Public acceptance of nature-based solutions: towards sustainable natural hazard risk reduction

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To Nate, Cara, Cyrus, and Milo

Abstract

Without action, global impacts from natural hazards are expected to increase in frequency and severity due to climate change and concurrent ecological and social crises. Nature-based solutions (NbS) are sustainable approaches to disaster risk reduction (DRR) that provide multiple additional benefits for nature and to a range of stakeholders. NbS contrast with ‘grey’ infrastructure measures, which rely on non-natural materials, generally aim to address a single issue, and have fewer societal co-benefits. NbS are generally conceptualized as ‘green’ measures, although ‘hybrid’ measures (combining green and grey) are also NbS. DRR measures often rely on public and community buy-in for their success, but NbS amplify this reliance with their emphasis on co-creation, -implementation, and -monitoring.

Public acceptance is therefore directly linked to the ability of NbS to provide benefits, including DRR. Although NbS research increasingly focuses on barriers to its uptake, there is a lack of research on public acceptance of local residents in NbS ‘host communities’. Instead, it is often taken for granted that current high levels of public acceptance of NbS at European scale will be replicated at local levels and maintained over time. Additionally, there is a lack of past research that compares perceptions of NbS and grey measures, explores a broad range of factors that may influence public acceptance, and determines preferences across the full green-hybrid-grey spectrum.

This research, conducted within the Horizon 2020 OPERANDUM project, aims to determine factors that contribute to positive or negative attitudes and behaviours towards NbS for DRR. A systematic literature review was carried out, followed by citizen surveys and focus groups at planned European NbS sites. Surveys were conducted in Scotland (landslides; n=66 respondents), Finland (lake eutrophication; n=204) and Greece (flooding; n=84), followed by in-depth focus groups (n=4) at the Scotland site.

Results from the three methods noted above show generally high public acceptance, but also consistently highlight scepticism regarding NbS effectiveness for DRR and uncertainty surrounding the approach as barriers to acceptance. Dozens of factors that can influence acceptance were identified and, despite variation in the strength of factors across study sites, several consistencies emerged. For example, public trust in implementers was important for positive attitudes towards the NbS, while perceptions of place were important for pro-NbS behaviour (i.e., engagement). Cultural ecosystem services, and especially aesthetic value, were highlighted as crucial determinants of acceptance throughout. However, in the Scotland site, the effectiveness of the NbS for reducing risk was paramount and therefore the perceived limitations of NbS drove preferences towards greyer (i.e., more hybrid) measures. This thesis emphasises a need for more focus on the importance of meeting public expectations for risk reduction, providing cultural ecosystem services as co-benefits, centering people-place relations in NbS work, and considering the efficacy and support of hybrid rather than purely green options.

Additionally, the Public Acceptance of NbS framework [PA-NbS] is introduced in the review as a starting point for NbS researchers and practitioners to systematise their consideration of public acceptance and how it can be increased. It includes overarching recommendations: provide benefits, increase awareness of benefits, communicate effectively, and promote participation. Each recommendation has four corresponding success criteria which, through the subsequent analyses, are tailored to both the specific contexts of the study sites and for NbS projects globally. Using interdisciplinary concepts and a mixed-methods approach, this research takes a critical perspective with the practice-oriented aim of improving the sustainable success of NbS for DRR. With this, further research is called for to better understand public expectations of NbS, how best to frame NbS and their (co-)benefits to different stakeholders, and how acceptance may change through time based on evidence of NbS performance.

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Preface

I conducted this research within the context of the OPERANDUM project, and I am grateful to project managers for allowing me to engage as an equal member. It is important to note that while the research included in this thesis was partially motivated by the demands and characteristics of OPERANDUM study sites, it was carried out independently of project deliverables. I was never directed to alter research questions, foci, or findings to align with the project. Instead, these are motivated by the existing state of academic research on NbS and related concepts along with the aim of informing global NbS research and practice. OPERANDUM colleagues who assisted with data collection and were willing to provide feedback on drafts of Papers 2 and 3 of this thesis were invited to participate as co-authors on those papers. Specifically, in Greece and Finland, colleagues helped translate survey material from English, disseminate surveys, and collect and send me completed surveys. Specific author contributions are provided on the title pages of the three papers, which form three chapters of this thesis. I have been solely responsible for writing all the material in this thesis, as well as conducting the data analysis.

My PhD research began in 2019 and my progress and ability to collect data was impacted by the Covid-19 pandemic. I was lucky to have conducted in-person surveys in Catterline, Scotland and the Spercheios River Valley in Greece prior to the first wave of the virus in Europe. However, several research designs, with corresponding ethical reviews, were completed that could not be carried out. Additionally, my research was significantly delayed due to an inability to travel in 2020. I am grateful to the University of Glasgow for their support considering the difficulties I faced.

Three papers published open-access (CC-BY) in peer-reviewed journals present empirical research and form the main body of this thesis. In accordance to minor changes requested by the reviewers of this thesis, there are several differences between the published versions of the articles and the versions included here. Most notably, information on the representativeness of the survey sampling approach has been added in Chapter 3, Section 3.2.1 (e.g., Table 3-2). Please be aware that there are some lengthy 5th level headings (e.g., section 2.3.3.2.1). I apologize for this, but felt it was best to preserve all the sections of the published papers, which include 4th level headings, now embedded within chapter headings of this thesis. I hope that such detailed sections, accessible through bookmark links in this .PDF, (further) enhance the reader's pleasure.

I have attempted to standardise spelling to British English throughout the text of this thesis. The careful reader will likely encounter oversights in this regard, given my continued lack of expertise in the subject and since Papers 2 and 3 were originally published in American English as per journal guidelines. The papers here also diverge from the published versions in that all references to supplementary material have been standardised and now instead refer to items in the appendix of this thesis. All original supplementary material has been included in the appendix, with the exception of the full surveys from two case study sites due to word limit constraint. Lastly, the style of font has been standardised across the papers, but some tables and figures retain their original fonts to avoid changes negatively affecting their spacing, design, and readability.

Acknowledgements

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Thanks to all my University of Glasgow and OPERANDUM colleagues, who have been nothing but supportive. In particular, thanks to the Glasgow Caledonian University team for their trust and collaboration throughout, Eija Pouta and Katriina Soini at LUKE (Finland) for help with data collection and critical feedback, and team Greece from ITC S.A. also for data collection, including hosting me in their beautiful country. Thanks also to Miranda for being a world class hall-mate and the other lovely friends I made in Dumfries.

Thanks to Fabrice Renaud for his trust, openness, and kindness. In 2016, he gave a curious master's student in Bonn the time to chat and an opportunity to learn and grow. I remain grateful.

Thanks to Stuart Hanscomb for his critical thoughtfulness and for agreeing to join our team and make it stronger.

Thanks to my family, the source of both a lifelong debt and lifelong motivation.

Most of all, thanks to Mar, who followed me to Dumfries to live on a "windswept island" and then agreed to continue the journey.

An additional thanks for the time and careful reading by the reviewers of this thesis.

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Printed Name: Carl Anderson

Signature:

Chapter 1 Introduction

Recently, nearly every year brings record-breaking high temperatures and natural hazard events in Europe. For example, unprecedented wildfires in Northern Europe and Greece, floods in Germany, Belgium, and the United Kingdom, and series of droughts and heatwaves across the continent have negatively impacted social, economic, and natural systems in recent years (Below and van Loenhout 2021; Kron et al. 2019; World Bank Group 2016). While climate change exacerbates these events, both in Europe and globally their impacts on social-ecological systems are also driven by other concurrent and ongoing crises. Most prominently, vulnerability to hazards is increased by inadequate and unsustainable human development along with biodiversity loss, species extinction, and ecosystem collapse (IUCN 2018; Turner, II et al. 2003; United Nations 2021; van Loon et al. 2016). Therefore, efforts at reducing risk from natural hazards have been strengthened and increasingly align with sustainable development goals to address multiple issues with long-term adaptive solutions (UNISDR 2015). Following the Intergovernmental Panel on Climate Change (IPCC), ‘hazard’ is the potential occurrence of a physical event that may cause negative impacts while ‘risk’ is the potential or likelihood of such adverse impacts (IPCC 2012).

In this context, nature-based solutions (NbS) have emerged as an approach to address societal challenges such as disaster risk while providing multiple and often synergistic benefits in the form of ecosystem services (Cohen-Shacham et al. 2016). NbS contrast with ‘grey’ infrastructure measures that are generally made of non-natural materials and built-for-purpose rather than providing a range of ecosystem services, while ‘hybrid’ measures combine aspects of (green) NbS and grey measures (Depietri and McPhearson 2017; Dominique et al. 2021; IUCN 2020a). Although ecosystem services are highly diverse and their provision from NbS is tailored to local contexts and interests, they often include the creation of wildlife habitat, recreational areas, economic or livelihood opportunities, improved aesthetics, and climate change mitigation and adaptation (Cohen-Shacham et al. 2016; MEA 2005a).

There has been a steady increase in the implementation of NbS over the past decade, building on the uptake of more specific approaches that now fall under the NbS umbrella such as ecosystem-based disaster risk reduction (Eco-DRR) and ecosystem-based adaptation (EbA). A recent increase in NbS implementation in Europe is the result of investments by the European Commission under their Horizon 2020 Research and Innovation programme (European Commission 2015b), through which they aim to position Europe as the global leader in NbS (Maes and Jacobs 2017; Pauleit et al. 2017).[1] Behind this is the objective of economic growth (through research and innovation) while also improving well-being and 'future-proofing' society (European Commission 2015b, p. 4). Due to the infancy of the formalized NbS approach, the complexity and diversity of measures and global ecosystems, and a persistent dearth of empirical evidence, the European Commission also recognises that "the potential for transferability and upscaling of solutions… requires further investigation" (European Commission 2015b, p. 4). The research presented in this thesis was carried out at rural NbS sites within one Horizon 2020 project, OPERANDUM[2] (OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks), and has the overarching practical aim of increasing the success of NbS and its further uptake.

Along with the European Commission, prominent NbS literature emphasizes engaging with stakeholders, including the public, for the success of NbS (Cohen-Shacham et al. 2016; Eggermont et al. 2015). Local residents who live near, interact with, and benefit from NbS should be considered active collaborators throughout NbS project phases (e.g., planning, development, implementation, monitoring) and afterwards through long-term stewardship and further monitoring (Cohen-Shacham et al. 2019; Nesshöver et al. 2017). Therefore, public perceptions and degrees of acceptance of NbS can be critical for successful outcomes. My research focuses on public acceptance as one success factor for NbS projects and the continued societal uptake of NbS, albeit recognizing the many other necessary economic, engineering, and political considerations. In turn, potential factors contributing to public acceptance are

[1] The European Commission's emphasis on NbS has been taken up in the recently released Horizon Europe: Strategic plan 2021-2024.

[2] https://www.operandum-project.eu

identified and explored in detail. A series of overarching and related research questions drives the work presented:

1. Why, when, and how does public acceptance matter for NbS and how does this compare to grey DRR measures?
2. What is the strength of different factors behind public acceptance and do they show consistency or differ across European NbS contexts?
3. Do local residents at planned NbS sites prefer NbS over hybrid or grey measures and what factors and/or (mis)perceptions influence their preferences?

To answer these questions, three papers published in peer-reviewed journals present empirical research and form the main body of this thesis. The questions listed above correspond to each of the three papers, which present 1) a systematic literature review on public acceptance of NbS compared to grey infrastructure measures, 2) the results of a quantitative survey on public acceptance conducted at three European sites where NbS were being planned within the OPERANDUM project, and 3) further survey results combined with findings from in-depth focus groups discussions (FGDs) from one site regarding preferences for green, hybrid, or grey measures. I abbreviate the papers as such: 'Paper 1 (Review)'; 'Paper 2 (Survey)'; and 'Paper 3 (FGDs)'.

In the following sections of the introduction, the research is first positioned within its historical context, which allows for an understanding of its broader societal relevance. Next, the thematic background of the research is described, focusing on NbS, public acceptance, and other related interdisciplinary concepts used in this thesis. Prior relevant research along with the disciplinary and theoretical approach used is described, thereby supplementing the introduction sections of the three papers. Lasty, explicit knowledge gaps from the introduction are synthesized, which lead to specific research questions from each of the three papers and an overview of their content, structure, and flow.

1.1 Historical development and societal relevance

Defining characteristics of the NbS approach and the associated relevance of public acceptance can be traced to interconnected historical trajectories that converge on its current global uptake. I provide a brief selective background on the expansive and increasingly interconnected themes of human-nature relations and human-risk relations to position NbS within its current research and practice landscape (Figure 1-1). Because NbS aim to improve human well-being by avoiding, for example, negative health, economic, or environmental impacts of natural hazards, these historical trajectories unfold within the broader field of global sustainable development.

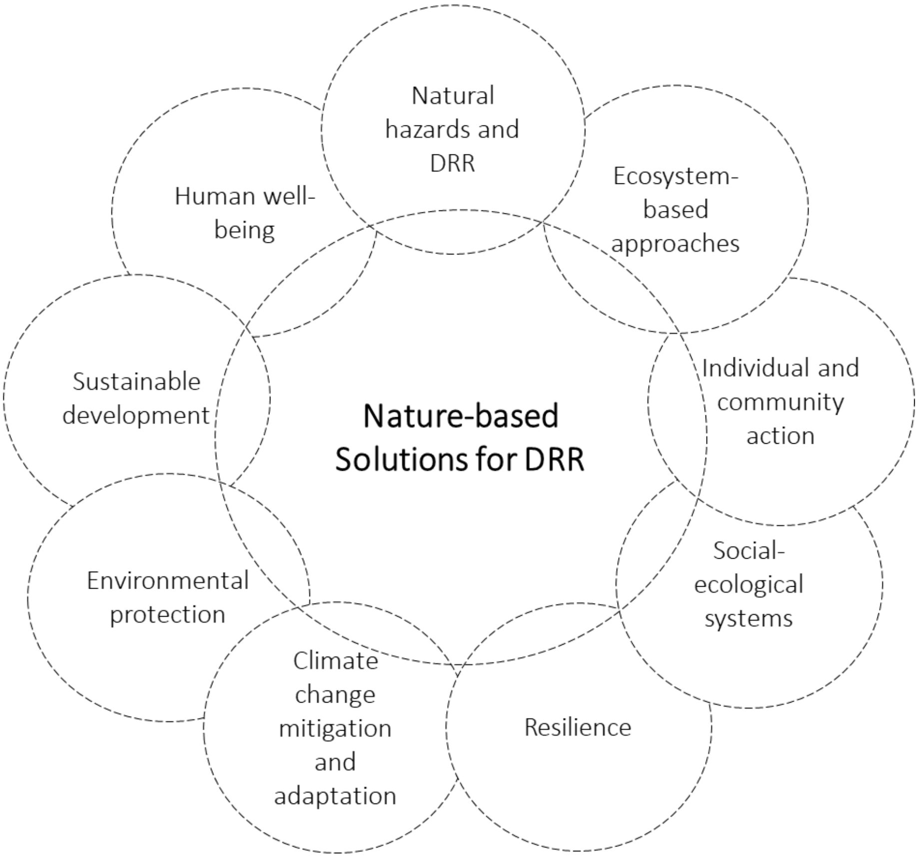

Figure 1-1 Interconnected NbS for DRR research themes. The themes have historical developments relevant to the conceptualization of NbS for DRR in this research.

The Stockholm Conference in 1972 and the creation of the United Nations Environment Programme (UNEP) served to recognise the important role of our environment for development and has been cited as a starting point for the modern iteration of the sustainable development field (Newsham and Bhagwat 2015). The term ‘sustainable development’ was later popularized in the landmark contribution of the *Our Common Future* report by the Brundtland Commission in 1987, recognizing the systemic connections among society, economy, and environment (Brundtland et al. 1987). The Rio Conference in 1992 detailed political commitments to environmental goals, further recognizing the link between efforts at environmental protection and improving global human well-being. Progress since then has been sporadic (Newsham and Bhagwat 2015), evidenced by periodic goal-setting, inadequate regional and global progress, and the subsequent need to reflect on shortcomings and re-energize political ambitions. Prominent examples of this include the Rio+20 Conference, 20 years after the original conference; the United Nation's Millennium Development Goals [MDGs] during 2000-2015; the Convention on Biological Diversity's [CBD] Strategic Plan for Biodiversity 2011-2020 (including the Aichi Biodiversity Targets); and the ongoing Sustainable Development Goals [SDGs] covering the period 2015-2030.

However, advances have been made, lessons learned, and many research and practice theories and approaches created that link the environment and development. Among these, a recognition of the potential for 'win-win' or synergistic effects of relevant efforts emerged (MEA 2005a; Newsham and Bhagwat 2015; Renaud et al. 2013b). This progress brought a recognition of the benefits of nature to people (i.e., ecosystem services) and the roles of local individuals and communities within social-ecological systems whose beliefs, attitudes, and behaviours are essential for positive outcomes (Berkes et al. 1994; Díaz et al. 2015; Loft et al. 2015; MEA 2005a). With people at the centre of sustainable development, there was also increasing recognition that technocratic and top-down approaches over the past centuries have at times been unethical, self-serving, or generally unsuccessful for addressing root problems and achieving lasting change (Eade 1997; Sachs 2015; Wisner et al. 2003).

Global efforts at reducing environmental risk have followed a similar historical trajectory towards exploring interconnected causes and solutions within systems and the role of human actors. *Our Common Future* emphasized risks to humans and the environment from "industrial and natural hazards" through the lens of sustainable development (Brundtland et al. 1987). Along with scientific advancement, the report reflected decades of public fear from the Cold War, fostering links between human 'development' (or 'growth') with the risk of annihilation through nuclear or environmental destruction. Later, the Rio+20 conference in 2012 brought disaster risk further into the same conversation as environmental protection and sustainable development (Munang et al. 2013).

To address risk from natural hazards and reduce their negative impacts within the context of climate change and sustainable development, global conferences on DRR have been held in Japan. As outcomes, these generated the *Yokohama Strategy and Plan of Action for a Safer World* in 1994 (United Nations 1994), leading in 2005 to the *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters* (UNISDR 2005) and most recently the *Sendai Framework for Disaster Risk Reduction 2015-2030* (UNISDR 2015). The Sendai Framework recognizes that disasters “impede progress towards sustainable development” and both describes “ecosystem decline” as exacerbating hazard risk and “ecosystem-based approaches” as one viable solution (UNISDR 2015). Additionally, the Sendai Framework furthers a trend of recognizing the breadth of key stakeholders for successful DRR. This includes the participation of the public and individual actors through an “all-of-society approach” with “all-of-society engagement” (UNISDR 2015).

The recognition within these frameworks of interconnections among DRR, sustainable development and the environment, and public attitudes and behaviours represents substantial progress in identifying causal influence behind impacts of natural hazards (Hewitt 1983; Lisowski 2000). From millennia of understanding disasters as questions of fate and later as failures in a battle between ‘man’ and nature, emerged a 20th century recognition of the role of society for generating risk (Beck 1992; Bernstein 1996; White 1945). A recognition of ‘natural’ disasters as societally-generated (O'Keefe et al. 1976; White 1945) opened the possibility that technocratic approaches to reducing risk (e.g., building higher and stronger dikes to reduce flooding) can be counter-productive. Such approaches may increase risk directly by creating the conditions for future catastrophic failure or by diverting attention away from the stronger societal and systemic drivers of risk (Hewitt 1983; White 1945). Rather than a lack of physical protection from hazards, social science insights increasingly underlined the role of vulnerability to modulate negative outcomes. As such, and influenced by Marxist theory, root causes such as power structures that dictate unfair economic and societal systems were highlighted (Wisner et al. 2003).

