Research (CLAMER)* (pp. 16).

Clark, P. U., Dyke, A. S., Shakun, J. D., Carlson, A. E., Clark, J., Wohlfarth, B., Mitrovica, J. X., Hostetler, S. W., & McCabe, A. M. (2009). The last glacial maximum. *Science, 325*(5941), 710-714.

CMap Tools. (2013). CMap Tools (Version 4.03): Institute for Human and Machine Cognition (IHMC).

Cohen, L., Manion, L., & Morrison, K. (2000). *Research Methods in Education* (5th ed.). London: Routledge Falmer.

Collins, H. M., & Evans, R. (2002). The third wave of science studies: studies of expertise and experience. *Social Studies of Science, 32*(2), 235-296.

Colman, A. M. (2009). *Oxford Dictionary of Psychology* (3rd ed.). New York: Oxford University Press.

Cook, J., Nuccitelli, D., Green, S. A., Richardson, M., Winkler, B., Painting, R., Way, R., Jacobs, P., & Skuce, A. (2013). Quantifying the consensus on anthropogenic global warming in the scientific literature. *Environmental Research Letters, 8*(2), 024024.

Corner, A., Venables, D., Spence, A., Poortinga, W., Demski, C., & Pidgeon, N. (2011). Nuclear power, climate change and energy security: Exploring British public attitudes. *Energy Policy, 39*(9), 4823-4833.

Corner, A., Whitmarsh, L., & Xenias, D. (2012). Uncertainty, scepticism and attitudes towards climate change: biased assimilation and attitude polarisation. *Climatic change, 114*(3-4), 463-478.

Cox, P., Niewöhner, J., Pidgeon, N., Gerrard, S., Fischhoff, B., & Riley, D. (2003). The use of mental models in chemical risk protection: Developing a generic workplace methodology. *Risk Analysis, 23*(2), 311-324.

Cox, P., Pidgeon, N., Lake, I., & Poortinga, W. (2005). Public risk perceptions of the health effects of ionising radiation and power frequency electromagnetic fields: Centre for Environmental Risk, University of East Anglia, Norwich.
Craik, K. J. W. (1943). *The nature of explanation*. New York: Cambridge University Press.
Crosby, R. A., & Yarber, W. L. (2001). Perceived versus actual knowledge about correct condom use among US adolescents: results from a national study. *Journal of adolescent health, 28*(5), 415-420.
Dake, K. (1991). Orienting dispositions in the perception of risk an analysis of contemporary worldviews and cultural biases. *Journal of cross-cultural psychology, 22*(1), 61-82.
Dake, K. (1992). Myths of nature: Culture and the social construction of risk. *Journal of Social issues, 48*(4), 21-37.
Darier, E., & Schüle, R. (1999). Think globally, act locally? Climate change and public participation in Manchester and Frankfurt. *Local Environment, 4*(3), 317-329.
Davidson, D. J., & Freudenburg, W. R. (1996). Gender and environmental risk concerns: A review and analysis of available research. *Environment and behavior, 28*(3), 302-339.
Davis, S. J., Caldeira, K., & Matthews, H. D. (2010). Future CO2 emissions and climate change from existing energy infrastructure. *Science, 329*(5997), 1330.
de Bruin, W. B., & Bostrom, A. (2013). Assessing what to address in science communication. *Proceedings of the National Academy of Sciences, 110*(Supplement 3), 14062-14068.
de Groot, J. I. M., & Thøgersen, J. (2013). Values and pro-environmental behaviour. In L. Steg, A. E. van den Berg & J. I. M. de Groot (Eds.), *Environmental psychology: An introduction*: British Psychological Association and John Wiley and Sons.
DECC. (2010). Severn Tidal Power:Feasibility Study Conclusions and Summary Report. In Department of Energy and Climate Change (Ed.), (pp. 75). London: The Stationary Office.
Defra. (2005). The threat posed by tsunami to the UK. In D. Kerridge (Ed.), *Study commissioned by Defra Flood Management and produced by British Geological Survey, Proudman Oceanographic Laboratory, Met Office and HR Wallingford.* (pp. 167): Department for Environment, Food and Rural Affairs.
Defra. (2006). *Flood and Coastal Defence Appraisal Guidance, FCDPAG3 Economic Appraisal, Supplementary Note to Operating Authorities – Climate Change Impacts*. London.
Defra. (2012). UK Climate Change Risk Assessment: Government Report. In HM Government (Ed.). London: The Stationary Office.
Defra & Environment Agency. (2011). *Flood Risk Management in England*. London: The Stationary Office.
Denzau, A. T., & North, D. C. (1994). Shared mental models: ideologies and institutions. *Kyklos, 47*(1), 3-31.
Dessai, S., & Hulme, M. (2004). Does climate adaptation policy need probabilities? *Climate Policy, 4*(2), 107-128.
Dezenski, E. (2012). *World Economic Forum. Speaking at SRA Conference, San Francisco.* Paper presented at the Society for Risk Analysis, San Francisco.
Ding, D., Maibach, E. W., Zhao, X., Roser-Renouf, C., & Leiserowitz, A. (2011). Support for climate policy and societal action are linked to perceptions about scientific agreement. *Nature Climate Change, 1*, 462-466.
Dodds, W. (2010). Severn Estuary Planning Review: Phase One Report. In IMCORE (Ed.), (pp. 105). Cardiff: School of Earth and Ocean Sciences, Cardiff University.
Douglas, M., & Wildavsky, A. (1983). *Risk and culture: An essay on the selection of technological and environmental dangers*. United States of America: University of California Press.
Dray, A., Perez, P., Jones, N., Le Page, C., D'Aquino, P., White, I., & Auatabu, T. (2006). The AtollGame experience: from knowledge engineering to a computer-assisted role playing game. *Journal of Artificial Societies and Social Simulation, 9*(1).
Dunning, D., Heath, C., & Suls, J. M. (2004). Flawed self-assessment. *Psychological science in the public interest, 5*(3), 69.
Durand, R. M., & Lambert, Z. V. (1988). Don't know responses in surveys: Analyses and interpretational consequences. *Journal of Business Research, 16*(2), 169-188.
Edge, D. (1995). Reinventing the Wheel. In S. Jasanoff, G. E. Markle, J. C. Peterson & T. Pinch (Eds.), *Handbook of science and technology studies*. California: Sage.
Elliott, M., & McLusky, D. S. (2002). The need for definitions in understanding estuaries. *Estuarine, Coastal and Shelf Science, 55*(6), 815-827.
Environment Agency. (2006). The Severn Estuary Coastal Habitat Management Plan (CHaMP).