Studying individuals within relevant streams of risk research has persisted alongside an increased recognition of power structures and context (O'Keefe et al. 1976), spurred on by 20th century scientific progress in the fields of psychology and behavioural science (Eiser et al. 2012). The dominant shift from this perspective moved from behaviourism (i.e., considering behaviour primarily as a product of stimuli and conditioning), to viewing humans as rational decision-makers, and finally to incorporating a recognition of humans as agents who act predictably ‘irrationally’ (Tversky and Kahneman 1974). From this emerged the field of behavioural economics and a new perspective on explaining behaviour and decision-making. This centres around biases associated with both intuitive/emotional and reflective appraisals acting on pre-existing values, beliefs, and interests (Kahneman 2012). ‘Nudging’, i.e., leveraging these factors and corresponding biases and heuristics to steer behaviour through implementing seemingly minor adjustments to contexts or messaging, has become increasingly prevalent in the fields of global development and sustainability (Byerly et al. 2018; World Bank Group 2015). Although ground-breaking work such as that of Tversky and Kahneman (1974) emphasized biases and heuristics in relation to economic-oriented decision-making under risk and uncertainty, Slovic (1987) and others (Fischhoff 2013; Kasperson 1983; Kasperson et al. 1988; Sjöberg 2000b) applied them to socio-natural hazards and risks. I return to concepts of risk perception and risk tolerance in section 1.2.2, which appear in the three papers presented.

Along with the attribution of agency to individuals and the general public in relevant studies, there have been shifts in views regarding stakeholder involvement and associated burdens of responsibility for the management and governance of risk from natural hazards (Aven and Renn 2010; Klinke and Renn 2014; Lisowski 2000). Most relevant is the recent push for greater individual and community participation and responsibility, particularly prevalent in Europe and the US (Bark et al. 2021; Begg et al. 2018; Dendler and Böl 2021; Kuhlicke et al. 2020; Lisowski 2000). Among other reasons, neoliberal governance and the diminished role of the state have been credited with furthering the shift or ‘turn’ in responsibility for risk reduction from public institutions to private-public partnerships and the public itself (Hutter et al. 2014; Kendra et al. 2018; Tierney 2015). The shift is not unique to natural hazards and risk reduction research and practice. Loft et al. (2015), in reference to ecosystem services, describe a shift away from government-based to multi-actor governance and a reliance on the public since the 1990s. As drivers, they cite “the alignment of conservation and sustainable use of biodiversity, the failure of traditional policy instruments to reduce the rate of biodiversity loss and environmental degradation, and decreasing governmental involvement in environmental governance” (p. 150).

The concept of ‘resilience’ has combined the increased focus on local actors as collaborators in risk governance and the need for multi-stakeholder involvement to manage the provision of ecosystem services (Hutter et al. 2021; Kendra et al. 2018; Tierney 2015). Resilience has been used to study the capacity of agentic individuals, communities, and social-ecological systems to ‘bounce back’ following a hazard event (Gallopín 2006; Norris et al. 2008). ‘Adaptive capacity’ has become prevalent as a related concept within climate change literature (IPCC 2012). Other relevant conceptualizations of resilience emphasize the role of interconnected factors and complexity and uncertainty in systems, path dependency, and how states of systems may remain stable within certain boundaries, shift, or *transform* due to disturbance (Folke 2006; Renaud et al. 2010; Walker et al. 2006).

Likewise, the rapid growth in climate change research has brought a greater emphasis on individual decision-making and the need for bottom-up rather than top-down approaches. This has been driven in part by characteristics of climate change that demand a greater emphasis on integrating psychological research into understanding the role of individual attitudes and behaviours. These include the differing degrees of saliency of climate change (i.e., what is unseen is generally unimportant); the spatial and temporal scales involved (i.e., psychological distance); uncertainty and the associated difficulty in communicating its causes and effects along with the related susceptibility to misinformation; and the urgent need for universal action across sectors and scales (starting from the individual) (Gifford 2011; Spence et al. 2012; Spence and Pidgeon 2009; Swim et al. 2011). The widely acknowledged and deeply studied ‘gap’ between values, beliefs, attitudes and people’s actual behaviour has been one important facet of this research (Blake 1999; Brink and Wamsler 2019; Sheeran 2002; Wachinger et al. 2013). Additionally, the recognition of the need to adapt to climate change to avoid devastating impacts, rather than only mitigate (IPCC 2007), has spurred research on individual decision-making and behaviour (e.g., Yousefpour et al. 2012).

Lastly, the ongoing Covid-19 pandemic is currently redefining our relationship with environmental risk and bringing the study of risk perception and risk tolerance to the fore (Dryhurst et al. 2020; van Bavel et al. 2020). Policymakers are learning that individual attitudes, behaviours, and public acceptance can determine the severity of negative impacts despite revolutionary technological advancements (e.g., the creation of mRNA vaccines followed by public hesitancy to get vaccinated) (Kerr et al. 2020). Long-standing lessons from the field of DRR such as the cost-effectiveness of preparedness and the importance of clear and consistent risk communication have been overwhelmingly reinforced. Along with vulnerability and its many facets, denialism, misinformation, trust, 'vaccine hesitancy', and socio-cultural tendencies such as individualism vs. communalism have become predictive factors for horrific death tolls (Siegrist et al. 2021; Siegrist and Bearth 2021). The pandemic highlights the current rapid developments in scientific and popular understanding of human-nature-risk relations and the immense societal relevance of this broader field of research.

The historical trajectories described above converge on NbS with potential multiple and interconnected benefits in relation to risk, nature, and sustainable development that rely on the collaboration of a broad range of responsible stakeholders. The NbS approach is not the pinnacle of research or practice within these fields and must continue to evolve. However, many lessons resulting from the advancements made along the historical trajectories described have been formalized in policies and guidelines and are embodied in the NbS concept. As a reflection of interdisciplinary NbS characteristics and the scientific advancements behind them, the body of research detailed in this thesis emphasizes the role of the individual public stakeholder and their acceptance of NbS through attitudes and behaviours as an important contributor towards successful NbS.

This historical commentary provides a justification for three starting points from which this research departs:

1. Individual attitudes and behaviours towards risk and risk reduction measures are one important consideration for successfully reducing the negative impacts of natural hazard events;
2. There are individual and environmental factors that, in turn, influence how people think and act in relation to hazards and approaches to risk reduction;
3. By understanding these factors and their relative and contextual strengths, it is possible to improve public acceptance of NbS and ultimately NbS outcomes.

1.2 Thematic and theoretical background

Several thematic reviews provide background information needed to describe the theoretical basis and practical utility of this research and its specific aims. The reviews are divided into sections on NbS (1.2.1), and public acceptance and related concepts (1.2.2). Only selective backgrounds are provided here to avoid unnecessary repetition with the three papers presented in chapters 2, 3, and 4. The aim here is to touch on relevant historical underpinnings of the concepts, corresponding bodies of work and streams of research behind them, and how they are defined and applied in the context of this research.

1.2.1 Nature-based solutions

Physical environmental management practices that could be described as ‘nature-based solutions’ (NbS; also abbreviated as ‘NBS’) have existed for millennia, but the term was only recently coined and promoted by the World Bank (MacKinnon et al. 2008) and the International Union for the Conservation of Nature (IUCN) (IUCN 2009). MacKinnon et al. (2008) referred to NbS in the title of their World Bank report, *Biodiversity, Climate Change, and Adaptation: Nature-Based Solutions from the World Bank Portfolio*, applying it loosely thereafter to describe investments and projects with a focus on biodiversity and conservation that have also provided climate change adaptation and sustainable development benefits. In line with the IUCN’s work, the approach/framework for climate change mitigation ‘REDD+’ (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) was central in their position paper for the 15th Conference of the Parties (COP15) in Copenhagen in 2009 (IUCN 2009), framing it as an ‘ecosystem-based approach’ and ‘nature-based solution’. The paper also mentions ‘ecosystem-based adaptation’ (EbA), one NbS approach, as “the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people and local communities to adapt to the adverse effects of climate change” (IUCN 2009, p. 4). These key early adoptions of the term in official documents highlight a central defining characteristic of NbS – their ability to address urgent global issues while providing a range of natural and societal co-benefits through ecosystem services (Pauleit et al. 2017) (Figure 1-2).

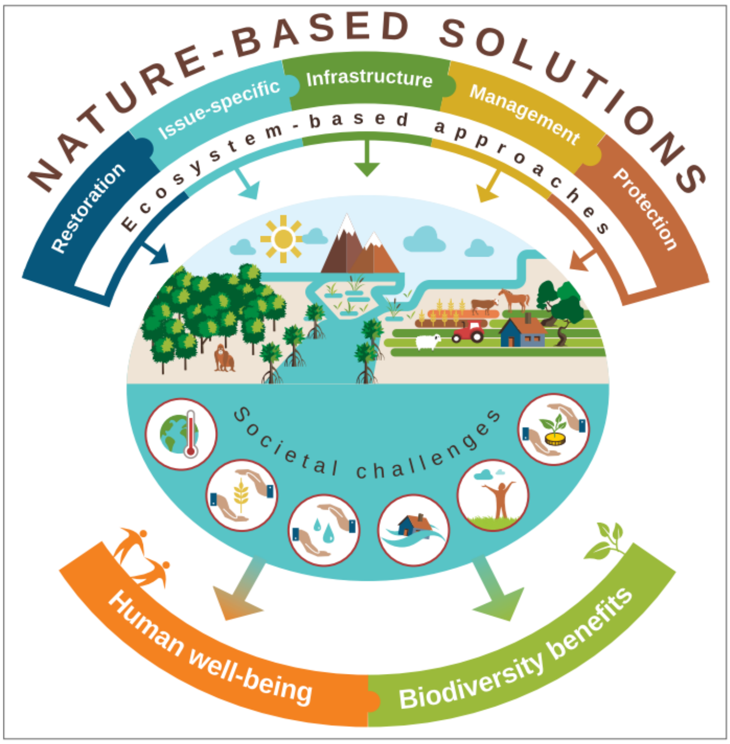

Figure 1-2 Conceptualization of NbS by the IUCN. NbS includes a broad range of ‘ecosystem-based approaches’ that aim to address societal challenges (listed in the report and symbolized in the figure, from left to right: climate change, food security, water security, disaster risk reduction, human health, and economic and social development) to improve human well-being and provide biodiversity benefits. Taken from the 2016 IUCN report *Nature-based Solutions to address global societal challenges* (Cohen-Shacham et al. 2016, p. 11). Reproduction authorised.

NbS is used both in reference to a novel concept or in a general sense to supplant more specific terminology referring to approaches (also ‘actions’ or ‘measures’) that now fall within its scope (Han and Kuhlicke 2021). In the latter case, as with the example of EbA above, ‘ecosystem-based disaster risk reduction’ (Eco-DRR) is an approach that has been increasingly supplanted by the more general ‘NbS’. Eco-DRR is the most relevant NbS approach in this thesis, defined by Estrella et al. (2013, p. 30) as “(…) the sustainable management, conservation and restoration of ecosystems to reduce disaster risk, with the aim to achieve sustainable and resilient development”. For the purpose of my research, there is no need to distinguish between Eco-DRR and NbS with the primary intention of reducing risk. I use ‘NbS’ throughout this thesis since the term has become increasingly established through its explicit use in academic and practice-oriented literature, including distinct guidelines and best practices. Additionally, the research is carried out within the OPERANDUM NbS project that uses NbS terminology and framing to communicate with stakeholders and disseminate findings. When it is useful to avoid ambiguity, I follow the example of the European Commission by referring to, for example, ‘NbS for DRR’ (European Commission 2021a).

As an umbrella term, ‘NbS’ compiles the characteristics and lessons learned from its more specific approaches, promoted by private, public, and third-sector actors who have generated guidelines, best practices, knowledge-sharing platforms, and funding streams that further establish it as a broad yet clearly defined concept. Two definitions from two of its most influential actors, the IUCN and the European Commission, have emerged as dominant:

> **IUCN:** “actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits” (Cohen-Shacham et al. 2016, p. xii).

> **European Commission:** “solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes, and seascapes, through locally adapted, resource-efficient and systemic interventions” (European Commission 2015b).

Eggermont et al. (2015) provide a useful commentary distinguishing the two primary perspectives of NbS by each actor, explaining that the IUCN “puts biodiversity and local human communities at the heart of NBS”, while the European Commission “underlines that NBS can transform environmental and societal challenges into innovation opportunities, by turning natural capital into a source for green growth and sustainable development” (p. 244). The definitions are mostly complementary, evidenced by the European Commission citing the IUCN’s definition as supportive of its own (European Commission 2021a), and both are adequate within the context of this thesis. However, I rely on the IUCN’s definition because their conservation and ecological restoration norms emphasize the role of individuals and communities for successful NbS, while the economic opportunities provided by NbS at scales beyond these actors is less relevant for my research. Two slight deviations from this definition are useful considerations in the context of my research within the OPERANDUM project on society-NbS relations. First, its exclusive focus on ecosystems (i.e., to protect, manage, or restore) excludes or marginalises NbS that, for example, are minor and localised interventions, occur in dense urban areas, or provide a range of co-benefits but with little gain in habitat or biodiversity. Second, the IUCN definition implies that NbS are a priori effective and adaptive, but my research on public acceptance demands exploring the potential for unsuccessful NbS and associated causes.

The fields of conservation and environmental management heavily influence NbS and NbS guidelines. Close historic ties to ‘The Ecosystem Approach’ and associated guidelines developed by the Convention on Biological Diversity (CBD 2004) have led to an emphasis on considering integrated systems with humans as central actors. For NbS, and central to my research, is the focus on public stakeholders whose decision-making and actions can determine long-term success or failure (Cohen-Shacham et al. 2016; Raymond et al. 2017). Directly enveloping many of the lessons learned by NbS approaches, including Eco-DRR and EbA (McVittie et al. 2018), has invited some criticism of the concept for being overly broad (Osaka et al. 2021). However, the breadth of NbS approaches also offers an opportunity to integrate siloed bodies of knowledge, emphasize their practical problem-solving aspects as ‘solutions’ (Dorst et al. 2019), recognise their multiple benefits beyond any specific approach, and shift their focus towards long-term and systemic sustainability (Seddon et al. 2021). Additionally, NbS can contribute back to sub-fields and approaches under its umbrella by improving practice through internationally accepted guidelines (IUCN 2020a) and lessons learnt (e.g., Bark et al. 2021).

The centrality of multiple stakeholders (including the public) for NbS is captured in principles for NbS outlined in Cohen-Shacham et al. (2016) and Cohen-Shacham et al. (2019) and in several criteria for NbS in the recent formalization of NbS guidelines in the IUCN's 'Global Standard' report (IUCN 2020b) (Table 1-1). Criterion 5 in particular, "NbS are based on inclusive, transparent and empowering governance processes", reflects the emphasis on 'co-approaches' to NbS. These include co-design, co-development, co-creation, and co-management; highlighting the role of participatory approaches and stakeholder engagement for instrumental benefits (in line with environmental, social, and economic aims of the NbS) as well as for research and knowledge production (Frantzeskaki 2019; Giordano et al. 2020; Puskás et al. 2021; Zingraff-Hamed et al. 2020). Co-approaches also demonstrate the implicit and explicit reliance of NbS on the public and other stakeholders.

Table 1-1 IUCN's eight Global Standard criteria with only the most relevant corresponding indicators for public acceptance shown. (IUCN 2020b).

Criterion 1: NbS effectively address societal challenges
1.1 The most pressing societal challenge(s) for rights-holders and beneficiaries are prioritised
Criterion 2: Design of NbS is informed by scale
2.1 The design of the NbS recognises and responds to interactions between the economy, society and ecosystems
Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity
Criterion 4: NbS are economically viable
Criterion 5: NbS are based on inclusive, transparent and empowering governance processes
5.1 A defined and fully agreed upon feedback and grievance resolution mechanism is available to all stakeholders before an NbS intervention is initiated
5.2 Participation is based on mutual respect and equality, regardless of gender, age or social status, and upholds the right of Indigenous Peoples to Free, Prior and Informed Consent (FPIC)
5.3 Stakeholders who are directly and indirectly affected by the NbS have been identified and involved in all processes of the NbS intervention
5.4 Decision-making processes document and respond to the rights and interests of all participating and affected stakeholders
5.5 Where the scale of the NbS extends beyond jurisdictional boundaries, mechanisms are established to enable joint decision-making of the stakeholders in the affected jurisdictions
Criterion 6: NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits
6.2 The rights, usage of and access to land and resources, along with the responsibilities of different stakeholders, are acknowledged and respected

6.3 The established safeguards are periodically reviewed to ensure that mutually-agreed trade-off limits are respected and do not destabilise the entire NbS
Criterion 7: NbS are managed adaptively, based on evidence
Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context
8.1 The NbS design, implementation and lessons learnt are shared to trigger transformative change
8.2 The NbS informs and enhances facilitating policy and regulation frameworks to support its uptake and mainstreaming
8.3 Where relevant, the NbS contributes to national and global targets for human well-being, climate change, biodiversity and human rights, including the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP)

Another important characteristic of NbS both generally and in this thesis is its distinction from alternative methods, most prominently the use of grey infrastructure (Depietri and McPhearson 2017; Dominique et al. 2021). The terms ‘structural’, ‘traditional’ and ‘engineering’ are often used in tandem to describe grey infrastructure (IUCN 2020a, 2020b; Jones et al. 2012a), although I mostly avoid these terms in this research since ‘traditional’ is ambiguous and NbS often should involve (structural) engineering considerations. This is clear in the NbS approaches of green infrastructure (GI) and ecological engineering (or eco-engineering), often applied with DRR as a primary objective (Gonzalez-Ollauri et al. 2021; Sebesvari et al. 2019). Through a comparison with grey infrastructure, NbS can be considered green (in relation to terrestrial ecosystems), blue (aquatic ecosystems), a combination of green/blue, or a combination of either of these with traditional grey elements to form ‘hybrid’ measures (Depietri and McPhearson 2017; Kalsnes and Capobianco 2019) (see appendix Table. A-1 for examples of different types of NbS approaches from Paper 1). Hybrid measures generally also fall under the inclusive NbS umbrella (Depietri and McPhearson 2017; Sutton-Grier et al. 2015; Turkelboom et al. 2021) given their provision of benefits and other advantages over strictly grey measures. Another distinction of NbS is their ‘low- regret’ or ‘no-regret’ characteristic, since they can provide benefits that outweigh their costs despite potential severe future climate and hazard risk scenarios (IPCC 2012). Grey measures, on the other hand, may degrade ecosystems and create trade-offs in the form of diminished or lost ecosystem services beyond their primary objective (Estrella et al. 2013). They also entail the potential for more catastrophic failure, due to societal overconfidence or hazard magnitudes surpassing engineering thresholds (Kim et al. 2020).

NbS guidelines published by the IUCN (IUCN 2020a) and others, as well as the emergent body of academic NbS literature on the concept itself (e.g., Cohen-Shacham et al. 2016; Cohen-Shacham et al. 2019; Eggermont et al. 2015; Seddon et al. 2020) have further established the NbS concept and its boundaries, thereby also defining what NbS are *not*. Because the concept is relatively new, there is still some dispute regarding what should qualify as NbS or ‘natural’, both explicitly and implied through varied use of the term (Dorst et al. 2019; Han and Kuhlicke 2021). As discussed in Paper 3 (FGDs), the way NbS are communicated matters for public acceptance, with mistrust or unrealistic expectations as potential associated issues. Nesshöver et al. (2017) and Seddon et al. (2021) warn against the labelling of projects as NbS that are poorly implemented, may have detrimental ecological and social side effects, or co-opt the concept as a quick ‘ecological fix’. Another typical example of mislabelling is the use of a single plant species for green infrastructure or monoculture plantations that are promoted for carbon sequestration but result in reduced biodiversity (Chausson et al. 2020; Eggermont et al. 2015).

As part of the effort to establish the NbS concept and its boundaries, as well as promote its uptake, many typological commentaries and NbS examples can be found in the literature. The European Commission (2015b) provides a list of 310 examples of NbS within different primary purposes and within different ecosystems, and Cohen-Shacham et al. (2016), Seddon et al. (2021), and Faivre et al. (2017) also discuss NbS examples and case study projects. Pauleit et al. (2017), Depietri and McPhearson (2017), Albert et al. (2019), Dorst et al. (2019), Ruangpan et al. (2020), and Nesshöver et al. (2017), amother others, provide typological descriptions and/or historical commentaries on NbS in relation to related concepts such as green, blue, hybrid and grey infrastructure, EbA, Eco-DRR, and ecosystem services. Eggermont et al. (2015) developed a prominent 3-class spectrum typology of NbS based on the degree of engineering and management, in which Type 3 (high degree), also means greater optimization of targeted ecosystem services and associated stakeholder groups. This theoretical perspective on types of NbS was taken up in the IUCN’s Global Standard for NbS (IUCN 2020b). Lastly, prominent platforms also now exist that provide search databases of NbS case studies and provide information regarding best practice, including OPPLA[3], PANORAMA[4], and Climate-ADAPT[5].

The action- and problem-solving orientation of NbS highlights the benefits of ecosystems for people to address societal issues. Since the conceptualization of NbS, ecosystem services have been at their core (Seddon et al. 2020). The Millennium Ecosystem Assessment (MEA) defines ecosystem services as simply “the benefits that people obtain from ecosystems” and classifies them as provisioning, regulating, cultural, and supporting services, that interact and are accrued differently across spatial and temporal scales (MEA 2005a) (Figure 1-3).

[3] https://oppla.eu

[4] https://panorama.solutions/en

[5] https://climate-adapt.eea.europa.eu

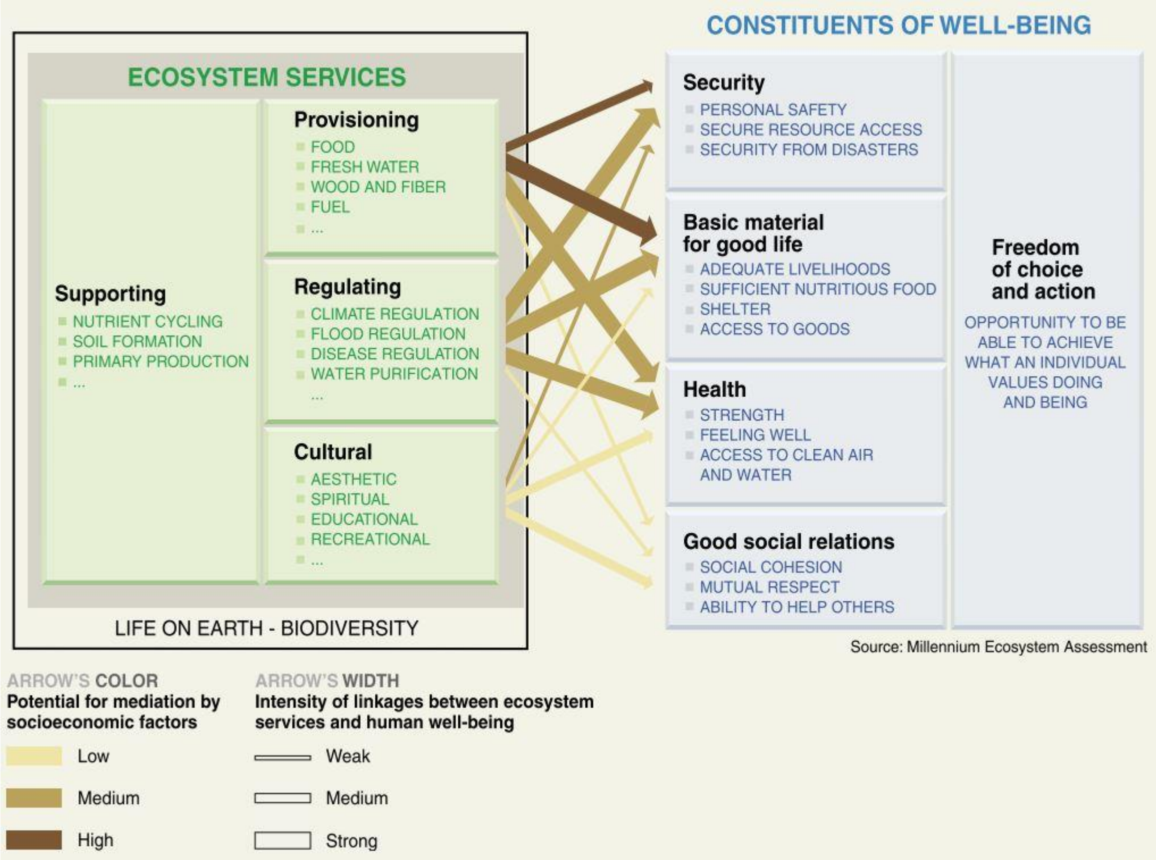

Figure 1-3 The Millennium Ecosystem Assessment (MEA) framework. The figure is taken from (MEA 2005a, p. 15) and shows linkages and their strength between the different types of ecosystem services and common components of human well-being. Available at: [https://www.millenniumassessment.org/en/GraphicResources.html.](https://www.millenniumassessment.org/en/GraphicResources.html) Reproduction authorised.

The MEA framework provides a starting point for research on public acceptance of NbS since perceived benefits are hypothesized to be one factor for influencing public acceptance. NbS for DRR, as the topic of this thesis, positions the primary goal of NbS as providing regulating services for mitigating the hazard and exposure elements of risk (IPCC 2012). However, ecosystems and their services can also reduce risk in indirect or non-obvious ways by enhancing recovery processes, supporting people’s capacity to cope and adapt to impacts, and reducing their vulnerability (Walz et al. 2021). This may occur through, for example, ecosystem contributions to well-being, income, and nutrition by providing food, medicine, and building materials (MEA 2005a). Particularly relevant to the OPERANDUM NbS study sites used in this research, the European Commission survey on citizen’s views of NbS (European Commission 2015a) found that ecosystem services such as aesthetics and recreation were highly valued.

The increasingly rapid uptake of the NbS terminology is reflected in relevant policy- and practice-oriented documents. Several prominent examples include the United Nation's UN-Water report *Nature-Based Solutions for Water* (WWAP 2018), the European Commission's *Evaluating the Impact of Nature-Based Solutions* (European Commission 2021a), the UK Joint Nature Conservation Committee's *NbS Triple Win Toolkit* (JNCC 2021), and the World Bank's *Integrating Green and Grey* (Browder et al. 2019). NbS have also been increasingly discussed within the global climate change conversation. For example, a Nature Based Solution Coalition composed of governments, private sector actors, and international organizations was formed at the 2019 UN Climate Action Summit and published a *Nature-Based Solutions for Climate* manifesto (UNEP 2019).

The rapid uptake in use of the term 'NbS' does not necessarily equate to an equal uptake in domestic policy and subsequent action (Waylen et al. 2018). One important stream of NbS research, within which the body of research presented here is situated and aims to advance, focuses on the identification of barriers to NbS uptake. Barriers identified in the literature can be grouped into general overlapping categories of technical, planning and governance, financial, and social. Among these, a common theme is path-dependency (i.e., the momentum of doing things the way they have been done that makes it difficult to change and face inherent uncertainties) and stakeholder perceptions associated with it (Han and Kuhlicke 2021; Sarabi et al. 2019).

Technical barriers are mostly related to a lack of evidence of effectiveness. This includes long-term evaluation of co-benefits in relation to cost compared to grey measures (Depietri and McPhearson 2017; Kabisch et al. 2016), site-specific rather than standardised evidence (Dominique et al. 2021; Sudmeier-Rieux et al. 2021), and the architecture and engineering knowledge centred on grey infrastructure within (DRR) implementing agencies and organizations (Kabisch et al. 2016; Murti and Mathez-Stiefel 2019).

Planning barriers include the ability of implementing agencies and organizations to carry out effective participatory methods or to properly understand the mechanisms through which ecosystem services can reduce risk (Ramírez-Agudelo et al. 2020; Renaud et al. 2013a; Sutton-Grier et al. 2015); a response-and-relief-centric approach rather than being forward looking and long-term (Gupta and Nair 2013; Kabisch et al. 2016); the complexity of cooperation among multiple governance levels (Triyanti and Chu 2018), among agencies/organization that may have different work cultures (Thorne et al. 2018; Waylen et al. 2018), and among interdisciplinary experts (Kabisch et al. 2016; Murti and Mathez-Stiefel 2019); the continued use of existing policy frameworks and institutional arrangements (Dominique et al. 2021); the unclear attribution of responsibility for long-term monitoring and management (Kabisch et al. 2016); a time lag between investment and realization of benefits (Dominique et al. 2021; Han and Kuhlicke 2021); and design and planning difficulties due to climate change (i.e., changing conditions) (Thorne et al. 2018).

Financial barriers include the ability to access public investment (Dominique et al. 2021; Kok et al. 2021); the need for long-term funding commitment (Cheong et al. 2013; Kabisch et al. 2016; Waylen et al. 2018); an overemphasis on economic growth and construction in cities (also reducing space for NbS) (Kabisch et al. 2016; Sutton-Grier et al. 2015); a lack of business models and legal regulations to support inclusion of the private sector for NbS (Ramírez-Agudelo et al. 2020; Sarabi et al. 2019); a disconnect between who benefits and who pays (Geaves and Penning-Rowsell 2015); the difficulty in quantifying and monetising benefits (Dominique et al. 2021); and the high transaction cost associated with multi-stakeholder planning and co-creation (Dominique et al. 2021).

Social barriers, often related to individual stakeholder perceptions, include inaccurate or insufficient understanding (Thorne et al. 2018) often caused by new uncertainties. This uncertainty, in turn, may also go against the public’s desire for ‘command and control’ risk mitigation (Bark et al. 2021; Han and Kuhlicke 2021) and produce a fear of change and unknown outcomes (Kabisch et al. 2016). Other closely related barriers are a lack of public involvement (Ramírez-Agudelo et al. 2020), perceived ineffectiveness (Gray et al. 2017; Han and Kuhlicke 2019), and the perception of NbS as merely ‘add-on’ natural elements to grey infrastructure (Han and Kuhlicke 2021).

My research explores social barriers through the lens of public acceptance. However, other barriers and individual stakeholders' understanding of them may also act to shape public perceptions. For example, the cost of NbS (as a possible financial barrier) may be perceived as unacceptable. By treating public acceptance as an additional potential barrier to NbS, I follow existing research that uses terms such as buy-in, uptake, support, or engagement to explore NbS-society-individual relations (Cheong et al. 2013; Kabisch et al. 2016; Thorne et al. 2018).

1.2.2 Public acceptance and related concepts

This thesis primarily aims to advance research within the larger field of NbS, serving as evidence for guiding practical efforts towards increasing public acceptance within the OPERANDUM NbS project and NbS work globally. This practice-oriented approach, directed at a wide range of societal issues, is common in acceptance research (Busse and Siebert 2018; Wüstenhagen et al. 2007). The commentary provided in this section serves as a background to the research presented, which applies a general approach from the broad public acceptance research tradition to the topic of NbS. The papers are thus situated more firmly within literature on NbS-societal-individual relations rather than building on non-NbS public acceptance research. Given the practical orientation and lack of past research on public acceptance of NbS for DRR specifically, I rely heavily on Paper 1 (Review), to frame the research questions in the second and third papers. However, the theoretical underpinnings of this body of work are grounded in advancements in studying public acceptance generally, and particularly within a sustainability science context (e.g., Busse and Siebert 2018; Wüstenhagen et al. 2007).

1.2.2.1 Acceptance research and its evolution in related fields

One influential stream of research on public acceptance within the broader field of sustainability is that of renewable energy. Wüstenhagen et al. (2007) describe early research on wind energy in which there was an assumption, based largely on survey data, that public acceptance was high and therefore implementation would present no related issues. However, local opposition became a consistent issue, an inconvenience described as a 'non-technical factor', thought to be caused primarily by visual impact and perceptions of landscape (Carlman 1982; Wolsink 2007). The inconsistency between broad public support and difficulties with the actual siting and implementation of projects has been referred to as the 'social gap' (Bell et al. 2005). In addition to higher visibility, wind energy was described as particularly sensitive to local/community public acceptance due to its smaller scale (with corresponding energy provision per hectare and associated requirement of land-use decisions) and because its implementation represents a choice between long-term benefits versus potential short-term gains from other energy sources (Wüstenhagen et al. 2007).

In line with the boom in wind energy research starting in the 1980s, and research on nuclear power even some years prior (e.g., Otway et al. 1978), public acceptance studies are often undertaken in the context of new technologies. Most recently, vaccination technology has rapidly progressed during the Covid-19 pandemic and research has sought to understand public fear and 'vaccine hesitancy' (Kerr et al. 2020; Siegrist and Bearth 2021). The introduction of new perceived risks and uncertainties (despite benefits), combined with high variation in degrees of knowledge and familiarity, can create polarizing views (Gupta et al. 2012). This is also true of acceptance studies within innovation research, which often concentrate on psychological and behavioural barriers to the adoption of new technologies (Davis et al. 1989; Venkatesh et al. 2003). Technologies related to climate change mitigation beyond sustainable energy have become a more recent focus of the field (Poumadère et al. 2011), including geoengineering techniques to capture and store carbon (CCS) (Anderson et al. 2012; van Os et al. 2014) or manage solar radiation (Cummings et al. 2017; Poumadère et al. 2011). Literature reviews of public acceptance studies for these technologies describe the influential roles of, among other factors, risk/benefit perception, perceived degree of uncertainty, trust in authorities/implementers, familiarity and confidence in the measure, degree of human intervention in nature, experiences and availability of accidents, and positive/negative mental associations (Cummings et al. 2017; Gupta et al. 2012; Poumadère et al. 2011).

Public acceptance research on sustainable technology has been concentrated in North-West Europe and North America (Gupta et al. 2012). Poumadère et al. (2011) point out that "public opinion in many parts of the world is not considered to be a topic meriting research or, for that matter, a variable to be integrated into decision-making regarding energy choices” (p. 722). The practical and action-oriented nature of public acceptance research (Busse and Siebert 2018) may be more conducive to contexts in which the public is an influential stakeholder and findings thus have implications for policy and societal change. Historically, the dearth in research beyond the developed countries of Europe and North America may also be explained by fewer instances of deployment and potential adoption of technologies (Gupta et al. 2012).

The field of public acceptance is interdisciplinary, and since most of its research is applied, studies tend to pragmatically approach their corresponding issue choosing theories from a range of disciplines (Busse and Siebert 2018; Upham et al. 2015). Apart from the sub-area of acceptance of renewable energy, Busse and Siebert (2018) identify sociology, ethics, innovation research, and psychology as the dominant disciplines of the larger field. Ellis and Ferraro (2016), in relation to acceptance of wind energy, categorise previous research into the disciplines of economics, sociology and human geography, social psychology, cultural theory, and “frameworks and methods driven work”. However, psychology and especially social psychology generally lends most of theoretical underpinning to acceptance studies, given its treatment of values, attitudes, and behaviours (Busse and Siebert 2018; Gupta et al. 2012; Upham et al. 2015). For example, risk perception has been a major focus of research (Gupta et al. 2012; Wüstenhagen et al. 2007), due to its potential negative consequences for the commercialization of technologies (e.g., wind energy or genetically modified crops) (Wüstenhagen et al. 2007), events/accidents that have captured the public’s imagination (e.g., nuclear disasters) (Gupta et al. 2012), and the realization that the public and decision-makers consistently assess risk differently and often misjudge risks based on their characteristics and contexts (Slovic et al. 1980; Slovic 1999). In turn, acceptance research is driven by the potential economic and well-being benefits if misperceptions can be addressed (Breakwell 2007).

The concept of risk acceptance (or risk tolerance) combines risk perception and public acceptance research. An emphasis on the acceptability of risks presented by various hazards also allows for the exploration of how potential benefits are perceived and their relation to acceptance (e.g., the benefits of technologies or of *taking* risks) (Breakwell 2007; Fischhoff et al. 1978). Natural hazards have been one consideration, but early studies were particularly spurred by advances in chemical technology and public opposition to nuclear energy (e.g., Slovic et al. 1980). This research has mostly considered tolerance to risks as implicitly derived from risk perception or as one factor that composes risk perception (Breakwell 2007; Rohrmann and Renn 2000). There has been much less research on risk perception and risk acceptance in relation to the acceptance of risk reduction measures[6], a knowledge gap that this thesis addresses.

A principal contribution of risk perception research has been the identification and cataloguing of *factors* that influence risk perception in relation to individuals, such as past hazard experience, knowledge, self-efficacy, and emotional state; and in relation to hazards such as their (perceived) lethality, randomness, and familiarity (Sjöberg 1999; Slovic et al. 1980; Slovic et al. 1981). This risk perception research stream is referred to as following the psychometric paradigm, given its focus on quantitative methods and measuring risk perception and its dimensions (Breakwell 2015; Raue et al. 2018). Several of the influential factors have received particular attention due to their consistent strength in influencing risk perception and subsequent attitudes and behaviours across contexts. Among others, the role of public (dis)trust in relevant authorities, scientists, and experts in general has proven to be key (Bronfman et al. 2016; Slovic 1999; Terpstra 2011). Trust is also one such factor that increases the practicality of risk perception research since it has operational implications for communication between risk managers and the public (Breakwell 2007). By identifying and understanding beliefs and values that influence risk-related decisions, risk communication deals with the designed application of this information to bridge gaps in awareness, knowledge, and expectations (Breakwell 2007; Fischhoff 2013).