Environment Agency. (2011a). Coastal flood boundary conditions for UK mainland and islands: Design sea levels *Delivering benefits through evidence* (pp. 142). Bristol: Environment Agency.
Environment Agency. (2011b). Managing flood risk on the Severn Estuary: Gloucestershire *Severn Estuary Flood Risk Management Strategy* (pp. 17).
Environment Agency. (2011c). Severn Estuary Flood Risk Management Strategy: Strategic Environmental Assessment Report.
Environment Agency. (2012). What's in your backyard? Retrieved 19 October, 2012, from http://www.environment-agency.gov.uk/homeandleisure/37793.aspx
European Parliament. (1992). *Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora*. Strasbourg.
European Parliament. (2002). *Recommendation 2002/413/EC of the European Parliament and of the Council of May 2002 concerning the implementation of Integrated Coastal Zone Management in Europe*. Strasbourg.
European Parliament. (2007). *Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks*. Strasbourg.
Evans, J. R., & Mathur, A. (2005). The value of online surveys. *Internet Research, 15*(2), 195-219.
Evans, L., Milfont, T. L., & Lawrence, J. (2012). Perceptions of sea-level rise in Wellington City and Kapiti Coast districts (pp. 39). Wellington, NZ: Victoria University of Wellington.
Falk, J. H., & Dierking, L. D. (2010). The 95 Percent Solution: School is not where most Americans learn most of their science. *American Scientist, 98*(6), 486-493.
Fernandez-Bilbao, A. (2012). Adaptation to Climate Change by Coastal Communities. In S. Kabisch, A. Kunath, P. Schweizer-Ries & A. Steinfuehrer (Eds.), *Vulnerability, Risks, and Complexity: Impacts of Global Change on Human Habitats*. Cambridge, MA: Hogrefe Publishing.
Festinger, L. (1962). Cognitive dissonance. *Scientific American, 207*(4), 93-107.
Field, A. (2009). *Discovering statistics using SPSS* (3rd ed.). London: Sage.
Fiorino, D. J. (1990). Citizen participation and environmental risk: A survey of institutional mechanisms. *Science, technology & human values, 15*(2), 226-243.
Fischhoff, B. (2001). Defining Stigma. In J. Flynn, P. Slovic & H. Kunreuther (Eds.), *Risk, media, and stigma: Understanding public challenges to modern science and technology* (pp. 361-368). London: Earthscan.
Fischhoff, B. (2011). Applying the science of communication to the communication of science. *Climatic Change, 108*(4), 701-705.
Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S., & Combs, B. (1978). How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. *Policy sciences, 9*(2), 127-152.
Fisher, R. J. (1993). Social desirability bias and the validity of indirect questioning. *Journal of Consumer Research*, 303-315.
Flynn, J., Slovic, P., & Mertz, C. K. (1994). Gender, race, and perception of environmental health risks. *Risk analysis, 14*(6), 1101-1108.
Foresight. (2011). International Dimensions of Climate Change: Final Project Report. London.
Foulds, C., Macrorie, R., Franz, B., & Wang, X. (2013). Unpublished working paper: The Challenges of Interdisciplinary Research: An Early Career Researcher Perspective on Crossing Disciplinary Boundaries.
Fowler, F. J. J., & Mangione, T. W. (1990). *Standardized Survey Interviewing: Minimizing Interviewer-Related Error* (Vol. 18). Newbury Park, California: Sage Publications.
Frame, D. J., & Stone, D. A. (2012). Assessment of the first consensus prediction on climate change. *Nature Climate Change, 3*, 357-359.
Franzosi, R. P. (2004). Content Analysis. In M. A. Hardy & A. Bryman (Eds.), *Handbook of data analysis*. London: Sage.
Frewer, L., Hunt, S., Brennan, M., Kuznesof, S., Ness, M., & Ritson, C. (2003). The views of scientific experts on how the public conceptualize uncertainty. *Journal of risk research, 6*(1), 75-85.
Galton, F. (1907). Vox populi. *Nature, 75*, 450-451.
Garthwaite, P. H., Kadane, J. B., & O'Hagan, A. (2005). Statistical methods for eliciting probability distributions. *Journal of the American Statistical Association, 100*(470), 680-701.
Gehrels, W. R., Marshall, W. A., Gehrels, M. J., Larsen, G., Kirby, J. R., Eiriksson, J., Heinemeier, J., & Shimmield, T. (2007). Rapid sea-level rise in the North Atlantic Ocean since the first half of the nineteenth century (vol 17, pg 419, 2007). *Holocene, 17*(3), 419-420.

Goldstein, K. (2002). Getting in the door: sampling and completing elite interviews. *PS: Political Science & Politics, 35*(04), 669-672.
Gregory, R. (2012). *Public Opinion of Managed Realignment at the Newport Wetlands: A Contingent Valuation Study.* (MESci), Cardiff University.
Gregory, R. S., & Satterfield, T. A. (2002). Beyond perception: The experience of risk and stigma in community contexts. *Risk analysis, 22*(2), 347-358.
Grichting, W. L. (1994). The meaning of "I don't know" in opinion surveys: Indifference versus ignorance. *Australian Psychologist, 29*(1), 71-75.
Grothmann, T., & Reusswig, F. (2006). People at risk of flooding: why some residents take precautionary action while others do not. *Natural hazards, 38*(1-2), 101-120.
Halcomb, E. J., & Davidson, P. M. (2006). Is verbatim transcription of interview data always necessary? *Applied Nursing Research, 19*(1), 38-42.
Hamilton, C., & Kasser, T. (2009). *Psychological adaptation to the threats and stresses of a four degree world*. Paper presented at the Four degrees and beyond Conference, Oxford University, UK.
Hamilton, L. C. (2008). Who cares about polar regions? Results from a survey of US public opinion. *Arctic, Antarctic, and Alpine Research, 40*(4), 671-678.
Hamilton, L. C., Cutler, M. J., & Schaefer, A. (2012). Public knowledge and concern about polar-region warming. *Polar Geography, 35*(2), 155-168.
Hansen, J. E., & Sato, M. (2012). Paleoclimate implications for human-made climate change. *Climate Change* 21-47.
Hansson, A., & Bryngelsson, M. (2009). Expert opinions on carbon dioxide capture and storage--A framing of uncertainties and possibilities. *Energy Policy, 37*(6), 2273-2282.
Hargreaves, I., Lewis, J., & Speers, T. (2003). *Towards a better map: Science, the public and the media*: Economic and Social Research Council Swindon,, UK.
Hargreaves, I., & Thomas, J. (2002). New news, old news: Broadcasting Standards Commission.
Harris, C., Daniels, K., & Briner, R. B. (2002). Using cognitive mapping for psychosocial risk assessment. *Risk Management, 4*(3), 7-21.
Harvatt, J., Petts, J., & Chilvers, J. (2011). Understanding householder responses to natural hazards: flooding and sea-level rise comparisons. *Journal of Risk Research, 14*(1), 63-83.
Haslett, S. K., & Bryant, E. A. (2004). The AD 1607 coastal flood in the Bristol Channel and Severn Estuary: historical records from Devon and Cornwall (UK). *Faculty of Science-Papers*, 95.
Haslett, S. K., & Bryant, E. A. (2007). Reconnaissance of historic (post-AD 1000) high-energy deposits along the Atlantic coasts of southwest Britain, Ireland and Brittany, France. *Marine Geology, 242*(1-3), 207-220.
Haslett, S. K., & Bryant, E. A. (2009). Meteorological Tsunamis in Southern Britain: An Historical Review. *Geographical Review, 99*(2), 146-163.
Heckathorn, D. D. (2011). Comment: Snowball versus Respondent-Driven Sampling. *Sociological methodology, 41*(1), 355-366.
Henwood, K. L., & Pidgeon, N. F. (1992). Qualitative research and psychological theorizing. *British Journal of Psychology, 83*(1), 97-111.
Hine, D. W., & Gifford, R. (1991). Fear appeals, individual differences, and environmental concern. *The Journal of Environmental Education, 23*(1), 36-41.
Horsburgh, K. (2011, 23 September). *Coastal flooding, 1607 floods, recent storm surges and weather events in the Severn estuary.* Paper presented at the Severn Estuary Forum, Cardiff, UK.
Horsburgh, K., & Horritt, M. (2006). The Bristol Channel floods of 1607: reconstruction and analysis. *Weather, 61*(10), 272-277.
Houghton, J. (2009). *Global Warming: The Complete Briefing* (4th ed.). New York: Cambridge University Press.
House of Commons. (2013). *A Severn Barrage? Second Report of Session 2013-14*. (HC 194).
Hovey, C. (2010). Climate Change on the Severn Estuary. Cardiff, UK: IMCORE (Innovative Management for Europe's Changing Coastal Resource).
HR Wallingford. (1997). Estuaries: The case for research into morphology and processes (pp. 48).
Huggel, C., Stone, D., Auffhammer, M., & Hansen, G. (2013). Loss and damage attribution. *Nature Climate Change, 3*(8), 694-696.
Hulme, M., Pielke, R., & Dessai, S. (2009). Keeping prediction in perspective. (0911), 126-127.
IMCORE. (2011). Expert Couplet for the Severn Estuary. Retrieved 24 January, 2011, from http://imcore.wordpress.com/partners/severn-estuary/

IPCC. (2000). IPCC Special Report: Emissions Scenarios. Summary for Policymakers *A Special Report of Working Group III of the Intergovernmental Panel on Climate Change*.
IPCC. (2001). Climate change 2001: Impacts, adaptation, and vulnerability. Summary for Policy Makers: Working Group II of the Intergovernmental Panel on Climate Change.
IPCC. (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In Core Writing Team, R. K. Pachauri & A. Reisinger (Eds.), (pp. 104). Geneva, Switzerland: IPCC.
IPCC. (2012). Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. In C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. K. Allen, M. Tignor & P. M. Midgley (Eds.), *A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change* (pp. 19).
IPCC. (2013). Summary for Policy Makers. Climate Change 2013: The Physical Science Basis: Intergovernmental Panel on Climate Change.
Irwin, A., Dale, A., & Smith, D. (1996). Science and Hell's kitchen: the local understanding of hazard issues. In A. Irwin & B. Wynne (Eds.), *Misunderstanding science? The public reconstruction of science and technology* (pp. 47-64). Cambridge: Cambridge University Press.
Irwin, A., Simmons, P., & Walker, G. (1999). Faulty environments and risk reasoning: the local understanding of industrial hazards. *Environment and planning A, 31*(7), 1311-1326.
Istre, G. R., McCoy, M. A., Womack, K. N., Fanning, L., Dekat, L., & Stowe, M. (2002). Increasing the use of child restraints in motor vehicles in a Hispanic neighborhood. *American journal of public health, 92*(7), 1096-1099.
Jackson, D. N., & Messick, S. (1958). Content and style in personality assessment. *Psychological Bulletin, 55*(4), 243-252.
Jenkins, G. J., Murphy, J. M., Sexton, D. M. H., Lowe, J. A., Jones, P., & Kilsby, C. G. (2009). UK Climate Projections: Briefing report. Exeter, UK: Met Office Hadley Centre.
Jenkinson, D. (2005). The elicitation of probabilities-a review of the statistical literature. *University of Aberdeen, Aberdeen, Scotland*.
Johnson-Laird, P. N. (2013). Mental models and cognitive change. *Journal of Cognitive Psychology, 25*(2), 131-138.
Johnson, B. B. (1999). Ethical issues in risk communication: Continuing the discussion. *Risk Analysis, 19*(3), 335-348.
Johnson, B. B., & Slovic, P. (1995). Presenting uncertainty in health risk assessment: initial studies of its effects on risk perception and trust. *Risk Analysis, 15*(4), 485-494.
Jones, N. A., Ross, H., Lynam, T., Perez, P., & Leitch, A. (2011). Mental models: an interdisciplinary synthesis of theory and methods. *Ecology and Society, 16*(1), 46.
Jonkman, S. N., & Kelman, I. (2005). An analysis of the causes and circumstances of flood disaster deaths. *Disasters, 29*(1), 75-97.
Jonkman, S. N., Maaskant, B., Boyd, E., & Levitan, M. L. (2009). Loss of life caused by the flooding of New Orleans after Hurricane Katrina: analysis of the relationship between flood characteristics and mortality. *Risk Analysis, 29*(5), 676-698.
Kahan, D. M., Jenkins-Smith, H., & Braman, D. (2011). Cultural cognition of scientific consensus. *Journal of Risk Research, 14*(2), 147-174.
Kahan, D. M., Peters, E., Wittlin, M., Slovic, P., Ouellette, L. L., Braman, D., & Mandel, G. (2012). The polarizing impact of science literacy and numeracy on perceived climate change risks. *Nature Climate Change*.
Kahan, D. M., Slovic, P., Braman, D., & Gastil, J. (2006). Fear of democracy: A cultural evaluation of Sunstein on risk. *The Harvard Law Review, 119*(4), 1071-1109.
Kahlor, L., & Rosenthal, S. (2009). If we seek, do we learn? Predicting knowledge of global warming. *Science Communication, 30*(3), 380-414.
Kahneman, D. (2002). *Maps of bounded rationality: A perspective on intuitive judgment and choice.* Paper presented at the Nobel prize lecture.
Kant, I. (1996). Critique of pure reason (W. S. Pluhar, Trans.). Cambridge: Hackett Publishing.
Kasperson, R. E., Renn, O., Slovic, P., Brown, H. S., Emel, J., Goble, R., Kasperson, J. X., & Ratick, S. (1988). The social amplification of risk: A conceptual framework. *Risk analysis, 8*(2), 177-187.