Climate change and DRR research has rarely been positioned entirely within what is historically considered acceptance research. However, as noted in the historical commentary in section 1.1, the long tradition of research that concentrates on explaining the gap between values, attitudes, and preferences

[6] Two prominent exceptions in early risk perception research are Fischhoff et al. 1978 and Sjöberg 1999.

on the one hand, and actual behaviour on the other (e.g., Wicker 1969), has been taken up by researchers in this context (Blake 1999; Brink and Wamsler 2019; Gifford 2011; Keshavarz and Karami 2016; Lo 2013; Tierney 1993). Behavioural research for climate change mitigation and adaptation has spanned the breadth of causes and impacts of climate change (van der Linden et al. 2020), as reflected in studies ranging from farming practices (Keshavarz and Karami 2016; Müller-Mahn et al. 2020) to the consumption of green products (Biswas and Roy 2015). The field has been useful for systematically studying biases and heuristics relevant for climate change (in)action and outcomes of different communication strategies. For example, Gifford (2011) describes psychological barriers to pro-climate behaviour change including uncertainty, self-efficacy, worldviews, undervaluing future risk, perceived inequity, and social norms.

The relevance of DRR research is highlighted in the three papers of this thesis. One trend in this field is the noted combination of -and increased emphasis on- individual and public stakeholders within decision-making processes and for directly reducing risk or increasing resilience (Aven and Renn 2010; Kuhlicke et al. 2020). However, research that has been conducted on public acceptance for instrumental purposes, i.e., to reduce risk, has mostly focused on ‘soft’ DRR measures most closely linked with individual planning and self-protective behaviours, including education, awareness, insurance acquisition, or evacuation (Burns and Slovic 2012; Lo 2013; Mojtahedi and Oo 2017; Tierney 1993). From a broader public engagement perspective, findings in DRR and sustainability science have led to the recognition of improved outcomes but also a moral and ethical imperative to involve local citizens (i.e., with potential normative, substantive, and instrumental benefits) (Aven and Renn 2010; Reed 2008; Renn 2015). Including individuals and communities as collaborating stakeholders has been embraced as an advancement beyond top-down approaches in which one-way communication from decision-makers to stakeholders was prevalent (Aven and Renn 2010; Everett et al. 2021). Participation has also been seen as a means to increase stakeholder acceptance of decisions and the decision-making process for risk management and governance through collaborative problem-framing and trust-building (Aven and Renn 2010).

A useful and prominent typology of degrees of participation was proposed in Arnstein's (1969) article "A Ladder of Citizen Participation". Described in relation to NbS in Puskás et al. (2021), the ladder is climbed moving through three classes with embedded sub-levels (as rungs of the ladder): 1) nonparticipation (manipulation, therapy), 2) degrees of tokenism (informing, consultation, placation), and finally 3) degrees of citizen power (partnership, delegated power, citizen control). Higher levels of stakeholder engagement are generally viewed positively, reflecting ideals of democracy, pluralism, transparency, and inclusiveness. In their review of levels of participation in NbS projects, Puskás et al. (2021) show that 47% of the articles included in their sample describe a level of participation considered 'consultation', within the second class of participation labelled 'tokenism' by Arnstein (1969). This suggests a persistent lack of power transfer to participants in NbS projects that may 'tick boxes' to fulfil evaluative requirements rather than investing the time, money, and thought needed for the deeper forms of collaborative decision-making outlined in NbS guidelines (IUCN 2020a) and offered in project descriptions (see case studies in, e.g., Cohen-Shacham et al. 2016; Faivre et al. 2017; JNCC 2021). Serious deliberation is required to determine which stakeholders are needed to participate, the depth of participation, and how exactly this should be achieved (van der Vegt 2018). Positive outcomes can strongly depend on the quality of this process (Aven and Renn 2010). Additionally, certain situations are less conducive to participation (or at least to different levels of participation): for example, if important technical decisions have necessarily already been made; the cultural context does not allow it; there is a lack of necessary institutional capacity; or there is a history of past failed attempts that must first be reckoned with (Puskás et al. 2021; van der Vegt 2018; Wamsler et al. 2019).

In addition to the review by Puskás et al. (2021) described above, there has been some attention given already to the study of public acceptance of NbS. Paper 1 (Review) addresses this comprehensively from the perspective of peer-reviewed research and includes an exploration of the degree of reliance on the public for successful NbS. Here, it is worth acknowledging as a starting point for my research that public acceptance for NbS is highly context dependent, ranging from indispensable support regarding land use rights or the collaborative planting and monitoring of vegetation (Barbier 2006; Waylen et al. 2018), to attitudes expressed through community fora that may manifest in approval or rejection (possibly within democratic decision-making systems) (Badola et al. 2011; Otto et al. 2018). Regardless of case-specific NbS context, the role of multi-stakeholder engagement and co-creation, including with ‘locals’ and ‘host communities’, is considered integral to the NbS approach (IUCN 2020b).

A European-wide survey on public perceptions of NbS carried out in 2015 provides some baseline insight for my research. The survey was conducted by the European Commission and described in their Special Eurobarometer 444 report *Citizen’s view on nature-based solutions* (European Commission 2015a). Several of the key findings include:

1. 60% of Europeans say it is preferable to use NbS for improving the environment and the economy, compared to 13% who prefer technological solutions and 11% who think both should be used;
2. 83% are generally in favour of the EU promoting NbS throughout Europe while only 11% are generally not in favour;
3. 56% of respondents would like to participate in some way if NbS were implemented in their area, by volunteering to do work (24%), sharing information or promoting the project (20%), participating in planning and decision-making (15%), or volunteering advice or expertise (12%).

There are only several noteworthy differences among the 28 European Union member states (including the UK) and very few socio-demographic differences among respondents for points 1 and 2 above. However, respondents who were the most willing to participate with NbS were under 55 years old, students and those with over 20 years of schooling, and those who would like more natural features in their area (European Commission 2015a). Perceptions regarding the DRR potential of NbS were not explicitly included in the survey, although some respondents listed hazards as “significant problems in their area”[7] and “combatting climate change” was generally not considered one of the main benefits of NbS by respondents (16%)[8].

[7] Heatwaves (9%), flooding (8%), droughts (8%), forest fires (5%), soil erosion (4%), coastal erosion (4%)

[8] Respondents considered the main benefit of NbS to be better quality of life (53%), followed by aesthetics (41%), improved health (36%), cleaner air and water (35%), recreational activities (27%), and increased biodiversity (23%); European Commission 2015a.

The Eurobarometer results suggest that, at European scale, DRR benefits from NbS are not as valued as other benefits and that there is (based on 2015 data) a moderate to high acceptance of NbS, both in relation to attitudes and willingness to engage. A clear parallel can be drawn between this and early survey results showing general public acceptance of wind energy (described above). The important lesson from the evolution of research on renewable energy is that the scale of acceptance studies is crucial. This is highlighted by the observation that small but vocal community members can effectively oppose projects that are otherwise generally accepted, and some respondents will have favourable attitudes towards an idea but oppose its implementation in their vicinity (i.e., NIMBYism) (Bell et al. 2005; Wüstenhagen et al. 2007). As highlighted in the three papers presented in this thesis, characteristics of NbS often mirror those of the principal foci of acceptance research: uncertainty, complexity, opportunity costs related to other options (e.g., grey measures), multiple actors, as well as the high potential for societal benefits and issues related to their equitable distribution. Technology and technological advancement in the realms of design, engineering, and planning are also often central to NbS.

1.2.2.2 Theoretical and terminological perspective

My research is interdisciplinary, drawing first from NbS social science research and social/environmental psychology but also from human geography and its focus on place and space (Figure 1-4). This positions NbS as embedded within society and larger social-ecological systems and allows for the assumption that human attitudes and behaviours affect NbS, NbS affect attitudes and behaviours, and dynamic spatial and temporal interactions are possible within a system of contextual factors (Breakwell 2007). The body of work presented is also positioned within practice-driven acceptance research that seeks to identify factors that influence acceptance (generally with the ultimate aim of increasing it) (Carlman 1982; Ellis and Ferraro 2016; Gupta et al. 2012; Leitinger et al. 2010). Additionally, according to the social acceptance typology presented by Upham et al. (2015), I explore community acceptance, within which the foci are on local public and stakeholder acceptance. The object of the research is application (household/end-user) and infrastructure (local), rather than the more general ‘technology’ at societal level (Upham et al. 2015).

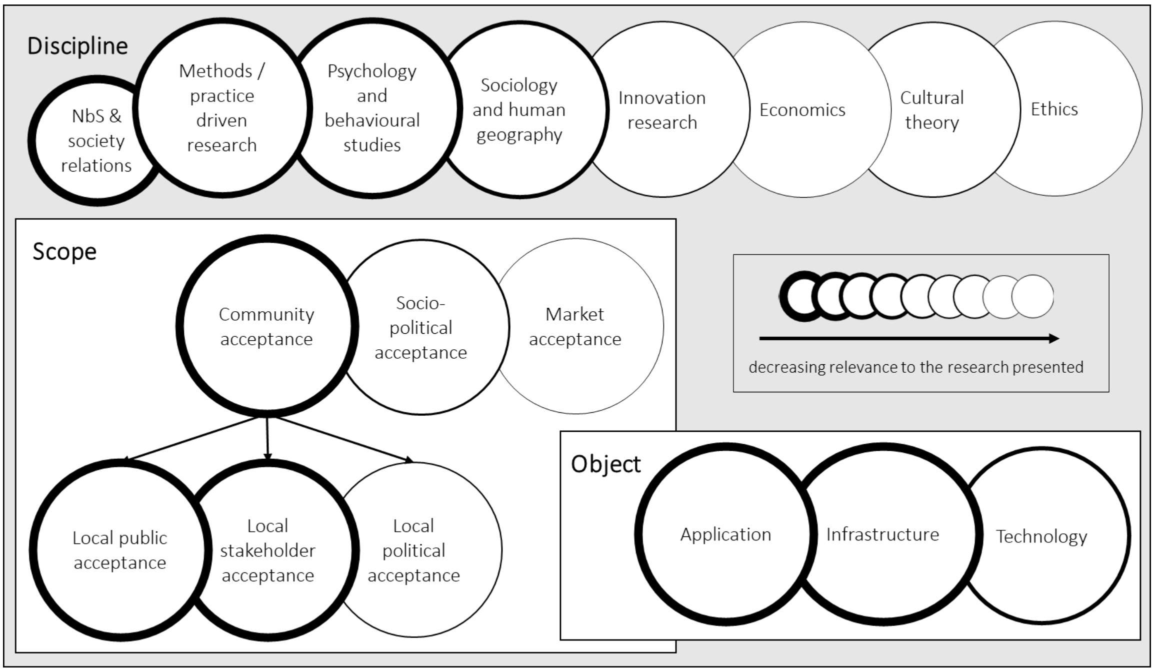

Figure 1-4 Discipline, scope, and object of my research. Moving from left to right and from wider to thinner outline thickness, the approximate relevance of the discipline, scope, and object to the research presented in this thesis decreases. Classifications are taken from Busse and Siebert (2018) and Upham et al. (2015). 'NbS & society relations' is a term used by Kabisch et al. (2016) that I include to describe the core theme behind my disciplinary practice-driven research.

As described in detail in Paper 1 (Review), I consider concepts such as participation, engagement, buy-in, and support as potential forms or manifestations of acceptance (Table. A-2). In other words, these concepts may be used to either describe or measure degrees of acceptance and are only used explicitly in this research when specificity is necessary. Acceptance has generally been treated as positively connotated, associated with passiveness (Anderson et al. 2012), and unidimensional as a concept in academic literature (Busse and Siebert 2018). I follow recommendations from Busse and Siebert's (2018) review on acceptance studies in relation to sustainable land use and treat acceptance as bi-polar, potentially active, and complex. Concepts such as rejection, stakeholder fatigue, protest, and lack of support thus fall on a spectrum of *degrees of acceptance* (from low to high that can be increased or decreased) (D'Souza et al. 2021; Wolsink 2007; Wüstenhagen et al. 2007)[9]. These varying degrees of acceptance are understood as potentially influenced by a range of factors, but crucially also the implicit or explicit comparison of the

[9] To not always write 'high' or 'low' public acceptance, and given the general positive connotation of the term, just 'public acceptance' can be used to denote a sufficiently high level, whereas 'low acceptance' is always explicitly specified.

perceived reality of a situation in relation to potential alternatives (Brunson 1993) (e.g., 'NbS versus no NbS' or 'NbS versus grey measure').

'Public' is understood in my research as a group of individuals who reside within or near the NbS and are (or will be) directly or indirectly affected by it. The *affected public* as stakeholders are of primary interest rather than the broader *observing public* (Renn et al. 2006; Upham et al. 2015), although 'affected' here can be indirect (e.g., related to risk of impacts on the broader community or related to spatially bound decision-making processes). Living 'within NbS' refers to large-scale NbS such as ecological restoration or managed coastal realignment in which residents may live on site. Upham et al. (2015) and Wüstenhagen et al. (2007) refer to the acceptance of such local residents as 'community acceptance'. I use 'public acceptance' because I consider the potential broader implications of findings at local levels to the field of NbS and society. My research focuses on the individual stakeholders who interact with NbS and are likely beneficiaries of them, and whose attitudes and behaviours play some role in their success. Therefore, 'public acceptance' can be considered the positive or negative attitudes and behaviours of these individuals, on aggregate, towards the NbS (Upham et al. 2015). Such individuals may or may not hold professional appointments as decision-makers, scientists, or other positions with the potential to influence NbS beyond their role as local citizen stakeholders.

'Acceptability' is sometimes used interchangeably with 'acceptance' in academic literature but is understood as a property of the object (NbS in this case), rather of the subject, i.e., actors capable of 'accepting' (Heldt et al. 2016; Sattler and Nagel 2010). Here, I focus on the subject as actors (public in this case), whose degree of acceptance may be influenced by attributes of the object (NbS) but may also be influenced by a range of contextual and cognitive factors. 'Attitudes' are closely related to degrees of acceptance (Busse and Siebert 2018; Shindler et al. 2002) and are often treated as causal precursors to acceptance (Stigka et al. 2014; Wolsink 2007) or to behaviour that equates to acceptance (e.g., following public health measures against Covid-19 (Siegrist et al. 2021) or purchasing green products (Chen and Hung 2016)). My research shares this attitude-behaviour perspective, in line with one of the most commonly applied and consistently predictive behavioural theories, the Theory of Planned Behaviour (Ajzen 1991). However, following Leitinger et al. (2010)

and Hitzeroth and Megerle (2013), among others, I also treat attitudes as manifestations of acceptance. In this regard, attitudes are seen not only as potential precursors of behaviour, but as end-point indications of acceptance that should be evaluated and addressed in the context of NbS projects.

‘Attitudinal acceptance’ is thus complex and multi-dimensional as an underlying measurable characteristic of individuals (Upham et al. 2015). Perspectives on NbS represented by statements such as “I think the NbS is beautiful” or “I think the cost of the NbS is too high” represent perspectives that may indicate underlying attitudes, which, in turn, comprise attitudinal acceptance. I also assess ‘behavioural acceptance’ as the willingness to actively support/engage in different ways with the NbS and NbS project. This follows the classification of ‘end-user acceptance’ by Upham et al. (2015) and the Eurobarometer survey *Citizens views on nature-based solutions* in that it assesses the public’s willingness to voluntarily support NbS (European Commission 2015a). As reiterated in Paper 2 (Survey), it is important to clarify that I assess behavioural *intention* rather than actual behaviour.

‘Perceptions’ are another closely related concept and often treated as a specific element of acceptance or indeed a synonymous term (Busse and Siebert 2018). Perceptions are treated here as potential contributors to attitudes and behaviours (Myatt et al. 2003a), which then comprise acceptance (Upham et al. 2015; Warren and Birnie 2009). Perceptions are generally more sensory and less cognitively evaluative and expressive than attitudes, and their aggregation (likely across time) can shape attitudes that are then directed towards an object (NbS) (Shindler et al. 2002; Upham et al. 2015). For example, perceptions of benefits from NbS may influence the formation of attitudes towards NbS that form dimensions of acceptance of NbS. However, ‘perception’ can also be used more generally in reference to a normative position on an object, as in work by Han and Kuhlicke (2019) on perceptions of NbS.[10]

The background and operationalization of ‘participation’ and similarly ‘engagement’ are highly relevant in public acceptance research and their

[10] This phrasing can be useful since ‘misperceptions’ due to novelty, complexity, and associated uncertainty are a commonly identified barrier to acceptance (Ellis and Ferraro, 2016; Shindler et al., 2002).

relevance in the broader NbS context have been discussed in previous sections. In my research, an individual's degree of willingness to engage with the project is a manifestation of behavioural acceptance (Paper 2). This is a practice-oriented and measurable perspective in relation to direct actions to support the NbS work (i.e., to help implement, monitor, attend meetings, etc.). The more general processes of stakeholder engagement and co-creation within the OPERANDUM NbS project are not central to this research. Instead, these are relevant in their potential relation to public acceptance, starting with the assumption that carefully planned engagement activities that follow best practice and meet their objectives likely act to increase public acceptance, while poorly planned communication, outreach, and participatory activities likely have the opposite effect (Anderson et al. 2012; Rau et al. 2012; Wamsler et al. 2019). Participation does not always equate to or precede high levels of acceptance, since the latter implies support (albeit possibly resulting from *successful* participation) and results from individual and contextual factors (Hildebrand et al. 2018). This perspective highlights the importance of assessing both attitudinal and behavioural acceptance as related but distinct concepts.

1.3 Research gaps, questions and objectives

The underlying historical, theoretical, and thematic background in the previous sections has demonstrated the utility of conducting this research. The review described how public acceptance can be crucial for the uptake of new ideas and technologies for addressing societal challenges. The theoretical approach of the research was described, and concepts such as risk perception and ecosystem services were highlighted throughout as potentially shaping public attitudes and behaviours and therefore also public acceptance. Most importantly, it has shown that the NbS approach has great promise, but targeted social science research can address barriers to its success. In summary, public engagement with NbS is emphasized in academic and grey literature, along with a greater reliance on public 'host communities' of NbS for DRR for their co-design, co-implementation, co-monitoring, and long-term protection. However, the public's contextual willingness to engage and the full range of factors that may motivate this remain unclear, while both NbS and non-NbS research point to public perceptions as one potential barrier to uptake. Against this background, more specific knowledge gaps emerge that correspond to the aims of the three papers (Table 1-2).

Table 1-2 Knowledge gaps in relevant research areas that each of the three papers in this thesis, and their corresponding research questions, aims to address.

	There is a lack of NbS for DRR research that…
Paper 1 (Review)	• explores societal interactions and associated barriers • directly compares NbS with grey measures • comprehensively identifies factors that may influence public acceptance
Paper 2 (Survey)	• goes beyond weighting of criteria to explore public attitudes and behaviours • includes variables for perceptions of risk, nature, and place in the same study • compares across distinct rural NbS sites
Paper 3 (FGDs)	• considers community preferences for the full spectrum of green, hybrid, or grey measures • explores public perceptions of NbS benefits in relation to their 'no-regret' framing • considers public perceptions of risk, effectiveness of NbS, and nature with the same participants and how they influence acceptance • explores public acceptance of NbS using open and in-depth qualitative methods to assess perceptions

Corresponding to the three papers, three overarching research questions were outlined at the beginning of this section: 1) Why, when, and how does public acceptance matter for NbS and how does this compare to grey DRR measures?; 2) What is the strength of different factors behind public acceptance and do they show consistency or differ across European NbS contexts?; and 3) Do local residents at planned NbS sites prefer NbS over hybrid or grey measures and what factors and/or (mis)perceptions influence their preferences?