Kates, R. W. (1971). Natural hazard in human ecological perspective: hypotheses and models. *Economic Geography, 47*(3), 438-451.
Kearney, A. R., & Kaplan, S. (1997). Toward a methodology for the measurement of knowledge structures of ordinary people. *Environment and Behavior, 29*(5), 579-617.
Keith, D. W. (1996). When is it appropriate to combine expert judgments? *Climatic Change, 33*(2), 139-143.
Kellens, W., Terpstra, T., & De Maeyer, P. (2013). Perception and communication of flood risks: a systematic review of empirical research. *Risk Analysis, 33*(1), 24-49.
Kellstedt, P. M., Zahran, S., & Vedlitz, A. (2008). Personal efficacy, the information environment, and attitudes toward global warming and climate change in the United States. *Risk Analysis, 28*(1), 113-126.
Kempton, W. (1997). How the public views climate change. *Environment: Science and Policy for Sustainable Development, 39*(9), 12-21.
Kerr, R. A. (2009). Amid worrisome signs of warming, 'climate fatigue'sets in. *Science, 326*(5955), 926-928.
Kirby, R. (2010). Distribution, transport and exchanges of fine sediment, with tidal power implications: Severn Estuary, UK. *Marine pollution bulletin, 61*(1-3), 21-36.
Knowles, S., & Myatt-Bell, L. (2001). The Severn Estuary Strategy: a consensus approach to estuary management. *Ocean and Coastal Management, 44*(12), 135-159.
Korontzi, D. (2009). Severn Tidal Tributaries Catchment Flood Management Plan: Summary Report *Catchment Flood Management Plans (CFMP)* (pp. 32): Environment Agency.
Kort, E. A., Wofsy, S. C., Daube, B. C., Diao, M., Elkins, J. W., Gao, R. S., Hintsa, E. J., Hurst, D. F., Jimenez, R., Moore, F. L., Spackman, J. R., & Zondlo, M. A. (2012). Atmospheric observations of Arctic Ocean methane emissions up to 82 Deg North. *Nature Geoscience, 5*, 318-321.
Kovats, S. (2008). *Health Effects of Climate Change in the UK 2008: An update of the Department of Health Report 2001/2002*.
Krasovskaia, I., Gottschalk, L., Sælthun, N. R., & Berg, H. (2001). Perception of the risk of flooding: the case of the 1995 flood in Norway. *Hydrological sciences journal, 46*(6), 855-868.
Kreibich, H., Thieken, A. H., Grunenberg, H., Ullrich, K., & Sommer, T. (2009). Extent, perception and mitigation of damage due to high groundwater levels in the city of Dresden, Germany. *Natural Hazards and Earth System Science, 9*(4), 1247-1258.
Kriegler, E., Hall, J. W., Held, H., Dawson, R., & Schellnhuber, H. J. (2009). Imprecise probability assessment of tipping points in the climate system. *Proceedings of the National Academy of Sciences, 106*(13), 5041-5046.
Krosnick, J. A., Holbrook, A. L., Lowe, L., & Visser, P. S. (2006). The origins and consequences of democratic citizens' policy agendas: A study of popular concern about global warming. *Climatic change, 77*(1-2), 7-43.
Kuhn, T. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.
Kunreuther, H., Heal, G., Allen, M., Edenhofer, O., Field, C. B., & Yohe, G. (2013). Risk Management and Climate Change. *Nature Climate Change, 3*, 447-450
Kunreuther, H., & Slovic, P. (2001). Coping with Stigma: Challenges and Opportunities. In J. Flynn, P. Slovic & H. Kunreuther (Eds.), *Risk, media, and stigma: Understanding public challenges to modern science and technology* (pp. 331-352). London: Earthscan.
Langston, W. J., Jonas, P. J. C., & Millward, G. E. (2010). The Severn Estuary and Bristol Channel: A 25 year critical review. *Marine Pollution Bulletin, 61*(1-3), 1-4.
Lapadat, J. C. (2000). Problematizing transcription: Purpose, paradigm and quality. *International Journal of Social Research Methodology, 3*(3), 203-219.
Lash, S. (2000). Risk culture. In B. Adam, U. Beck & J. Van Loon (Eds.), *The Risk Society and Beyond: Critical Issues for Social Theory* (pp. 47-62). London: Sage.
Lata, S., & Nunn, P. (2011). Misperceptions of climate-change risk as barriers to climate-change adaptation: a case study from the Rewa Delta, Fiji. *Climatic Change*, 1-18.
Leiserowitz, A. (2006). Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climatic Change, 77*(1), 45-72.
Leiserowitz, A. A., Smith, N., & Marlon, J. R. (2010). Americans' knowledge of climate change. Yale University, USA: Yale Project on Climate Change Communication: bridging science & society.
Lenton, T., Loutre, M.-F., Williamson, M., Warren, R., Goodess, C., Swann, M., Cameron, D., Hankin, R., Marsh, R., & Shepherd, J. (2006). Climate change on the millennial timescale. Norwich, UK: Tyndall Centre for Climate Change Research.

Liberman, N., & Trope, Y. (2008). The psychology of transcending the here and now. *Science, 322*(5905), 1201-1205.

Lonsdale, K. G., Downing, T. E., Nicholls, R. J., Parker, D., Vafeidis, A. T., Dawson, R., & Hall, J. (2008). Plausible responses to the threat of rapid sea-level rise in the Thames Estuary. *Climatic Change, 91*(1-2), 145-169.

Lorenzoni, I., & Hulme, M. (2009). Believing is seeing: laypeople's views of future socio-economic and climate change in England and in Italy. *Public Understanding of Science, 18*(4), 383-400.

Lorenzoni, I., Leiserowitz, A., De Franca Doria, M., Poortinga, W., & Pidgeon, N. F. (2006). Cross-National Comparisons of Image Associations with "Global Warming" and "Climate Change" Among Laypeople in the United States of America and Great Britain 1. *Journal of Risk Research, 9*(03), 265-281.

Lorenzoni, I., Nicholson-Cole, S., & Whitmarsh, L. (2007). Barriers perceived to engaging with climate change among the UK public and their policy implications. *Global environmental change, 17*(3), 445-459.

Lorenzoni, I., & Pidgeon, N. F. (2006). Public views on climate change: European and USA perspectives. *Climatic Change, 77*(1-2), 73-95.

Lowe, J. A., P., H. T., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., Reeder, T., Jenkins, G., Ridley, J., Dye, S., & Bradley, S. (2009). UK Climate Projections science report: Marine and coastal projections. Exeter: Met Office Hadley Centre, UK.

Lowe, T., Brown, K., Dessai, S., De França Doria, M., Haynes, K., & Vincent, K. (2006). Does tomorrow ever come? Disaster narrative and public perceptions of climate change. *Public understanding of science, 15*(4), 435-457.

Lowe, T. D., & Lorenzoni, I. (2007). Danger is all around: Eliciting expert perceptions for managing climate change through a mental models approach. *Global Environmental Change, 17*(1), 131-146.

Maharik, M., & Fischhoff, B. (1993). Contrasting perceptions of the risks of using nuclear energy sources in space. *Journal of Environmental Psychology, 13*(3), 243-250.

Marx, S. M., Weber, E. U., Orlove, B. S., Leiserowitz, A., Krantz, D. H., Roncoli, C., & Phillips, J. (2007). Communication and mental processes: Experiential and analytic processing of uncertain climate information. *Global Environmental Change, 17*(1), 47-58.

Mastrandrea, M. D., Field, C. B., Stocker, T. F., Edenhofer, O., Ebi, K. L., Frame, D. J., Held, H., Kriegler, E., Mach, K. J., & Matschoss, P. R. (2010). Guidance note for lead authors of the IPCC fifth assessment report on consistent treatment of uncertainties: Intergovernmental Panel on Climate Change (IPCC).

Mastrandrea, M. D., & Schneider, S. H. (2004). Probabilistic integrated assessment of "dangerous" climate change. *Science, 304*(5670), 571.

Matteson, S. M., & Lincoln, Y. S. (2009). Using Multiple Interviewers in Qualitative Research Studies: The Influence of Ethic of Care Behaviors in Research Interview Settings. *Qualitative Inquiry, 15*(4), 659-674.

Mautner, T. (1996). *The Penguin dictionary of philosophy*. London: Penguin books.

Maximiles. (2013). Elma Ingenierie Informatique. London, UK.

MCCIP. (2010). Marine Climate Change Impacts Partnership Annual Report Card 2010-11. In B. JM, B. PJ & C. Wallace (Eds.), *MCCIP* (pp. 12). Lowestoft: MCCIP.

McCright, A. M. (2010). The effects of gender on climate change knowledge and concern in the American public. *Population and Environment, 32*(1), 66-87.

McGranahan, G., Balk, D., & Anderson, B. (2007). The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones *Environment and Urbanization, 19*, 17-37.

McKechnie, R. (1996). Insiders and outsiders: identifying experts on home ground. In A. Irwin & B. Wynne (Eds.), *Misunderstanding science? The public reconstruction of science and technology* (pp. 126-151). Cambridge: Cambridge University Press.

McKenna, F. P. (1993). It won't happen to me: unrealistic optimism or illusion of control? *British Journal of Psychology, 84*(1), 39-50.

McLellan, E., MacQueen, K. M., & Neidig, J. L. (2003). Beyond the qualitative interview: data preparation and transcription. *Field Methods, 15*(1), 63.

Michael, M. (1992). Lay discourses of science: science-in-general, science-in-particular, and self. *Science, Technology & Human Values, 17*(3), 313-333.

Miller, A. C., Merkhofer, M. W., Howard, R. A., Matheson, J. E., & Rice, T. R. (1976). Development of automated aids for decision analysis: Stanford Research Institute.
Milne, G. A., Gehrels, W. R., Hughes, C. W., & Tamisiea, M. E. (2009). Identifying the causes of sea-level change. *Nature Geoscience, 2*(7), 471-478.
Morgan, M. G. (2011). Certainty, uncertainty, and climate change. *Climatic Change*, 1-15.
Morgan, M. G., Fischhoff, B., Bostrom, A., & Atman, C. J. (2002). *Risk Communication: A Mental Models Approach*. Cambridge: Cambridge University Press.
Morgan, M. G., & Henrion, M. (1990). *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis*. Cambridge: Cambridge University Press.
Morgan, M. G., & Keith, D. W. (1995). Subjective judgements by climate experts. *Environmental Science & Technology, 29*(10), 468-476.
Morgan, M. G., Pitelka, L. F., & Shevliakova, E. (2001). Elicitation of expert judgments of climate change impacts on forest ecosystems. *Climatic Change, 49*(3), 279-307.
Moser, C., Stauffacher, M., Krütli, P., & Scholz, R. W. (2011). The Crucial Role of Nomothetic and Idiographic Conceptions of Time: Interdisciplinary Collaboration in Nuclear Waste Management. *Risk Analysis, 32*(1), 138-154.
Moser, S. C. (2007). More bad news: The risk of neglecting emotional responses to climate change information. In S. C. Moser & L. Dilling (Eds.), *Creating a Climate for Change: Communicating Climate Change and Facilitating Social Change*. New York: Cambridge University Press.
Murphy, A. H., & Winkler, R. L. (1974). Credible interval temperature forecasting: some experimental results. *Monthly Weather Review, 102*, 784.
Myers, R. H. (1990). *Classical and modern regression with applications* (2nd ed.). California: Duxbury Press.
New, M., Liverman, D., & Anderson, K. (2009). Mind the gap. *Nature Reports Climate Change*(0912), 143-144.
New, M., Liverman, D., Schroder, H., & Anderson, K. (2011). Four degrees and beyond: the potential for a global temperature increase of four degrees and its implications. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 369*(1934), 6-19.
Nicholls, R. J. (2010). Impacts of and Responses to Sea-Level Rise. In J. Church, P. L. Woodworth, T. Aarup & S. Wilson (Eds.), *Understanding sea-level rise and variability*. Chichester: Wiley-Blackwell.
Nicholls, R. J. (2011). Planning for the impacts of sea level rise. *Oceanography, 24*(2), 144-157.
Nicholls, R. J., & Cazenave, A. (2010). Sea-Level Rise and Its Impact on Coastal Zones. *Science, 328*(5985), 1517-1520.
Nicholls, R. J., Hanson, S., Herweijer, C., Patmore, N., Hallegatte, S., Corfee-Morlot, J., Château, J., & Muir-Wood, R. (2008). Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates *OECD Environment Working Papers*.
Nicholls, R. J., Hanson, S. E., Lowe, J. A., Warrick, R. A., Lu, X., Long, A. J., & Carter, T. R. (2011a). Constructing Sea-Level Scenarios for Impact and Adaptation Assessment of Coastal Areas: A Guidance Document. Supporting material, Intergovernmental Panel on Climate Change Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA) (pp. 47): IPCC.
Nicholls, R. J., & Lowe, J. A. (2004). Benefits of mitigation of climate change for coastal areas. *Global Environmental Change Part A, 14*(3), 229-244.
Nicholls, R. J., Marinova, N., Lowe, J. A., Brown, S., Vellinga, P., de Gusmão, D., Hinkel, J., & Tol, R. S. J. (2011b). Sea-level rise and its possible impacts given a 'beyond 4° C world' in the twenty-first century. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 369*(1934), 161.
Nordhaus, W. D. (1994). Expert opinion on climatic change. *American Scientist, 82*, 45-45.
Nordstrom, K. F. (2009). Estuaries. In D. J. Cuff & A. S. Goudie (Eds.), *The Oxford Companion to Global Change*. New York: Oxford University Press.
O'Brien, D. P., Braine, M. D. S., & Yang, Y. (1994). Propositional reasoning by mental models? Simple to refute in principle and in practice. *Psychological Review, 101*(4), 711.
O'Connell, D. C., & Kowal, S. (1999). Transcription and the issue of standardization. *Journal of psycholinguistic research, 28*(2), 103-120.
O'Hagan, A., Buck, C. E., Daneshkhah, A., Eiser, J. R., Garthwaite, P. H., Jenkinson, D. J., Oakley, J. E., & Rakow, T. (2006). *Uncertain judgements: Eliciting experts' probabilities*. Chichester: Wiley.
O'Hagan, A., & Oakley, J. E. (2004). Probability is perfect, but we can't elicit it perfectly. *Reliability Engineering & System Safety, 85*(1-3), 239-248.

O'Neill, S., & Nicholson-Cole, S. (2009). "Fear Won't Do It" Promoting Positive Engagement With Climate Change Through Visual and Iconic Representations. *Science Communication, 30*(3), 355-379.
O'Neill, S. J., Osborn, T. J., Hulme, M., Lorenzoni, I., & Watkinson, A. R. (2008). Using expert knowledge to assess uncertainties in future polar bear populations under climate change. *Journal of Applied Ecology, 45*(6), 1649-1659.
Oberauer, K. (2006). Reasoning with conditionals: A test of formal models of four theories. *Cognitive Psychology, 53*(3), 238-283.
Office for National Statistics. (2012). Internet Access - Households and Individuals, 2012 (pp. 19): ONS.
Oliver, D. G., Serovich, J. M., & Mason, T. L. (2005). Constraints and opportunities with interview transcription: Towards reflection in qualitative research. *Social forces; a scientific medium of social study and interpretation, 84*(2), 1273.
Oppenheim, A. N. (1996). *Questionnaire design, interviewing and attitude measurement*: Pinter Publishers.
Oppenheimer, M., O'Neill, B. C., Webster, M., & Agrawala, S. (2007). The limits of consensus. *Science 317*(5844).
Otto-Banaszak, I., Matczak, P., Wesseler, J., & Wechsung, F. (2011). Different perceptions of adaptation to climate change: a mental model approach applied to the evidence from expert interviews. *Regional environmental change, 11*(2), 217-228.
Oulton, C., Dillon, J., & Grace, M. M. (2004). Reconceptualizing the teaching of controversial issues. *International Journal of Science Education, 26*(4), 411-423.
Ozesmi, U., & Ozesmi, S. L. (2004). Ecological models based on people's knowledge: a multi-step fuzzy cognitive mapping approach. *Ecological Modelling, 176*(1-2), 43-64.
Pahl, S. (2010, 22 September). *Psychological Distance: Exploring Construal Level Theory in the Context of Sustainability*. Paper presented at the Psychological Distance & Sustainability, Cardiff University.
Parkhill, K. A., Henwood, K. L., Pidgeon, N. F., & Simmons, P. (2011). Laughing it off? Humour, affect and emotion work in communities living with nuclear risk. *The British Journal of Sociology, 62*(2), 324-346.
Parkhill, K. A., Pidgeon, N. F., Henwood, K. L., Simmons, P., & Venables, D. (2010). From the familiar to the extraordinary: local residents' perceptions of risk when living with nuclear power in the UK. *Transactions of the Institute of British Geographers, 35*(1), 39-58.
Peach, S. (2012). Sea Level Rise, One More Frontier For Climate Dialogue Controversy. *The Yale Forum on Climate Change and the Media.* Retrieved 5 March, 2013, from http://www.yaleclimatemediaforum.org/2012/02/sea-level-rise-one-more-frontier-for-climate-dialogue-controversy/
Peterson, C. (2000). The future of optimism. *American psychologist, 55*(1), 44.
Phillips, L. D. (1984). A theory of requisite decision models. *Acta psychologica, 56*(1), 29-48.
Phillips, M. R., & Crisp, S. (2010). Sea level trends and NAO influences: The Bristol Channel/Severn Estuary. *Global and Planetary Change, 73*(3-4), 211-218.
Pidgeon, N. (2010). Report 5: Public Understanding of and Attitudes Towards Climate Change *International Dimensions of Climate Change*. London: Foresight.
Pidgeon, N. (2012). Public understanding of, and attitudes to, climate change: UK and international perspectives and policy. *Climate Policy, 12*(Supplement 01), 85-106.
Pidgeon, N., & Beattie, J. (1998). The Psychology of Risk and Uncertainty. In P. Calow (Ed.), *Handbook of Environmental Risk Assessment and Management* (pp. 289-318). Oxford: Blackwell.
Pidgeon, N., & Fischhoff, B. (2011). The role of social and decision sciences in communicating uncertain climate risks. *Nature Climate Change, 1*(1), 35-41.
Pidgeon, N., Hood, C., Jones, D., Turner, B., & Gibson, R. (1992). Risk perception. In The Royal Society (Ed.), *Risk: analysis, perception and management* (pp. 89-134).
Pidgeon, N., Simmons, P., & Henwood, K. (2006). Risk, Environment, and Technology. In P. Taylor-Gooby & J. O. Zinn (Eds.), *Risk in social science*. New York: Oxford University Press.
Poland, B. D. (2001). Transcription Quality. In J. F. Gubrium & J. A. Holstein (Eds.), *Handbook of Interview Research: Context and Method* (pp. 629-649). California: Sage Publications.
Poortinga, W., Pidgeon, N., & Lorenzoni, I. (2006). Public perceptions of nuclear power, climate change and energy options in Britain: summary findings of a survey conducted during October and November 2005 *Tyndall Centre for Climate Change Research*: Understanding Risk Working Paper.
Poortinga, W., & Pidgeon, N. F. (2003). Exploring the dimensionality of trust in risk regulation. *Risk analysis, 23*(5), 961-972.