Each paper that follows in sections of this thesis also includes explicit research questions at the end of their respective introduction sections. These are provided below under the papers' title to provide an overview of the flow and objectives of the research:

Paper 1: A review of public acceptance of nature-based solutions: the 'why', 'when', and 'how' of success for disaster risk reduction measures

RQ1) When and why is public acceptance of NbS important and do NbS diverge from grey measures in this regard?
RQ2) What are the factors that influence public acceptance of NbS and do NbS diverge from grey measures in this regard?
RQ3) How can we build public acceptance of NbS by leveraging the identified factors?

Paper 2: Public acceptance of nature-based solutions for natural hazard risk reduction: Survey findings from three study sites in Europe

RQ1) What is the degree of public acceptance within the NbS sites and how does this differ across the sites?
RQ2) What variables define attitudinal acceptance, what is their strength within and across sites, and are perceptions of risk, nature and place associated with them?
RQ3) What variables define, correlate with, and explain behavioural acceptance (i.e., willingness to engage), and do attitudes towards NbS moderate their strength?

Paper 3: Green, hybrid, or grey disaster risk reduction measures: What shapes public preferences for nature-based solutions?

RQ1) To what degree do residents in communities with planned NbS (green) prefer grey measures in addition to green measures (hybrid approach) or grey measures instead of green measures?
RQ2) Are perceptions of NbS effectiveness, risk, and nature associated with these preferences?
RQ3) What other factors, including the perceived importance of NbS benefits, influence preferences for measures to be greener or greyer?

a) Are nature and risk-related benefits perceived as complementary or non-complementary (conflicting)?

b) Are green measures perceived as ‘no-regret’ given their co-benefits even if they fail to prevent future landslides?

The research starts with a broad and exploratory approach, with findings from each paper then contributing to the focus and methodological details of subsequent work. Specifically, Paper 1 (Review) identified factors that influence public acceptance and combined them with recommendations for increasing acceptance within a framework (i.e, the Public Acceptance of NbS framework [PA-NbS]). A more targeted list of the factors identified are then incorporated into citizen surveys described in Paper 2 (Survey), carried out at three rural OPERANDUM sites: the Spercheios River Basin in Greece, the Lake Puruvesi area in Finland, and the village of Catterline, Scotland. Survey results showed interconnections among certain factors as well as potential preferences for hybrid or grey measures in Catterline, which informed the design of focus groups carried out there, as described in Paper 3 (FGDs) (Figure 1-5).

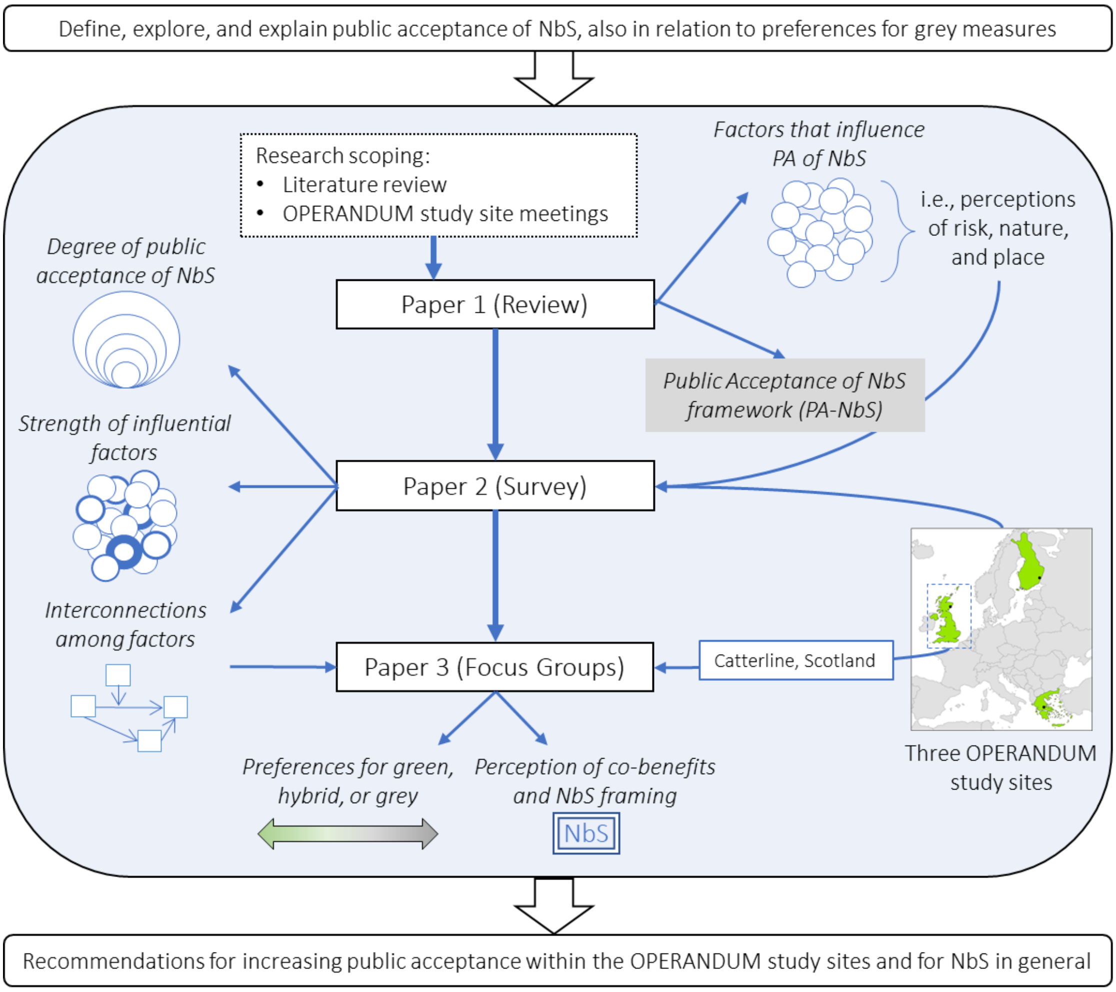

Figure 1-5 Composition and flow of the research presented. The overall research aim is divided into boxes above and below the flow diagram, with recommendations (*lower box*) emerging from the methods applied. Starting from a process of research scoping, the first paper then identified public acceptance (PA) factors that were used as variables in the survey (second paper) conducted at OPERANDUM NbS sites in the Spercheios River Basin in Greece, the Lake Puruvesi area in Finland, and the village of Catterline, Scotland. Subsequently, interconnections were found that were explored in detail in Catterline in the third paper.

Prior to commencing with work on Paper 1 (Review), a scoping review of background academic and grey literature concentrated on the rapidly increasing body of work explicitly on NbS; Eco-DRR and EbA; public acceptance and green technology adoption; risk perception, risk communication, and pro-environmental attitude and behaviour change; and public stakeholder engagement. As a loose boundary, the collection of background literature prioritised research conducted in relation to natural hazards and disaster risk reduction. This review, along with meetings with study site managers within the OPERANDUM project, helped define the scope of the research. The process was carried out to ensure the work would advance NbS research while also being both feasible within the larger project and potential study sites. As mentioned, the work presented does not contribute to any project deliverables and was neither decided on nor delegated by project managers. Additionally, the research presented is not dependent on the details of the OPERANDUM project and these are therefore not provided beyond a description of the study sites found in Paper 2 (Survey) and briefly reiterated in Paper 3 (FGDs). However, the research is designed to benefit the project by assessing public acceptance of NbS and providing relevant recommendations to site managers and other colleagues.

The next three chapters present each of the three papers without any additional commentary. These are followed by a conclusion chapter that summarises the overall implications of the body of work, discusses limitations and potential misinterpretations of the research, and provides a future outlook. Supplementary material from the published papers and the thesis, including selected additional analyses not included in the papers, are found in an appendix at the end of the document prior to all references.

Chapter 2 A review of public acceptance of nature-based solutions: the 'why', 'when', and 'how' of success for disaster risk reduction measures

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Author contributions:

Conceptualization, CCA and FGR; data collection, CCA; investigation, CCA; data curation, CCA; writing—original draft preparation, CCA; writing—review and editing, CCA, FGR; supervision, FGR; project administration, FGR; funding acquisition, CCA, FGR. All authors have read and agreed to the published version of the manuscript.

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Abstract:

Nature-based solutions (NbS) are increasingly recognised as sustainable approaches to address societal challenges. Disaster risk reduction (DRR) has benefited by moving away from purely 'grey' infrastructure measures towards NbS. However, this shift also furthers an increasing trend of reliance on public acceptance to plan, implement and manage DRR measures. In this review, we examine how unique NbS characteristics relate to public acceptance through a comparison with grey measures, and we identify influential acceptance factors related to individuals, society, and DRR measures. Based on the review, we introduce the PA-NbS model that highlights the role of risk perception, trust, competing societal interests, and ecosystem services. Efforts to increase acceptance should focus on providing and promoting awareness of benefits combined with effective communication and collaboration. Further research is required to understand interconnections among identified factors and how they can be leveraged for the success and further uptake of NbS.

Key words: citizen engagement; ecosystem-based disaster risk reduction; framework; public acceptance; nature-based solutions; stakeholder participation

2.1 Introduction

Public acceptance has become increasingly recognised as a key consideration within natural hazard risk reduction policy (Sarzynski and Cavaliere 2018). At the international level, the Sendai Framework for Disaster Risk Reduction 2015-2030 (UNISDR 2015) codified an “all-of-society” approach that hinges on participation and engagement and includes the words “public” or “society” in seven of its 11 guiding principles. At regional level, perhaps the best example is the European Union Water Framework Directive (European Commission 2000), which requires public participation for addressing flooding in river basin management plans.

In a review of complex environmental risk issues, van der Vegt (2018) argues that a decline in public trust of decision-makers, expert-public disagreements, and greater demand for inclusivity and transparency have motivated the increase in calls for public engagement. Additionally, Wamsler et al. (2019) synthesize motivations for increased citizen involvement in nature-based adaptation planning, citing the burden placed on disaster risk managers in the current context of rapidly changing climatic conditions, citizen-local authority conflicts regarding land-use as a result of these changes, and claims regarding “relevance; fairness; acceptance; and, ultimately, sustainability” (p. 2). Certainly, the push towards increased public engagement can lead to positive outcomes (Mees et al. 2016; Reed 2008). However, gains are predicated on context (Wamsler et al. 2019), and the willingness of the public to accept disaster risk reduction (DRR) efforts and actively engage is not a foregone conclusion (Godschalk et al. 2003).

At the same time, a paradigm shift (back) towards living with, rather than controlling nature (de Groot 2012) has been promoted, spurred by an increasing recognition of synergies among efforts for reducing risk, tackling climate change, and addressing human development issues by leveraging ecosystems and their services (Renaud et al. 2016). With this shift and particularly following the 2004 Indian Ocean Tsunami, ecosystem-based approaches for reducing risks have steadily gained recognition and their uptake continues to grow. These approaches are in contrast to ‘grey’ infrastructure measures such as dykes or seawalls, although the two are often combined in ‘hybrid’ measures.

Various ecosystem-based approaches for reducing risk such as ecosystem-based disaster risk reduction (Eco-DRR) and ecosystem-based adaptation (EbA) or green infrastructure (related to ecosystems on land and/or green spaces) and blue infrastructure (if aquatic ecosystems are involved) now fall under the nature-based solutions (NbS) umbrella concept (Cohen-Shacham et al. 2016). The International Union for Conservation of Nature (IUCN) defines NbS as “Actions to protect, sustainably manage and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (Ibid p.4). Increasing recognition of the concept is exemplified by the European Commission incorporating NbS as part of its 2020 research agenda and funding a number of large pan-European projects (Faivre et al. 2017). The success of these projects and the continued dissemination of NbS globally will depend on whether the public willingly accepts this approach.

Public acceptance has been a nebulous term as used in literature surrounding sustainability, often employed without a specific working definition (Wüstenhagen et al. 2007). Here, we define the public as a stakeholder group composed of individuals who are affected by the risk reduction measure and reside within or near the measure. Acceptance can be stated or demonstrated and exists on a broad spectrum ranging from rejection to active support (Wüstenhagen et al. 2007). Thus, public acceptance in this context is determined by individual or community attitudes and/or behaviour towards a DRR measure.

The importance of public acceptance varies contextually, but characteristics of NbS suggest that understanding its dimensions and causal determinants is crucial (Cohen-Shacham et al. 2016; Wamsler et al. 2019). The IUCN proposes eight principles that characterise NbS, within which public acceptance is one key theme (paraphrased; 1: embrace nature conservation norms, 2: be implemented alone or in an integrated manner, 3: be determined by site-specific contexts, 4: have fair and equitable benefits with transparency and participation, 5: maintain biological and cultural diversity, 6: be applied at landscape scale, 7: recognise trade-offs between immediate economic benefits and long-term ecosystem services, and 8: be an integral part of the design of methods to address a specific challenge) (Cohen-Shacham et al. 2016). For example, the third principle of NbS involves the integration of local and traditional knowledge within site-specific contexts. Knowledge integration is reliant on willing and broad participation, a key theme of the fourth principle. They also suggest that NbS be applied at landscape scale (principle 6) and consider long-term benefits (principle 7). Both principles imply a greater dependence on the public given the inherent value-based trade-offs of land-use and future visions. The multifunctional nature of NbS also creates more potential for value-dependent trade-offs (Nesshöver et al. 2017) as well as the need for multi-actor collaborations (Frantzeskaki 2019). This is further supported by several NbS approaches that rely entirely on some degree of public participation, such as Integrated Water Resource Management and Integrated Coastal Zone Management (e.g., Brandolini and Disegna 2015).

More recently, the IUCN has published the Global Standard for NbS. The standard has criteria aligned to the NbS principles but designed as a more practice-oriented indicator framework for ensuring successful NbS deployment (IUCN 2020b). Criterion 5, “NbS are based on inclusive, transparent and empowering governance processes” emphasizes the importance of stakeholder involvement and is the most closely aligned with public acceptance. Criteria 4 and 6 are related to benefits and trade-offs of NbS and also highlight the role of stakeholders for successful NbS deployment (IUCN 2020b).

Despite this, past studies on ecosystem-based approaches have focussed primarily on engineering and economic benefits rather than interactions among relevant actors (Triyanti and Chu 2018). Indeed, Kabisch et al. (2016) identify societal relations with NbS specifically as a major knowledge gap, including issues surrounding stakeholder involvement, equity of co-benefits and public communication. One exception is Wamsler et al.’s (2019) assessment of citizen involvement with NbS among Swedish municipalities. Among others, they identify barriers such as a lack of institutional capacity and resources, conflicting public interests, resistance to change, and place attachment. Moreover, they underscore that current organizational structures, often lacking flexibility, may not be conducive to successful citizen engagement, although the advent of NbS offers potential for change. A recent review by Han and Kuhlicke (2019) identifies core topics surrounding perceptions of NbS - co-benefits, risk reduction efficacy, socio-economic and location-specific factors, participation, environmental attitudes, and uncertainty. However, neither study directly compares NbS with grey DRR measures nor considers a set of comprehensive factors that may influence public acceptance and be leveraged to increase it.

These research gaps are reflected in overly generic policy guidelines for societal interactions in the context of NbS approaches. An emphasis is generally placed on stakeholder engagement and participation as instrumental for effectiveness, but recommendations are not tailored for potential unique characteristics of NbS or public acceptance as such. For example, recently published guidelines for design and implementation of Ecosystem-based Disaster Risk Reduction and Ecosystem-based Adaptation by the Convention on Biodiversity (CBD 2019) include a subsection on involving indigenous and local communities (2.3.1) but are largely based on the assumption of public interest and willingness. The following subsection in that document on “mainstreaming” NbS (2.3.2) also exemplifies a lack of systematic consideration of societal interaction within relevant policy guidelines. It emphasizes policy coherence and investment as well as the roles of institutional stakeholders, but disregards public support. However, uptake in policy can also rely on public acceptance, particularly within strong democratic systems.

Determining factors that may contribute to or detract from public acceptance of NbS is crucial given the identified research gaps and increasing investment in NbS projects. Along with providing insight into key areas that merit further research, such factors should allow for guidance towards better design, implementation, and dissemination of NbS. This literature review thus sets out to answer three principal questions:

1. When and why is public acceptance of NbS important and do NbS diverge from grey measures in this regard?
2. What are the factors that influence public acceptance of NbS and do NbS diverge from grey measures in this regard?
3. How can we build public acceptance of NbS by leveraging the identified factors?

Moreover, we integrate the theoretical perspectives of ecosystem services and risk perception of natural hazards to structure key findings. Characterizing NbS benefits from an ecosystem service perspective has been promoted by the IUCN (Cohen-Shacham et al. 2016) and others (e.g., Nesshöver et al. 2017). Risk perception has been used extensively for explaining individual and societal attitudes and behaviours in situations of risk from natural hazards (Terpstra et al. 2006). The results are structured on the basis of these three primary research questions as well as explicit subsections for ecosystem services and risk perception as key concepts. Prior to this, the methods outline the scope of the review and the key word search. Results are followed by a discussion, including limitations of the review and a call for future research guided by a proposed framework for understanding and increasing public acceptance (PA) of NbS – the PA-NbS framework.

2.2 Methods

2.2.1 Scope

We use three initial scoping criteria for determining which DRR measures are appropriate for the review. Measures must 1) be physical, 2) have public benefits and 3) have natural hazard risk reduction as a primary aim. By limiting the review to blue, green, hybrid, and grey measures, we exclude all measures that do not involve change in the physical environment (e.g., early warning systems). We classify blue, green, and hybrid measures as NbS since they include a natural element and therefore societal co-benefits (Cohen-Shacham et al. 2016). Grey measures are therefore defined by the absence of any natural component.

2.2.2 Key word search and article screening

We use the Scopus database and ROSES standards for systematic reviews in environmental research (Haddaway et al. 2017). Prior to defining search terms, 11 articles were selected to be included in the review based on expert knowledge and an extensive, non-systematic scan of literature using Scopus and Google Scholar. By ensuring these were found using the key word search, we were able to better train the search process and add confidence to the final composition of search terms.

Based on the guiding research questions for the review, we created three categories of search terms in Scopus applied to titles, key words and abstracts: 1) actors to accept, 2) ways to accept, and 3) DRR and NbS (Table 2-1). Because the actors listed in Group 1 engage in the actions listed in Group 2, these terms are coupled. For example, articles should include one or more instance of *public acceptance*, *public perception*, *social acceptance*, *social perception*, etc. rather than e.g., "*public* understanding of cultural *acceptance*". This was specified in Scopus using the proximity operator 'w/2' between the set of group one and group two terms.

To avoid selection bias, we add five key words to Group 2 to capture a potential lack of acceptance (apath*, indifferen*, burnout, fatigue, reject*). For Group 3, we use a list of categories and examples of NbS from a recent IUCN report on NbS (Cohen-Shacham et al. 2016). The list is necessary since NbS is still a new term and not always used systematically. The list is not exhaustive, but using the 'OR' operator with search terms referring generally to DRR, mitigation, adjustment, and management, we were able to capture relevant physical measures.