Poortinga, W., Spence, A., Whitmarsh, L., Capstick, S., & Pidgeon, N. F. (2011). Uncertain climate: An investigation into public scepticism about anthropogenic climate change. *Global Environmental Change, 21*(3), 1015-1024.
Popper, K. R. (1963). *Conjectures and refutations* (Vol. 28). London: Routledge & Kegan Paul.
Powell, M., Dunwoody, S., Griffin, R., & Neuwirth, K. (2007). Exploring lay uncertainty about an environmental health risk. *Public understanding of science, 16*(3), 323-343.
Prior, J., & Beswick, M. (2008). The exceptional rainfall of 20 July 2007. *Weather, 63*(9), 261-267.
Proctor, R., & Flather, R. A. (1989). Storm surge prediction in the Bristol Channel--the floods of 13 December 1981. *Continental Shelf Research, 9*(10), 889-918.
Qualtrics. (2013). Qualtrics (Version 37,892). Provo, Utah, USA.
Rahmstorf, S. (2007). A semi-empirical approach to projecting future sea-level rise. *Science, 315*(5810), 368.
Rahmstorf, S., Foster, G., & Cazenave, A. (2012). Comparing climate projections to observations up to 2011. *Environmental Research Letters, 7*(4), 044035-044040.
Rapoport, R. B. (1985). Like mother, like daughter: Intergenerational transmission of DK response rates. *Public Opinion Quarterly, 49*(2), 198-208.
Raymo, M. E., Grant, B., Horowitz, M., & Rau, G. H. (1996). Mid-Pliocene warmth: stronger greenhouse and stronger conveyor. *Marine Micropaleontology, 27*(1), 313-326.
Read, D., Bostrom, A., Morgan, M. G., Fischhoff, B., & Smuts, T. (1994). What do people know about global climate change? 2. Survey studies of educated laypeople. *Risk Analysis, 14*(6), 971-982.
Renn, O., & Levine, D. (1991). Credibility and trust in risk communication. In R. E. Kasperson & P. J. M. Stallen (Eds.), *Communicating Risks to the Public* (pp. 175-218). Netherlands: Kluwer Academic Publishers.
Renooij, S. (2001). Probability elicitation for belief networks: issues to consider. *The Knowledge Engineering Review, 16*(03), 255-269.
Reynolds, T. W., Bostrom, A., Read, D., & Morgan, M. G. (2010). Now what do people know about global climate change? Survey studies of educated laypeople. *Risk Analysis, 30*(10), 1520-1538.
Rice, G. (2010). Reflections on interviewing elites. *Area, 42*(1), 70-75.
Rick, U. K., Boykoff, M. T., & Pielke Jr, R. A. (2011). Effective media reporting of sea level rise projections: 1989–2009. *Environmental Research Letters, 6*, 014004-014009.
Roeser, S. (2012). Risk Communication, Public Engagement, and Climate Change: A Role for Emotions. *Risk Analysis*.
Rogers, R. W. (1975). A Protection Motivation Theory of Fear Appeals and Attitude Change. *The Journal of Psychology, 91*(1), 93-114.
Rohling, E. (2011). The rise and rise of the sea. *Planet Earth Online.* Retrieved 28 February, 2011, from http://planetearth.nerc.ac.uk/features/story.aspx?id=880
Ryan, A., Gorddard, R., Abel, N., Leitch, A. M., Alexander, K. S., & Wise, R. M. (2012). Perceptions of Sea-Level Rise Risk and the Assessment of Managed Retreat Policy: Results from an Exploratory Community Survey in Australia CSIRO: Climate Adaptation National Research Flagship.
Safford, T. G., & Hamilton, L. C. (2012). Demographic change and shifting views about marine resources and the coastal environment in Downeast Maine. *Population and Environment, 33*(4), 284-303.
Sandman, P., & Lanard, J. (2011). Explaining and Proclaiming Uncertainty: Risk Communication Lessons from Germany's Deadly E. coli Outbreak *The Peter Sandman risk communication web site.* Retrieved 1 March, 2013, from www.psandman.com/col/GermanEcoli.htm
Schaeffer, M., Hare, W., Rahmstorf, S., & Vermeer, M. (2012). Long-term sea-level rise implied by 1.5°C and 2°C warming levels. *Nature Climate Change, 2*, 867-870.
Scheier, M. F., Carver, C. S., & Bridges, M. W. (1994). Distinguishing optimism from neuroticism (and trait anxiety, self-mastery, and self-esteem): A reevaluation of the Life Orientation Test. *Journal of personality and social psychology, 67*, 1063-1063.
Schultz, P. W. (2001). The structure of environmental concern: Concern for self, other people, and the biosphere. *Journal of environmental psychology, 21*(4), 327-339.
Schuman, H., & Kalton, G. (1985). Survey methods. In G. Lindzey & E. Aronson (Eds.), *Handbook of social psychology* (3rd ed., Vol. 1, pp. 24). New York: Random House.
Schwartz, S. H. (1992). Universals in the content and structure of values: Theoretical advances and empirical tests in 20 countries. In M. P. Zanna (Ed.), *Advances in experimental social psychology* (Vol. 25, pp. 1-65). San Diego: Academic Press.

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Severn Estuary Partnership. (2009, 2009). The Partnership: Severn Estuary Partnership Boundary. *Severn Estuary Partnership: Working in partnership for the future of the Severn Estuary* Retrieved 11 August, 2011, from http://www.severnestuary.net/sep/partnership.html
Severn Estuary Partnership. (2011). State of the Severn Estuary Report: An initial overview of the Estuary's use and features (pp. 67). UK: SEP.
Shennan, I., & Horton, B. (2002). Holocene land- and sea-level changes in Great Britain. *Journal of Quaternary Science, 17*(5-6), 511-526.
Shuckburgh, E., Robison, R., & Pidgeon, N. (2012). Climate Science, the Public and the News Media: Living With Environmental Change.
Siegrist, M., & Gutscher, H. (2006). Flooding risks: A comparison of lay people's perceptions and expert's assessments in Switzerland. *Risk Analysis, 26*(4), 971-979.
Siegrist, M., & Gutscher, H. (2008). Natural hazards and motivation for mitigation behavior: People cannot predict the affect evoked by a severe flood. *Risk Analysis, 28*(3), 771-778.
Sims, J. H., & Baumann, D. D. (1972). The tornado threat: Coping styles of the North and South. *Science, 176*(4042), 1386-1392.
Slimak, M. W., & Dietz, T. (2006). Personal values, beliefs, and ecological risk perception. *Risk analysis, 26*(6), 1689-1705.
Slovic, P. (1995). The construction of preference. *American psychologist, 50*(5), 364.
Slovic, P., Finucane, M. L., Peters, E., & MacGregor, D. G. (2004). Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk, and rationality. *Risk Analysis, 24*(2), 311-322.
Slovic, P., Finucane, M. L., Peters, E., & MacGregor, D. G. (2007). The affect heuristic. *European Journal of Operational Research, 177*(3), 1333-1352.
Slovic, P., Monahan, J., & MacGregor, D. G. (2000). Violence risk assessment and risk communication: The effects of using actual cases, providing instruction, and employing probability versus frequency formats. *Law and human behavior, 24*(3), 271-296.
Smith, M. S., Horrocks, L., Harvey, A., & Hamilton, C. (2011). Rethinking adaptation for a 4° C world. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 369*(1934), 196.
Socolow, R. H. (2011). High-consequence outcomes and internal disagreements: tell us more, please. *Climatic change, 108*(4), 775-790.
Solomon, S., Qin, D., Manning, M., Alley, R. B., Berntsen, T., Bindoff, N. L., Chen, Z., Chidthaisong, A., Gregory, J. M., Hegerl, G. C., Heimann, M., Hewitson, B., Hoskins, B. J., Joos, F., Jouzel, J., Kattsov, V., Lohmann, U., Matsuno, T., Molina, M., Nicholls, N., Overpeck, J., Raga, G., Ramaswamy, V., Ren, J., Rusticucci, M., Somerville, R., Stocker, T. F., Whetton, P., Wood, R. A., & Wratt, D. (2007). IPCC Fourth Assessment Report: Technical Summary. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor & H. L. Miller (Eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.
Spence, A., & Pidgeon, N. (2010). Framing and communicating climate change: The effects of distance and outcome frame manipulations. *Global Environmental Change, 20*(4), 656-667.
Spence, A., Poortinga, W., Butler, C., & Pidgeon, N. F. (2011). Perceptions of climate change and willingness to save energy related to flood experience. *Nature Climate Change, 1*(1), 46-49.
Spence, A., Poortinga, W., & Pidgeon, N. (2012). The Psychological Distance of Climate Change. *Risk Analysis, 32*(6), 957-972.

Spence, A., Poortinga, W., Pidgeon, N., & Lorenzoni, I. (2010a). Public perceptions of energy choices: The influence of beliefs about climate change and the environment. *Energy & environment, 21*(5), 385-407.
Spence, A., Venables, D., Pidgeon, N., Poortinga, W., & Demski, C. (2010b). Public Perceptions of Climate Change and Energy Futures in Britain: Summary Findings of a Survey Conducted in January–March 2010. School of Psychology, Cardiff University: Understanding Risk Working Paper 10-01.
Spetzler, C. S., & Stael Von Holstein, C. A. S. (1975). Probability encoding in decision analysis. *Management Science, 22*(3), 340-358.
Stephens, N. (2007). Collecting data from elites and ultra elites: Telephone and face-to-face interviews with macroeconomists. *Qualitative Research, 7*(2), 203.
Sterenfeld, M. (2012). *Climate change perceptions: how recreational fishermen perceive the risk of climate change to themselves and the fishing industry as a whole.* (MESci), Cardiff University.
Stern, P. C., & Fineberg, H. V. (Eds.). (1996). *Understanding Risk: Informing Decisions in a Democratic Society*. Washington, D. C.: The National Academies Press.
Stirling, A. (2010). Keep it complex. *Nature, 468*(7327), 1029-1031.
Stirling, A. (2011). Intolerance: retain healthy scepticism. *Nature, 471*(7338), 305-305.
Sturgis, P., & Allum, N. (2004). Science in society: re-evaluating the deficit model of public attitudes. *Public understanding of science, 13*(1), 55-74.
Tansey, J., & O'Riordan, T. (1999). Cultural theory and risk: a review. *Health, risk & society, 1*(1), 71-90.
Taylor, S. E., & Brown, J. D. (1988). Illusion and Well-Being: A Social Psychological Perspective on Mental Health. *Psychological Bulletin, 103*(2), 193-210.
Taylor, S. E., & Gollwitzer, P. M. (1995). Effects of mindset on positive illusions. *Journal of personality and social psychology, 69*(2), 213.
Terpstra, T. (2011). Emotions, trust, and perceived risk: Affective and cognitive routes to flood preparedness behavior. *Risk Analysis, 31*(10), 1658-1675.
Terpstra, T., Lindell, M. K., & Gutteling, J. M. (2009). Does Communicating (Flood) Risk Affect (Flood) Risk Perceptions? Results of a Quasi-Experimental Study. *Risk Analysis, 29*(8), 1141-1155.
The British Psychological Society. (2010). Code of Human Research Ethics. Leicester.
The Royal Society. (2009). Geoengineering the climate: science, governance and uncertainty (pp. 98): The Royal Society.
Tikkanen, J., Isokaanta, T., Pykalainen, J., & Leskinen, P. (2006). Applying cognitive mapping approach to explore the objective-structure of forest owners in a Northern Finnish case area. *Forest Policy and Economics, 9*(2), 139-152.
Tillin, H. M., Houghton, A. J., Saunders, J. E., Drabble, R., & Hull, S. C. (2011). Direct and Indirect Impacts of Aggregate Dredging *Marine ALSF Science Monograph Series*.
Titus, J. G., & Narayanan, V. (1996). The risk of sea level rise. *Climatic Change, 33*(2), 151-212.
Tobler, C., Visschers, V. H. M., & Siegrist, M. (2012). Consumers' knowledge about climate change. *Climatic Change, 114*(2), 189-209.
Tol, R. S. J., Klein, R. J. T., & Nicholls, R. J. (2009). Towards successful adaptation to sea-level rise along Europe's coasts. *Journal of Coastal Research, 24*(2), 432-442.
Tonn, B., Hemrick, A., & Conrad, F. (2006). Cognitive representations of the future: survey results. *Futures, 38*(7), 810-829.
Trope, Y., & Liberman, N. (2003). Temporal construal. *Psychological Review, 110*(3), 403.
Trope, Y., & Liberman, N. (2010). Construal-level theory of psychological distance. *Psychological Review, 117*(2), 440.
Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive psychology, 5*(2), 207-232.
Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185*(4157), 1124.
UK Climate Projections. (2010). Technical note on storm projections.
UK Climate Projections. (2012). UK Climate Projections User Interface. Retrieved 1 October 2012, 2012, from http://ukclimateprojections.defra.gov.uk/21729
UKCIP. (2012). UK Climate Projections. Retrieved 18 July, 2012, from http://ukclimateprojections.defra.gov.uk/21729
van Asselt, M. B. A., van't Klooster, S. A., van Notten, P. W. F., & Smits, L. A. (2010). *Foresight in Action: Developing Policy-Oriented Scenarios*. London: Earthscan.