Table 2-1 Literature review search terms. Three search term groups are used and combined with Boolean operators (underlined) to form the search term sequence. All possible pairs of terms from Groups 1 and 2 are created using the operator 'w/2', which connects two words that must be 'within two' words each other. An 'AND' operator combines these pairs with words from Group 3.

Groups		Search terms with unique identifiers
1	Actors to accept (n=10)	(1.1) public, (1.2) social, (1.3) societ*, (1.4) stakeholder, (1.5) communit*, (1.6) individual, (1.7) household, (1.8) resident, (1.9) citizen, (1.10) local
2	Ways to accept (n=17)	(2.1) accept*, (2.2) perception, (2.3) participat*, (2.4) preference, (2.5) buy-in, (2.6) involv*, (2.7) engag*, (2.8) "collective action", (2.9) sentiment, (2.10) attitude, (2.11) belief, (2.12) behavio*, (2.13) apath*, (2.14) indifferen*, (2.15) burnout, (2.16) fatigue, (2.17) reject*
3	DRR and NbS (n=34)	(3.1) resilien*, (3.2) drr, (3.3) disaster, (3.4) nbs, (3.5) "nature-based solution", (3.6) "hazard mitigation", (3.7) "hazard adjustment", (3.8) "risk mitigation", (3.9) "risk reduction", (3.10) "risk management", (3.11) "risk communication", (3.12) "eco-engineering", (3.13) "ecological restoration", (3.14) "ecological engineering", (3.15) "forest landscape restoration", (3.16) "ecosystem-based adaptation", (3.17) "ecosystem-based mitigation", (3.18) "climate adaptation services", (3.19) "ecosystem-based disaster risk reduction", (3.20) "natural infrastructure", (3.21) "green infrastructure", (3.22) "integrated coastal zone management", (3.23) "integrated water resources management", (3.24) "protected area management", (3.25) "ecosystem-based management", (3.26) "wetland restoration", (3.27) "floodplain restoration", (3.28) "building with nature", (3.29) "natural infrastructure", (3.30) "river management", (3.31) "ecosystem services", (3.32) "landscape restoration", (3.33) "coastal management", (3.34) "coastal protection"

Search term sequence[1]

(1.1 w/2 2.1) OR (1.2 w/2 2.1) OR (1.3 w/2 2.1) OR ... (1.1 w/2 2.17) OR
(1.2 w/2 2.1) OR (1.2 w/2 2.2) OR (1.2 w/2 2.3) OR ... (1.2 w/2 2.17) OR
(1.3 w/2 2.1) OR (1.3 w/2 2.2) OR (1.3 w/2 2.3) OR ... (1.3 w/2 2.17) OR
...
(1.10 w/2 2.1) OR (1.10 w/2 2.2) OR (1.10 w/2 2.3) OR ... (1.10 w/2 2.17) OR
AND
3.1 OR 3.2 OR 3.3 OR ... 3.34

[1]See Text. A-1 in the appendix for the full search term sequence.

We include articles since 1990 and up to May 15, 2019 to be inclusive and since 1990 coincides with an increased awareness of the importance of ecosystems and their societal co-benefits (e.g., the Brundtland Report published in 1987 (Brundtland et al. 1987) and the Rio Earth Summit held in 1992).

All terms in Group 1 and Group 2 were paired, yielding 170 search terms. These terms were connected to Group 3 terms using an ‘AND’ operator, with all terms within groups separated by ‘OR’ operators. The new sequence yielded 18 147 returns in Scopus that were subsequently reduced using a step-wise exclusion methodology (Figure 2-1).

We first identified irrelevant terms found in the titles of the first 500 articles (automatically sorted by relevance in Scopus) to exclude thematically divergent articles. We then applied the ‘filter by subject area’ function, select to only include book chapters and articles in the languages English, French, German, Portuguese or Spanish (being inclusive as possible with language constraints of the reviewers), and removed duplicates.

With the 5 900 articles, we conducted an initial title screening, followed by a screening of abstracts and full articles when necessary. To amend the final 111 article count, all articles were carefully read and 19 more excluded during a round of preliminary coding. This was most commonly due to methodological proposals, bundling behavioural and structural measures in the analysis, or only focussing on technological hazards. All reference sections in the remaining 92 articles were scanned and seven more articles included, resulting in a final total of 99 articles.

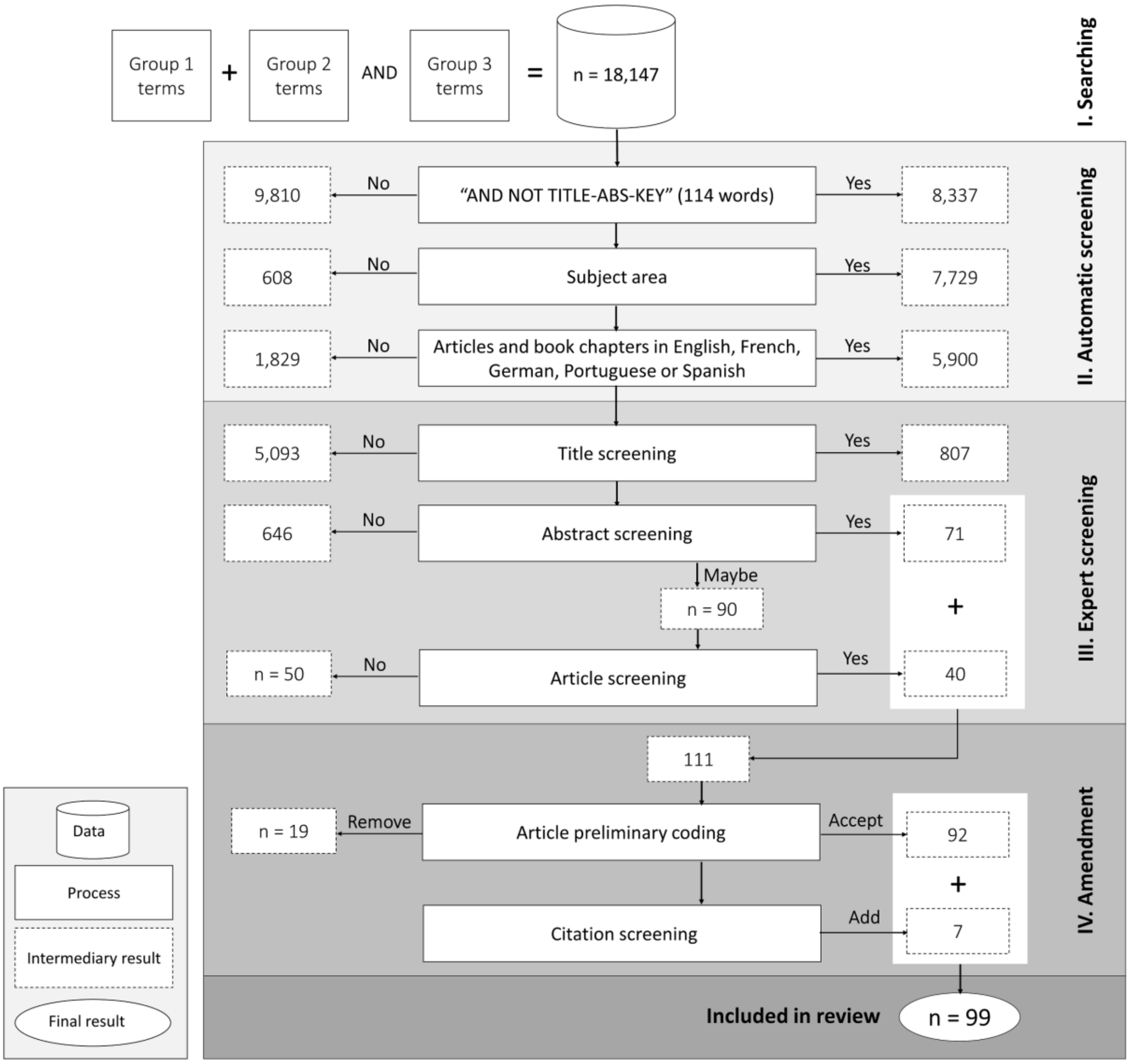


Figure 2-1 Literature review process flow chart. Flow chart of four broad steps (searching, automatic screening, expert screening and amendment) and detailed steps taken to determine the inclusion of articles in the systematic review.

2.2.3 Data extraction

We conducted thematic coding using the software NVivo Pro v.12. In a first reading, all articles were assigned to sets of descriptive categorical classes to better understand the dataset. These identify the case studies described in the articles as either urban/rural, by hazard type, scale, continent, and whether the article describes NbS or grey measures. For the latter, an additional code of "two or more" measure types was created for articles that do not differentiate between NbS and grey measures in their findings. These results are presented in the first results section "Descriptive statistics of the dataset".

Next, we conducted a round of inductive coding on the reviewed studies' findings and reflections (i.e., results, discussion, and/or conclusion sections). We broadly assigned all explicit or implicit mentions of public acceptance outcomes, influencing factors for acceptance, and ways to increase acceptance to corresponding codes. Subsequent results sections correspond to these three coding exercises. The remaining coding process was inductive and exploratory. Themes were allowed to emerge from the data by starting with this limited set of broad pre-defined codes and iteratively creating new and more detailed categories. These were further disaggregated into more specific themes. In the results section, the findings presented are based entirely on literature from the review dataset. These are the only referenced literature in this section; an exclusive list of which is provided in Text. A-2.

2.3 Results

2.3.1 Descriptive statistics of the dataset

In total, 97 articles and two book chapters were selected for coding (Text. A-2), all in the English language except one article in French. A trend of increasing relevant publications since 2001 is evident, particularly for NbS (Figure 2-2). Along with an increase in scientific publications generally, this likely reflects both the increase in implementation of participatory approaches and NbS approaches.

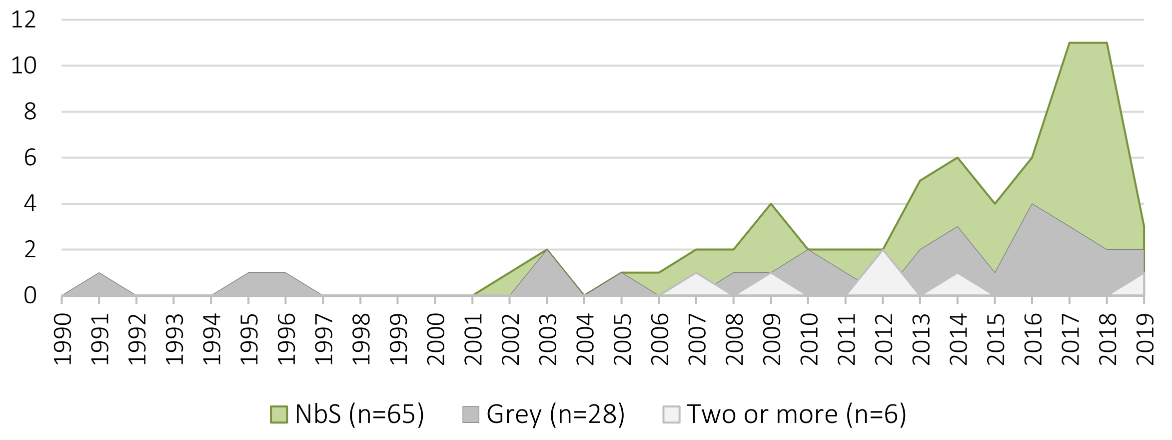


Figure 2-2 Review articles by year. Number of articles describing NbS, grey, or two or more measures by year published included in the literature review.

Although distinguishing between NbS and grey measures is relatively simple, grouping measures based on their underlying concepts is more difficult. This is a result of the breadth and complexity of terms used as well as their overlap. Relying primarily on how the authors define their own work, the most common forms of NbS in the review are ecological restoration (n=17), risk and ecosystem management (n=15), green and blue-green infrastructure (n=13), and managed realignment (n=6) (Table. A-1). Only one article makes explicit reference to NbS. For grey measures, descriptions are more generic due in part to less terminological/conceptual competition, the most common being simply “structural measures” (n=6).

The most common type of article describes rural NbS in Asia (n=12), driven by mangrove replanting/restoration. The second most common article type is NbS in an urban (n=10), rural (n=10) or mixed (n=10) context in Europe (Figure 2-3). There is considerable variation in the dataset, although there are no studies from Africa and only five between South America and Oceania.

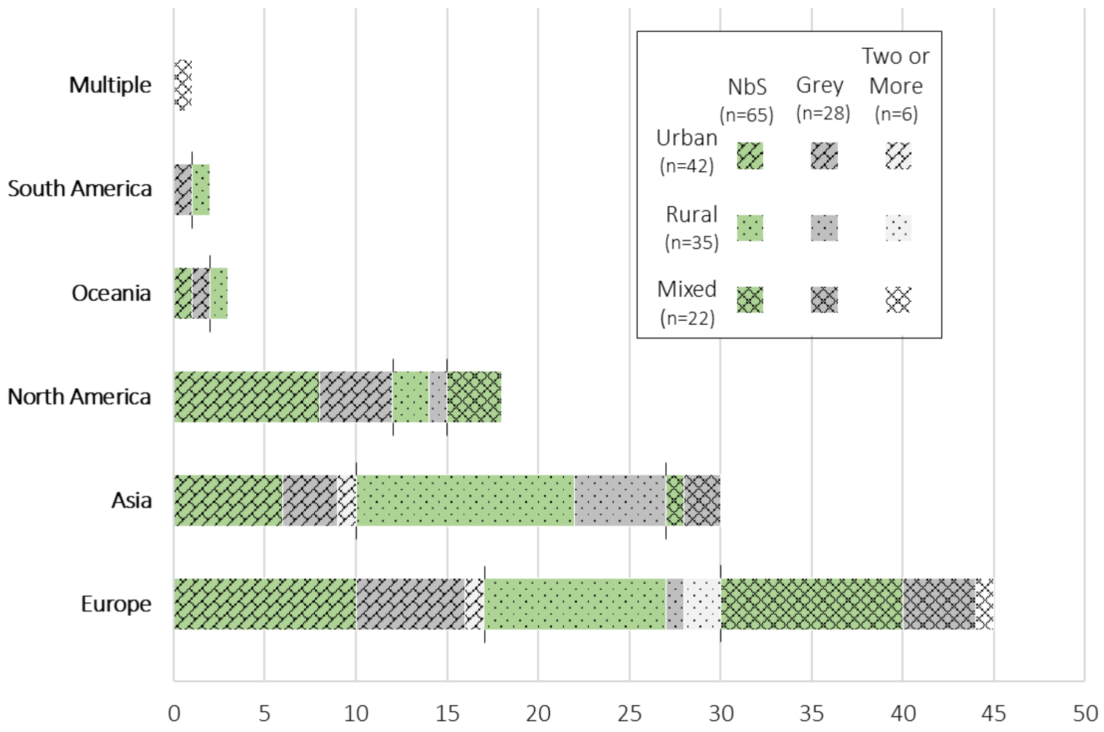


Figure 2-3 Review articles by geographies and measure type. Number of articles describing NbS, grey, or two or more measures in urban, rural, and mixed contexts by continent included in the literature review. No reviewed articles describe measures in Africa.

Nearly half of all articles describe measures implemented in a coastal setting (n=42). Despite some variation in land covers, low-lying areas are greatly overrepresented in the dataset, including also floodplains (n=9), (low-lying) rivers (n=8) and wetlands (n=6). Comparing NbS to grey measures in these environments, the influence of mangrove restoration as a coastal forest NbS and ecological restoration of wetlands is pronounced (Figure 2-4).

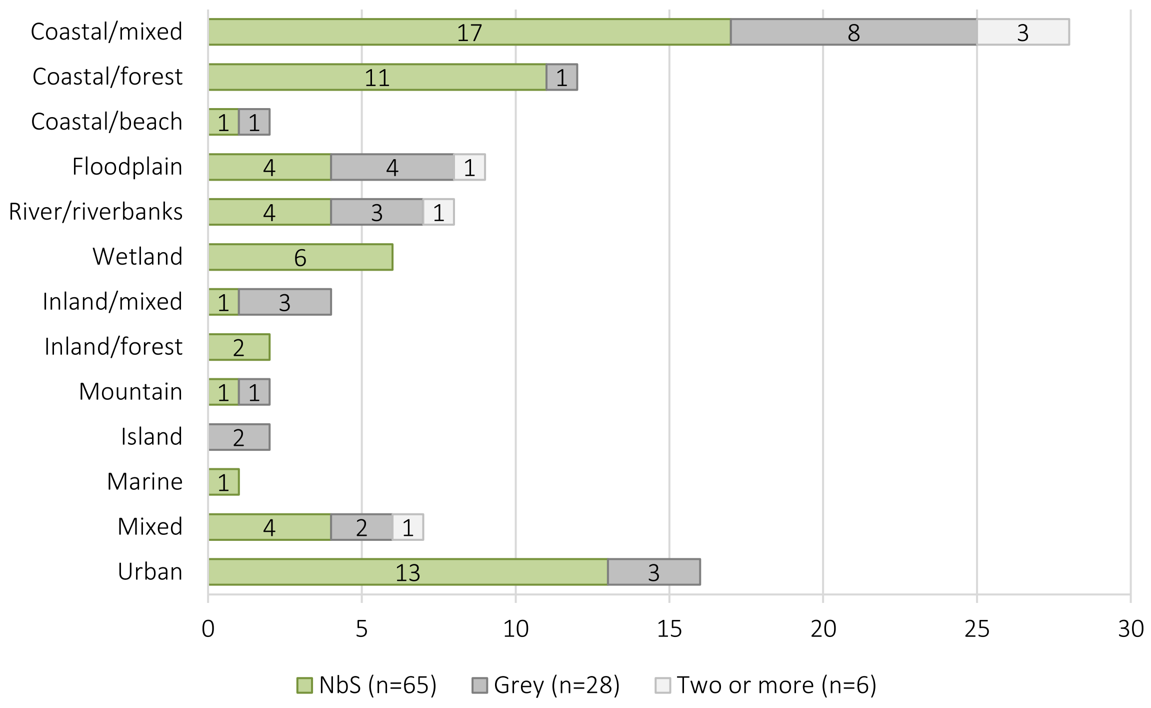


Figure 2-4 Review articles by land cover and measure type. Number of articles describing NbS, grey, or two or more measures by land cover included in the literature review. 'Mixed' denotes multiple land covers across geographies, while 'Coastal/mixed' and 'Inland/mixed' denote mixed land use within these respective geographies.

Only 16 articles are classified as urban land cover because measures focussing on rivers or riverbanks, for example, may occur within cities but are classified at this more specific level. Measures with urban land cover most often involve urban storm water, such as "sponge city" or SuDS (sustainable urban drainage system) designs.

Twelve different hazards were identified in the articles, with flooding being the most prominent (Figure 2-5). Many measures, particularly NbS, address multiple hazards (on average, two hazards per NbS article and 1.5 hazards per grey article). This is driven in part by the stated aim of coastal NbS to reduce erosion as a secondary benefit along with more sudden-onset coastal hazards like storm surge.