van der Pligt, J., de Vries, N. K., Manstead, A. S. R., & van Harreveld, F. (2000). The importance of being selective: Weighing the role of attribute importance in attitudinal judgment. *Advances in experimental social psychology, 32*, 135-200.
Varki, A. (2009). Human uniqueness and the denial of death. *Nature, 460*(7256), 684-684.
Vaughan, D. G., & Spouge, J. R. (2002). Risk estimation of collapse of the West Antarctic Ice Sheet. *Climatic Change, 52*(1), 65-91.
Vosgerau, J. (2010). How prevalent is wishful thinking? Misattribution of arousal causes optimism and pessimism in subjective probabilities. *Journal of Experimental Psychology: General, 139*(1), 32.
Wagner, K. (2007). Mental models of flash floods and landslides. *Risk Analysis, 27*(3), 671-682.
Wainwright, M. (2012, 17 October). Warnings of tidal surges and gales on south-west coast of UK, *Guardian*. Retrieved from http://www.guardian.co.uk/uk/2012/oct/17/flood-gales-south-west-uk
Walls, J., Pidgeon, N., Weyman, A., & Horlick-Jones, T. (2004). Critical trust: understanding lay perceptions of health and safety risk regulation. *Health, risk & society, 6*(2), 133-150.
Wallsten, T. S., & Budescu, D. V. (1983). Encoding subjective probabilities: A psychological and psychometric review. *Management Science, 29*(2), 151-173.
Warren, C. A. B. (2001). Qualitative Interviewing. In J. F. Gubrium & J. A. Holstein (Eds.), *Handbook of Interview Research: Context and Method* (pp. 83-101). California: Sage Publications.
Watson, S. R., & Buede, D. M. (1987). *Decision synthesis: The principles and practice of decision analysis*. Cambridge: Cambridge University Press.
Weber, E. U. (2006). Experience-based and description-based perceptions of long-term risk: Why global warming does not scare us (yet). *Climatic Change, 77*(1-2), 103-120.
Weber, E. U. (2010). What shapes perceptions of climate change? *Wiley Interdisciplinary Reviews: Climate Change, 1*(3), 332-342.
Weinstein, N. D. (1980). Unrealistic optimism about future life events. *Journal of personality and social psychology, 39*(5), 806.
Weinstein, N. D., Sandman, P. M., & Blalock, S. J. (2008). The Precaution Adoption Process Model. In K. Glanz, B. K. Rimer & K. Viswanath (Eds.), *Health Behavior and Health Education* (4 ed., pp. 123-147). San Francisco: Jossey-Bass.
Welsh Government. (2011). *National Strategy for Flood and Coastal Erosion Risk Management in Wales*. Crown Copyright.
White, A. (1996). Epistemology. In T. Mautner (Ed.), *The Penguin dictionary of philosophy*. London: Penguin books.
Whitmarsh, L. (2008). Are flood victims more concerned about climate change than other people? The role of direct experience in risk perception and behavioural response. *Journal of Risk Research, 11*(3), 351-374.
Whitmarsh, L. (2011). Scepticism and uncertainty about climate change: Dimensions, determinants and change over time. *Global Environmental Change, 21*(2), 690-700.
Whitmarsh, L., Kean, S., Peacock, M., Russell, C., & Haste, H. (2005). Connecting Science: what we know and what we don't know about science in society: British Association for the Advancement of Science.
Whitmarsh, L., & O'Neill, S. (2011). Introduction: Opportunities for and Barriers to Engaging Individuals with Climate Change. In L. Whitmarsh, S. O'Neill & I. Lorenzoni (Eds.), *Engaging the public with climate change: behaviour change and communication*. London: Earthscan.
Wikimedia Commons. (2012). from http://commons.wikimedia.org/wiki/Main_Page
Windschitl, P. D., Smith, A. R., Rose, J. P., & Krizan, Z. (2010). The desirability bias in predictions: Going optimistic without leaving realism. *Organizational behavior and human decision processes, 111*(1), 33-47.
Winkelmann, R., Levermann, A., Martin, M. A., & Frieler, K. (2012). Increased future ice discharge from Antarctica owing to higher snowfall. *Nature, 492*(7428), 239-242.
Wolf, J., & Moser, S. C. (2011). Individual understandings, perceptions, and engagement with climate change: insights from in-depth studies across the world. *Wiley Interdisciplinary Reviews: Climate Change, 2*(4), 547-569.
Wood, M. D., Bostrom, A., Bridges, T., & Linkov, I. (2012). Cognitive Mapping Tools: Review and Risk Management Needs. *Risk Analysis, 32*(8), 1333-1348.
Woodworth, P. L., Church, J., Aarup, T., & Wilson, W. S. (2010). Introduction. In J. Church, P. L. Woodworth, T. Aarup & S. Wilson (Eds.), *Understanding sea-level rise and variability*. Chichester: Wiley-Blackwell.

Woolf, D., & Wolf, J. (2010). Storms and Waves *in* MCCIP Annual Report Card 2010-11. In M. C. C. I. Partnership (Ed.), *MCCIP Science Review* (pp. 15pp).

World Economic Forum. (2011). Global Risks 2011 Sixth Edition: An initiative of the Risk Response Network. Geneva, Switzerland.

Wynne, B. (1991). Knowledges in Context. *Science, Technology, and Human Values, 16*(1), 111-121.

Wynne, B. (1996). May the Sheep Safely Graze? A Reflexive View of the Expert-Lay Knowledge Divide. In S. Lash, B. Szerszynski & B. Wynne (Eds.), *Risk, environment and modernity: towards a new ecology* (Vol. 40). London: Sage.

Wynne, B. (2011). Intolerance: science informs, not defines. *Nature, 471*(7338), 305-305.

Zickfeld, K., Levermann, A., Morgan, M. G., Kuhlbrodt, T., Rahmstorf, S., & Keith, D. W. (2007). Expert judgements on the response of the Atlantic meridional overturning circulation to climate change. *Climatic Change, 82*(3), 235-265.

Zickfeld, K., Morgan, M. G., Frame, D. J., & Keith, D. W. (2010). Expert judgments about transient climate response to alternative future trajectories of radiative forcing. *Proceedings of the National Academy of Sciences, 107*(28), 12451.

Zong, Y., & Tooley, M. J. (2003). A Historical Record of Coastal Floods in Britain: Frequencies and Associated Storm Tracks. *Natural Hazards, 29*, 13-36.

Zsamboky, M., Fernández-Bilbao, A., Smith, D., Knight, J., & Allan, J. (2011). Impacts of climate change on disadvantaged UK coastal communities: York, UK: Joseph Rowntree Foundation.