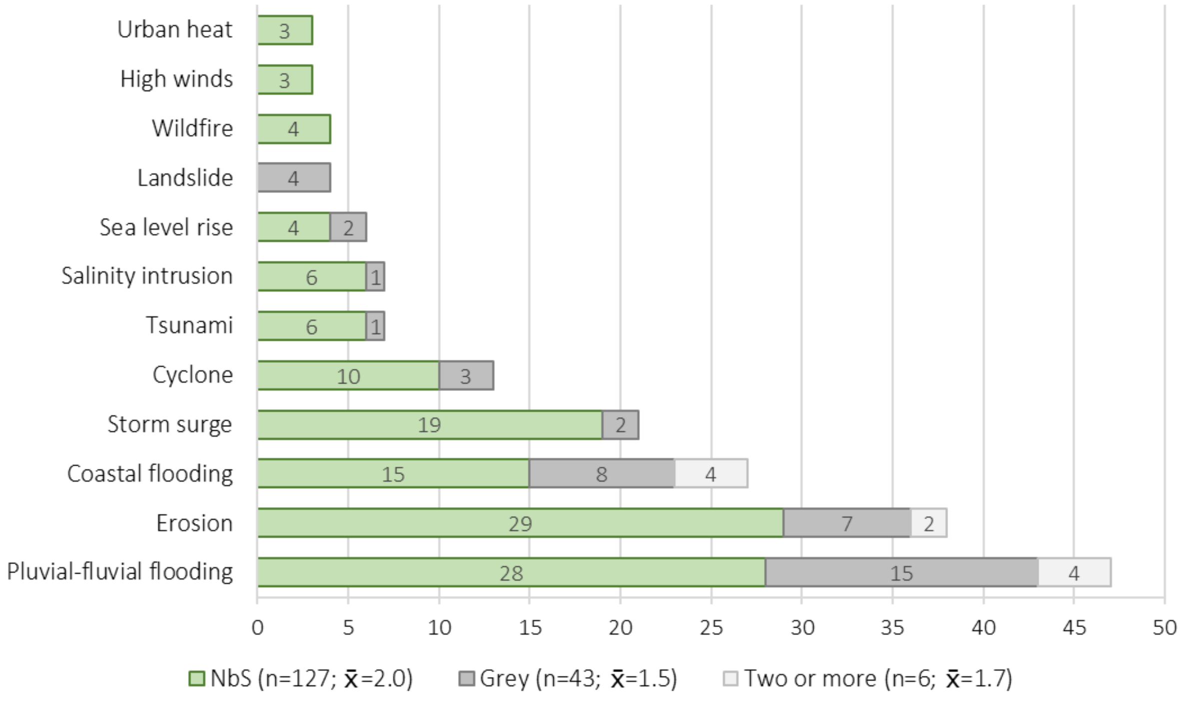


Figure 2-5 Review articles by natural hazard and measure type. Number of articles describing NbS, grey, or two or more measures aimed at reducing risk from different natural hazards included in the literature review. The total number of hazards addressed by each measure type and corresponding arithmetic mean are provided.

2.3.2 When and why is public acceptance of NbS and grey measures important?

There are many positive, negative, and neutral indicators and manifestations of acceptance in the reviewed literature (Table. A-2). As a consequence of these manifestations and indicators, we identify twelve broad benefits of public acceptance for DRR measures relevant to specific project phases (Table 2-2). For example, public provision of labour can reduce the cost of the measure (Abbas et al. 2016). This form of acceptance is most often referenced regarding the maintenance and management project phase (e.g., Barbier 2006), although cooperative implementation (e.g., Triyanti et al. 2017) and cooperative monitoring and evaluation (e.g., Verbrugge et al. 2017) are also cited. Public acceptance in relation to these latter two project phases is mentioned more in the context of NbS than grey measures. Examples include relying on local villagers to provide labour for mangrove replanting in Thailand (Barbier 2006) and Indonesia (Triyanti et al. 2017), and working with landowners in the context of managed realignment in the U.K. (Esteves and Thomas 2014) and fire management in Australia (Ryan and Wamsley 2008). The landscape scale and long-term nature of these measures, their reliance on limited and/or bottom-up funding, as well as their embeddedness within social-ecological systems increases reliance on public acceptance. Moreover, the relevance of monitoring and evaluation of such NbS is crucial given their long time-lines and lag-times between implementation and benefits (Verbrugge et al. 2017). Although ‘cooperative maintenance and management’ is not distinguished as a much more common benefit among articles that describe NbS compared to grey measures, ‘sustainable use’ is. This can be considered a form of maintenance, since overexploitation of (e.g., mangrove) resources could lead to degradation and ineffectiveness of the measure itself (Barbier 2006).

Table 2-2 Positive outcomes of public acceptance. Positive outcomes of public acceptance by measure type and project phase listed from highest frequency to lowest frequency considering all the articles (n=99; including articles describing NbS [n=65], grey measures [n=28], and two or more measures [n=6]). The second column *(green)* shows the number and percentage of NbS articles (out of the 65 total) that reference each outcome in relation to public acceptance. The third column (*grey)* replicates this for articles describing grey measures. An outcome's row is highlighted in green if the outcome a) occurs in n>=10 total articles and b) the percentage of NbS articles that reference it is at least double the percentage of grey articles that reference it. An example is provided in the footnote of the table.

Positive outcomes of public acceptance	Frequency of articles that reference each outcome					
	Measure type		Project phase			
NbS/Grey/Two or more (n=99)	NbS (n=65)	Grey (n=28)	1	2	3	4
Cooperative maintenance and management 26 (26%)	19 (29%)	7 (25%)	○	○	●	○
Integration of local skills and knowledge 23 (23%)	14 (22%)	8 (29%)	●	◑	◕	○
Protection against competing societal interests 21 (21%)	19 (29%)	2 (7%)	◑	◔	●	○
Reduced costs and more funding 18 (18%)	13 (20%)	5 (18%)	●	◑	◕	○
Sustainable use 17 (17%)	15 (23%)	2 (7%)	○	○	●	○
Upscaling and repetition 15 (15%)	13 (20%)	2 (7%)	○	○	○	●
Cooperation of private land holders[1] 12 (12%)	11 (17%)	0	●	●	○	○
Cooperative monitoring and evaluation 10 (10%)	9 (14%)	1 (4%)	○	○	●	○
Keeping project timeline and plans on track 10 (10%)	7 (11%)	2 (7%)	●	◑	○	○
Cooperative implementation 10 (10%)	9 (14%)	1 (4%)	○	●	○	○
Tailored and equitable benefits 7 (7%)	5 (8%)	2 (7%)	●	○	◔	○
Reduced risk of theft or sabotage by community 1 (1%)	0	1 (4%)	○	●	○	○

[1] 'Cooperation of private land holders' is referenced in 12% (n=12) of all 99 articles. It is referenced in 17% (n=11) of the 65 NbS articles and 0 of the 28 grey articles. The remaining 1 article of the 12 total in which it is referenced describes two or more measures. It is highlighted in green because a) the total mentions is greater than 10 (12 > 10) and b) the percentage of NbS articles is at least double the percentage of grey articles that reference this outcome (12 >= 0*2).

Project phases
1 = Design and planning
2 = Implementation
3 = Maintenance and sustainable use
4 = Upscaling and knowledge transfer

% article mentions by project phase

○	◔	◑	◕	●
0	1-24	25-49	50-74	75-100

There are higher percentages of NbS articles that describe positive outcomes of public acceptance for NbS compared to articles describing grey measures. This suggests that public acceptance is generally more important for the success of NbS when compared to the success of grey measures. Moreover, there are a number of positive outcomes that are much more relevant to NbS than grey measures, but not vice versa (based on the percentages in Table 2-2). For example, the outcome of 'sustainable use' illustrates the embeddedness of NbS in society, which also makes them particularly susceptible to changes in land-use and competing societal interests, both in the short- and long-term. Holstead et al. (2017) and Schaich (2009) describe natural flood management as conflicting with agricultural food production and therefore susceptible to farmers' perceptions. Moreover, Everett and Lamond (2018) describe blue-green infrastructure as more likely to be an object of public perceptions and attitudes than grey infrastructure since blue-green infrastructure often more drastically alters the landscape.

Acceptance leading to upscaling and repetition is also highlighted as being more relevant for NbS than grey measures. The novelty of NbS and associated lack of confidence in their effectiveness may make their dissemination more difficult (Buchecker et al. 2015; Chou 2016) although their aesthetic and pro-environmental appeal is promising in this regard (Buijs 2009).

Public acceptance is shown to be important throughout project phases. However, there is some indication of increased importance in the design and planning phase (phase 1) and again during maintenance and sustainable use (phase 3) (Table 2-2). The former likely reflects a threshold during the planning stage for preventing outright public rejection (Davis and Cole 2004; Godschalk et al. 2003). The phase of 'maintenance and sustainable use' is also related to the embeddedness of the measures, particularly NbS, within social-ecological systems. Although upscaling and knowledge transfer was rarely explicitly connected to other outcomes of public acceptance, it should be seen as feeding back into the design and planning phase.

2.3.3 What factors influence public acceptance of NbS and grey measures?

In total, we identify 36 interconnected factors that influence public acceptance of NbS and grey measures (Table. A-3). Here, factors referenced in at least five different articles are listed in order of frequency, although their importance for public acceptance is highly contextual (Table 2-3). We group the factors based on their characterization of the measure (and project, when relevant), the individual, or the society. Some societal factors are often attributed to individuals in the articles, but are classed as such because of their social nature (e.g., place attachment, trust). Although many of these factors are shared for NbS and grey measures, there are clear distinctions in their importance for each measure type as evidenced by their prevalence within the respective reviewed literature. In particular, several factors emerge as more relevant for NbS than grey measures highlighted in the table below: the benefits and trade-offs of the measures, their perceived effectiveness, their relevant costs and funding, an awareness and understanding of them, a sense of responsibility for them, as well as public participation and competing societal interests.

Table 2-3 Influencing factors for public acceptance. Influencing factors for public acceptance grouped by relation to the measure, the individual, or the society. Within these groupings, the factors are listed from highest frequency to lowest frequency considering all the articles (n=99; including articles describing NbS [n=65], grey measures [n=28], and two or more measures [n=6]). The second column *(green)* shows the number and percentage of NbS articles (out of the 65 total) that reference each factor in relation to public acceptance. The third column (*grey)* replicates this for articles describing grey measures. A factor's row is highlighted in green if the factor a) occurs in n>=10 total articles and b) the percentage of NbS articles that reference it is at least double the percentage of grey articles that reference it. An example is provided in the footnote of the table.

Influencing factors for public acceptance	Frequency of articles describing NbS or grey measures that reference each factor		Example references	
NbS/Grey/Two or more (n=99)	NbS (n=65)	Grey (n=28)	NbS	Grey
Factors related to the measure				
Benefits and trade-offs of measure[1] 62 (63%)	48 (74%)	10 (36%)	(Buijs 2009; Evans et al. 2017)	(Holcombe et al. 2018; Reilly et al. 2018)
Effectiveness of measure for risk reduction 37 (37%)	31 (48%)	4 (14%)	(Badola and Hussain 2005; Howgate and Kenyon 2009)	(Abbas et al. 2016; Verbrugge et al. 2017)
Costs and funding 13 (13%)	12 (18%)	1 (4%)	(Beery 2018; Brink and Wamsler 2019; Myatt et al. 2003a)	(Ghanbarpour et al. 2014)
Financial compensation or incentives 6 (6%)	5 (8%)	1 (4%)	(Buchecker et al. 2013; Otto et al. 2018)	(Abbas et al. 2016)
Effectiveness of communication and collaboration 6 (6%)	4 (6%)	1 (4%)	(Ding et al. 2019; Howgate and Kenyon 2009; Otto et al. 2018)	(Calvello et al. 2016)
Uncertainty and complexity of measure 6 (6%)	3 (5%)	2 (7%)	(Brink and Wamsler 2019; Schernewski et al. 2017)	(Godschalk et al. 2003; Reilly et al. 2018)
Equity of costs and benefits 5 (5%)	5 (8%)	0	(Drake et al. 2013; Geaves and Penning-Rowsell 2015; Otto et al. 2018)	N/A
Factors related to the individual				
Risk perception of natural hazards 33 (33%)	18 (28%)	12 (43%)	(Holstead et al. 2017; Kim and Petrolia 2013)	(Fordham et al. 1991; Holcombe et al. 2018)

Influencing factors for public acceptance	Frequency of articles describing NbS or grey measures that reference each factor		Example references	
Awareness and understanding of measure 20 (20%)	15 (23%)	3 (11%)	(Kienker et al. 2018; Ryan and Wamsley 2008; Schernewski et al. 2017)	(Hoque and Siddique 1995; Neef et al. 2013)
Awareness of benefits 17 (17%)	13 (20%)	4 (14%)	(Everett et al. 2018; Nguyen et al. 2015; Scholte et al. 2016)	(Abbas et al. 2016; Holcombe et al. 2018; Saengsupavanich 2012)
Responsibility for measure 17 (17%)	14 (22%)	3 (11%)	(Everett and Lamond 2018; Rambonilaza et al. 2016; Touili et al. 2014)	(Fuchs et al. 2017; Neef et al. 2013)
Participation 11 (11%)	9 (14%)	2 (7%)	(Herringshaw et al. 2010; Howgate and Kenyon 2009; On-prom 2014)	(Davis and Cole 2004; Fordham et al. 1991)
Fatalist or agentic perspective 8 (8%)	5 (8%)	3 (11%)	(Bihari and Ryan 2012; Brink and Wamsler 2019; Everett and Lamond 2018)	(Abbas et al. 2016; Fuchs et al. 2017; Schmidt et al. 2014)
Past experience with hazard 8 (8%)	5 (8%)	3 (11%)	(Badola et al. 2011; Bihari and Ryan 2012; Brink and Wamsler 2019)	(Ghanbarpour et al. 2014; Godschalk et al. 2003; Lara et al. 2010)
Age of individual 7 (7%)	5 (8%)	2 (7%)	(Myatt et al. 2003a; Schernewski et al. 2017)	(Abbas et al. 2016; Schmidt et al. 2014)
Expectations of measure 6 (6%)	5 (8%)	1 (4%)	(Biswas et al. 2008; Chou 2016; Schernewski et al. 2017)	(Verbrugge et al. 2017)
Perceived inclusion or exclusion 5 (5%)	5 (8%)	0	(Everett et al. 2018; Miller and Montalto 2019; Triyanti et al. 2017)	N/A
Factors related to the society				
Place attachment 13 (13%)	8 (12%)	2 (7%)	(Bihari and Ryan 2012; Brink and Wamsler 2019; Buijs 2009)	(Chowdhury 2002; Schmidt et al. 2014)
Trust in responsible party 11 (11%)	7 (11%)	3 (11%)	(Buchecker et al. 2015; Myatt et al. 2003a)	(Schmidt et al. 2014; Verbrugge et al. 2017)
Competing societal interests 11 (11%)	9 (14%)	2 (7%)	(Barbier 2006; Everett and Lamond 2018)	(Abbas et al. 2016; Holcombe et al. 2018)
Resistance to change and new concepts 7 (7%)	5 (8%)	1 (4%)	(Koutrakis et al. 2011; Schernewski et al. 2017)	(Davis and Cole 2004)

[1] 'Benefits and trade-offs of measure' is referenced in 63% (n=62) of all 99 articles. It is referenced in 74% (n=48) of the 65 NbS articles and 36% (n=10) of the 28 grey articles. The remaining four articles of the 62 total in which it is referenced describe two or more measures. It is highlighted in green because a) the total mentions is greater than 10 (62 > 10) and b) the percentage of NbS articles is at least double the percentage of grey articles that reference this factor (74 >= 36*2).

2.3.3.1 Factors related to the measure

Benefits and trade-offs are the most frequently mentioned among all the factors that influence public acceptance. 'Benefits' includes both the perceived primary function of the measure as well as any co-benefits. The frequencies for NbS and grey measures suggest more importance of a broader range of benefits for NbS. Given their importance for NbS, we use the concept of ecosystem services to further explore which specific benefits are most relevant in the following subsection.

The effectiveness of the measures for risk reduction is also a primary public concern – an unsurprising finding given that this is a principal goal of the measures in the reviewed articles. In 21 of the 37 articles that mention this factor, scepticism about the measure reduces acceptance. Of these, 18 describe NbS. A lack of evidence (Esteves and Thomas 2014), a belief in the displacement rather than reduction of risk (Davenport et al. 2010) and a greater trust in alternative grey measures (Chou 2016) help explain this tendency. Another factor, the uncertainty and complexity of the measure, is closely related since it can make awareness and understanding of NbS more difficult (Schernewski et al. 2017). Confidence in effectiveness for both measure types was often a result of past experiential evidence, gained through project participation (Buchecker et al. 2013), regular exposure to the measure (Kim and Petrolia 2013), or merely observation over time (Ding et al. 2019). The duration of implementation and time-lag for effectiveness of NbS is related to complexity and creates a broader time window for public dissent (Schernewski et al. 2017).

We also identify costs and funding as a crucial factor, mentioned in reference to NbS with only the exception of Ghanbarpour et al. (2014). In terms of influencing acceptance, cost is inextricably linked to perceived value (Everett et al. 2018), which in turn is also associated with perceived effectiveness of the measure.

2.3.3.1.1 Provision of ecosystem services

Since 59 of the 62 articles mentioning benefits draw an implicit or explicit connection between ecosystem services and acceptance, we describe the co-benefits of the measures using the Millennium Ecosystem Assessment typology for ecosystem services (MEA 2005b). Descriptions of an increase in acceptance are found in 48 articles, while descriptions of a decrease in acceptance are found in 30 articles. Several other articles (also) include descriptions of neutral or insignificant connections (n=8). Although most of these articles describe NbS (n=47), case studies of grey measures (n=8) also include a link between ecosystem services and public acceptance. Examples of the latter case include concrete drains that reduce landslide risk as well as stagnant water that can breed mosquitos (Holcombe et al. 2018), and a dam providing recreation opportunities (Reilly et al. 2018). For both NbS and grey measures, cultural services are the most prevalent in relation to acceptance. Within this category, high or low aesthetic value is mentioned the most as either increasing or decreasing acceptance, respectively (Figure 2-6). Other predominant cultural services include recreation opportunities arising from ecological restoration (e.g., Kim and Petrolia 2013) and either preservation of sense of place (e.g., Buijs 2009) or loss of sense of place through change (e.g., Goeldner-Gianella et al. 2015).

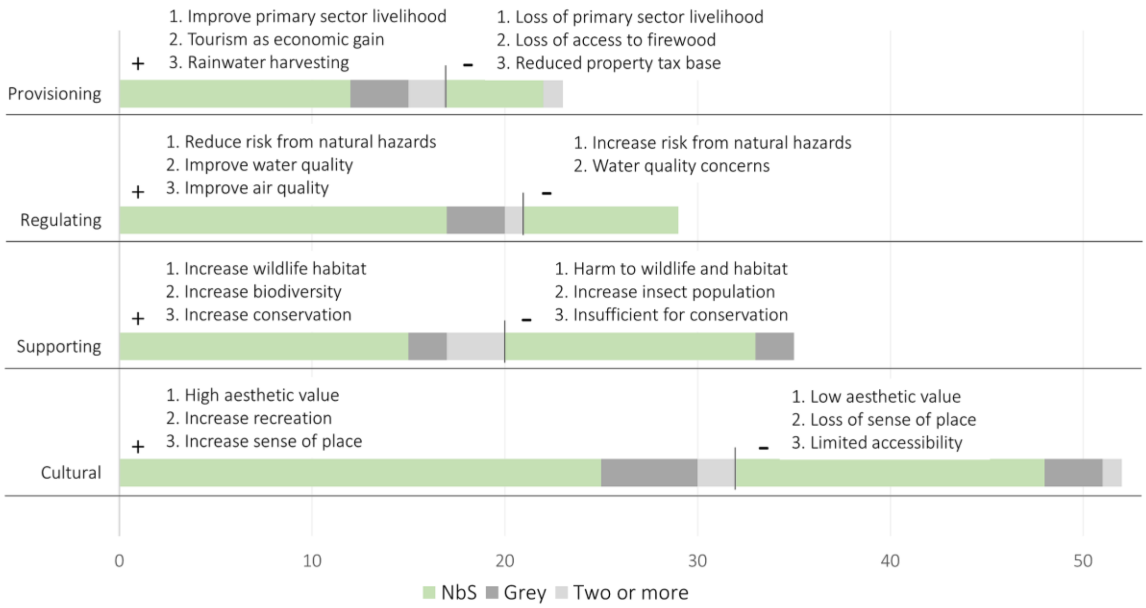


Figure 2-6 Ecosystem services for public acceptance by measure type. Number of articles in the review describing NbS, grey measures, or two or more measures that associate public perception of each ecosystem service (cultural, supporting, regulating, provisioning) with public acceptance of the measures. For each ecosystem service, there are positive associations ('+' i.e. lead to increased acceptance) and negative associations ('-' i.e., lead to decreased acceptance).

The three specific ecosystem services mentioned the most by the three article types are shown for each ecosystem service category and direction.

We include in supporting services general descriptions of benefits such as changes in habitat, biodiversity and conservation, since these contribute to other service types. Of the negative associations for each category, those describing supporting services form the largest percentage within any category. This is driven by perceived or anticipated harm to wildlife and habitat [n=8] (e.g., Koutrakis et al. 2011) and increased number of insects due to habitat provision, including mosquitos [n=5] (e.g., Scholte et al. 2016). Global climate regulation is only mentioned in three of the articles, two in a positive context (Brink and Wamsler 2019; Miller and Montalto 2019) and one in which it is seen as suppressing altruistic motivations for acceptance given its widespread rather than local provision (Drake et al. 2013).

The most common regulating service is the ability of the NbS to reduce risk from the relevant natural hazards. Coastal hazards (n=11) and pluvial/fluvial flooding (n=6) are the two most common hazards in this category (see Figure. A-1 and Figure. A-2 for the detailed composition of ecosystem services and disservices). Several articles also mention an improvement in quality of air (Miller and Montalto 2019) and water (Holcombe et al. 2018) as regulating services. Nearly half of the articles mentioning provisioning services describe mangrove planting or conservation efforts and refer most often to protection or enhancement of primary sector livelihoods (n=11) related to fishing (e.g., Evans et al. 2017) or agriculture (e.g., Badola and Hussain 2005).

2.3.3.2 Factors related to the individual

The degree of perceived risk of natural hazards by individuals as a factor for determining acceptance is mentioned in 33 articles, more than any other factor related to the individual. Given the frequency, complexity and highly contextual nature of this factor, we devote a separate subsection to it below.

‘Awareness and understanding of the measure’ is also crucial to acceptance, even more so for NbS than for grey measures. For example, Kienker et al. (2018) found that more informed residents were willing to pay more for ecological engineering in Australian harbours. For managed realignment schemes in the U.K., Myatt et al. (2003a) and Myatt-Bell et al. (2002) show that residents who consider themselves aware and well-informed are more convinced by their efficacy. Likewise, misconceptions of NbS, including misaligned expectations caused by overly technical language (Chou 2016), past financial incentives (Biswas et al. 2008), or high public standards for safety (Geaves and Penning-Rowsell 2015) can have antagonistic effects. Complexity and novelty of NbS also exacerbate this compared to grey measures (Schernewski et al. 2017; van den Hoek et al. 2014).

Closely connected to an understanding of the measure is an understanding of its benefits, found to be important for both NbS and grey measures. A low awareness of benefits was cited as reducing acceptance (n=9) more often than a high awareness increasing acceptance (n=6). For the former, focussing on a limited number of specialised benefits (Davenport et al. 2010), inadequate monitoring and reporting of benefits (Nguyen et al. 2015), and misattribution of benefits [i.e. to something other than the measure] (Everett and Lamond 2018) were highlighted as causal factors. Appreciation of more hidden ecosystem service benefits like climate change mitigation, wildlife corridors (Everett et al. 2018) and habitat provision (Badola et al. 2011) is often lacking.

A sense of responsibility for the measure can also act to increase or decrease acceptance. Nine articles reference a displacement of responsibility from individuals to e.g., the state (e.g., Buchecker et al. 2015), resulting in disinterest or unwillingness to participate or collaborate. A sense of burden of responsibility was described in seven of the articles, in which a feeling of liability for maintenance was prevalent (e.g., Everett et al. 2018). This is more of an issue for NbS than grey measures given their greater reliance on maintenance by the public. A positive sense of responsibility can also lead to ownership, described as being fostered by social altruism (Brink and Wamsler 2019) or project participation (On-prom 2014). Project participation is not only a potential indicator of acceptance, it is also identified as leading to trust and knowledge exchange (Herringshaw et al. 2010), spreading awareness (On-prom 2014), and aligning expectations of the measure (van den Hoek et al. 2014), all potentially feeding back into public acceptance.

2.3.3.2.1 Risk Perception

Nearly all of the 33 articles that link risk perception of natural hazards to acceptance do not disaggregate the concept of risk but rather assess it as a general idea and often refer to related concepts such as perceived concern (Ding et al. 2019), consequences (Bubeck et al. 2012b), fear (Rambonilaza et al. 2016), or threat (Schaich 2009).

Generally, a higher perceived risk of the hazards is described as leading to more acceptance of both NbS and grey measures (Chowdhury 2002; Everett et al. 2018; Rambonilaza et al. 2016). However, several articles also consider risk perception but find no significant directional relation with acceptance. Groot and Groot

(2009) and Schernewski et al. (2017) equate this to the lack of substantial ‘objective’ flood risk within the Netherlands and Germany, respectively. In the cases of Schaich (2009) and Kim and Petrolia (2013), the co-benefits of ecological restoration for flood risk reduction increase public support regardless of risk perception. This illustrates that the co-benefits of NbS can have more influence on acceptance than perceived risk and risk reduction capacity of measures. However, Kim and Petrolia (2013) also find that support for wetland restoration in the Mississippi Delta declines among respondents who perceive a high frequency of category 3 hurricanes or greater. Likewise, Goeldner-Gianella et al. (2015) make a connection between fear and acceptance of depolderisation. They suggest that a lack of fear of coastal storms in the U.K. has led to relatively greater acceptance of depolderisation, whereas higher risk perceptions due to past hazard events in France and Germany have had the opposite effect[11]. This suggests that once a certain threshold of perceived risk has been met, the perceived effectiveness of the measure strongly modulates acceptance.

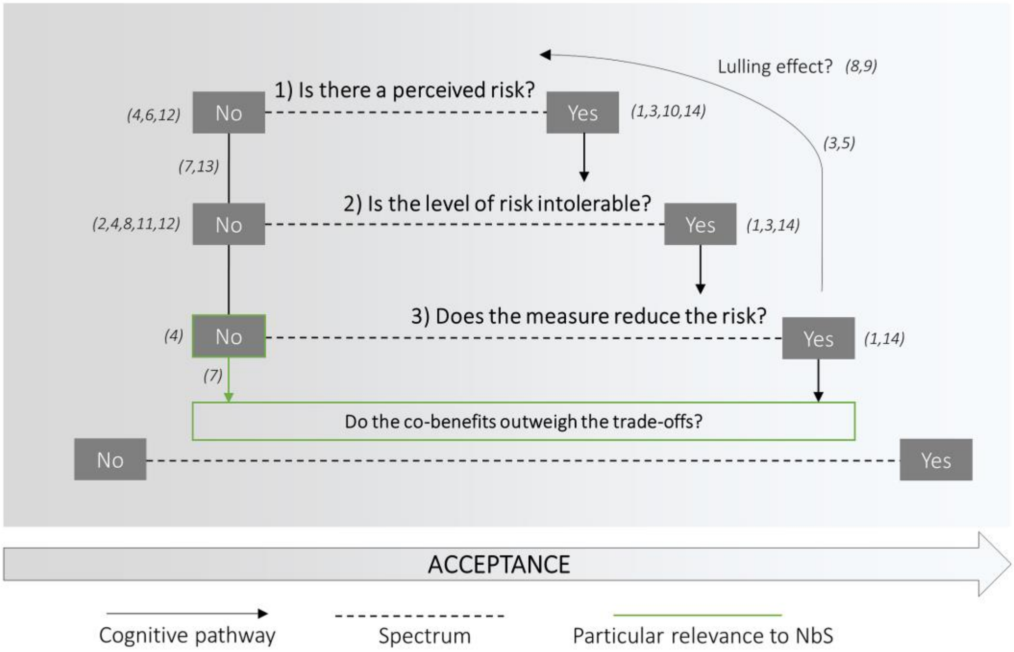
Along with risk perception and effectiveness, people’s acceptance of risk or risk (in)tolerance also seems to be an important explanatory factor. Buchecker et al. (2015) describe a low tolerance for damages from natural hazards among residents in the Swiss Alps increasing the demand for risk reduction measures from the state. Chowdhury (2002) assesses residents’ “preparedness to live with flooding” and finds an association with the perceived importance of embankments in Dhaka, while Holstead et al. (2017) find that if farmers are not “bothered by flooding” they are less likely to implement natural flood management plans.

The literature suggests three key differences between NbS and grey measures regarding the relation between risk perception and acceptance. Co-benefits of NbS can foster acceptance in the absence of high risk perception (Schaich 2009) while the complexity, novelty, and lack of evidence for the effectiveness of NbS can negate support in contexts of higher perceived risk (Goeldner-Gianella et al. 2015). Lastly, the “lulling effect” (a false sense of security due to exaggerated

[11] Other studies, however, indicate low acceptance of depolderisation in the U.K. (e.g., Esteves and Thomas 2014).

perceived effectiveness of the measure), was cited as influencing risk perception only due to grey measures (e.g., Kuo et al. 2016) but not NbS.

Clearly, the link between risk perception and acceptance of the risk reduction measures is often more complex than a linear relation and involves other mediating factors. Risk perception, mentioned in 33% of all articles, is the third most commonly mentioned factor that can influence acceptance of NbS in the reviewed literature (Table 2-3) and related to the two most commonly mentioned factors - perceived benefits and trade-offs (63%) and perceived effectiveness for risk reduction (37%). Given their importance and interconnections, we present a generalised theoretical model to link these concepts. The ‘Risk Perception – Measure Acceptance Model’ or RP-MAM takes the form of a decision tree that depicts the relation between these factors (Figure 2-7).



1) Badola et al. 2011; 2) Brink and Wamsler 2019; 3) Bubeck et al. 2012b 4) Chowdhury 2002; 5) Groot and Groot 2009; 6) Fuchs et al. 2017; 7) Goeldner-Gianella et al. 2015; 8) Holstead et al. 2017; 9) Kuo et al. 2016; 10) Myatt et al. 2003a, 2003b; 11) Neef et al. 2013; 12) Rambonilaza et al. 2016; 13) Schaich 2009; 14) Schmidt et al. 2014

Figure 2-7 The Risk Perception - Measure Acceptance Model or 'RP-MAM'. The RP-MAM is presented as a decision tree with three ordered questions – 1) Is there a perceived risk, 2) Is the level of risk intolerable, and 3) Does the measure reduce the risk? In this way, risk perception is modulated by risk tolerance and the latter modulated by perceived effectiveness. The respective answers fall on a spectrum that suggests either more or less acceptance of the measure. The final question also feeds back into the perceived risk, potentially creating a lulling effect of low risk perception. Co-benefits of measures, particularly of nature-based solutions, are included as possibly modulating acceptance more than the three risk-related questions, given that risk reduction is often not the primary perceived benefit. References in the figure match the phenomenon in the model to observations in the corresponding articles. Note that multiple observations are possible in the same article.

2.3.3.3 Factors related to the society

Place attachment is referenced in 13 articles as a factor for increasing or decreasing acceptance, more than any other societal factor. Support is shown for both NbS and grey measures that help preserve place (Bihari and Ryan 2012; Chowdhury 2002; Groot and Groot 2009), while strong opposition is shown to measures that shift from the status quo or the idealised environment (Roca and Villares 2012). In the context of NbS, Goeldner-Gianella et al. (2015) and Pueyo-Ros et al. (2019) describe a high degree of local attachment to coastal promenades under threat from depolderisation and wetland restoration, respectively. Measures are opposed among residents with higher place attachment due to changes in place and services, despite the fact that a wilder coastline would provide overall greater benefits to a broader swath of society. Similarly, Buijs (2009) finds that residents in the Netherlands feel less attached to floodplains after restoration, since local narratives, personal memories and a sense of what is “typical Dutch” are degraded.

High levels of trust and high acceptance are associated in three articles, while low trust reducing acceptance is more prominent (n=8). For both NbS and grey measures, trust was eroded by a fear of hidden agendas (Davenport et al. 2010), insufficient long-term investment (Myatt et al. 2003a), past failed or inadequate measures (Davis and Cole 2004; Schmidt et al. 2014), and low perceived technical competence for implementation (Ryan and Wamsley 2008). Past positive experiences of dealing with flooding in Switzerland (Buchecker et al. 2015) and the Netherlands (Verbrugge et al. 2017) and interacting with green infrastructure in China (Ding et al. 2019) increased public trust in authorities.

The factor ‘competing societal interests’ was found to be much more relevant for NbS than grey measures. Badola et al. (2011), Barbier (2006), and Davenport et al. (2010) indicate that more immediate quality of life concerns related to poverty can take precedent over support for ecological preservation or restoration. Both open green/blue spaces for flood risk management in the U.K. and bioswales in the U.S. met resistance due to perceived impact of decreased parking space and increased traffic (Everett et al. 2018; Everett and Lamond 2018).

2.3.4 How to increase public acceptance of NbS?

We categorise the coded interconnected ways to increase public acceptance of NbS suggested in the literature into four overarching non-chronological recommendations: provide benefits, increase awareness of benefits, communicate effectively, and promote participation and collaboration (Table 2-4). These broad categories, as well as the brief explanatory statements below them, represent our own classification of the coded segments. These are further broken down into four corresponding principal success criteria each, derived from sub-themes that emerge from the coded segments. We do not include a measure of confidence in the recommendations but rather aim to create a comprehensive “library” of all recommendations derived from the reviewed literature. The importance of each recommendation is context dependent. Although many of the same recommendations hold true for grey measures, we base these criteria on articles describing NbS and aim to highlight its aforementioned distinguishing characteristics.

Table 2-4 Recommendations for increasing public acceptance of NbS. Recommendations for increasing public acceptance of NbS are categorised by four general considerations: provide benefits, increase awareness of benefits, communicate effectively, and promote participation and collaboration, which are further disaggregated into four corresponding success criteria.

Success criteria	Recommendations/examples	Example citations
Provide Benefits		
Multifunctional Co-benefits and broad but definable goals are crucial to acceptance.	Improve aesthetics.	(Buijs 2009; Chen et al. 2018)
	Restore cultural elements.	(Davenport et al. 2010)
	Create synergies with community economic goals.	(Davenport et al. 2010)
	Support livelihoods.	(Badola and Hussain 2005; Biswas et al. 2008)
Equitable Benefits are subjective and can accrue differently in time and space, creating inequity.	Ensure effective communication and participation in decision-making.	(Roca and Villares 2012)
	Create a common vision and equitable outcomes.	(Schmidt et al. 2014)
	Redistribute benefits.	(Drake et al. 2013)
	Improve livelihoods.	(Badola and Hussain 2005; Biswas et al. 2008)
Tangible When benefits to residents are tangible, their impact is felt rather than passively acknowledged.	Provide physical benefits (e.g., creating a bike or canoe rental as a part of wetlands restoration project).	(Davenport et al. 2010)
	Make benefits as immediate as possible for attribution and early acceptance.	(Biswas et al. 2008)
	Prioritise subtle and effective changes rather than major overhauls.	(Groot and Groot 2009)
Non-competitive Although all NbS involve change and inevitable trade-offs, these should be limited and/or compensated when possible.	Implement landscape measures on e.g., less productive agricultural land.	(Holstead et al. 2017)
	Find synergies with prominent community issues like transportation, zoning, or development.	(Godschalk et al. 2003)
Increase Awareness of Benefits		

Success criteria	Recommendations/examples	Example citations
Attributable to the measure The more people recognise what the NbS is providing them, the more likely they are to be supportive (Trialfhianty and Suadi 2017).	Consider the full range and spatial scope of benefits in information and education campaigns.	(Brandolini and Disegna 2015; Davenport et al. 2010; Everett and Lamond 2018; Miller and Montalto 2019)
	Use ecosystem services as a theoretical starting point for identifying and conveying benefits for public understanding.	(Chen et al. 2018)
	Inform about what the NbS cannot provide, including the trade-offs of the measure, so that misaligned expectations are avoided.	(Kuo et al. 2016; Miller and Montalto 2019)
Salient Public recognition of "hidden" benefits is key. *How* risk is reduced may be hidden – e.g., the capacity of wetlands to regulate flooding (Davenport et al. 2010) or urban green infrastructure for heat (Miller and Montalto 2019) or flood reduction (Chou 2016).	Increase visibility of benefits by improving access to NbS areas.	(Miller and Montalto 2019; Schernewski et al. 2017)
	Demonstrate benefits through public participation (e.g., monitoring or citizen science).	(Holstead et al. 2017)
	Emphasize hidden co-benefits if these are of value (e.g., conservation, water purification, or soil formation).	(Chen et al. 2018; Davenport et al. 2010; Geaves and Penning-Rowsell 2015; Pueyo-Ros et al. 2019)
Evidence-based The novelty and complexity of NbS can breed scepticism, making proof of effectiveness critical.	Clearly communicate quantifiable costs and benefits to increase transparency and trust while also aligning public expectations.	(Esteves and Thomas 2014; Goeldner-Gianella et al. 2015; Holstead et al. 2017)
	Use other comparable and successful sites as proofs of concept.	(Roca and Villares 2012)
	Conduct experiments and long-term monitoring to provide evidence on-site after implementation.	(Evans et al. 2017)
Culturally significant	Appeal to safety interests.	(Everett and Lamond 2018)
	Appeal to economic/livelihood interests.	(Bubeck et al. 2012b; Everett and Lamond 2018; Goeldner-Gianella et al. 2015)

Success criteria	Recommendations/examples	Example citations
Benefits are only meaningful in contexts of values. Thus, they should be value-framed based on what is perceived as important or prevailing social norms (Everett and Lamond 2018).	Appeal to environmental or biodiversity interests.	(Everett and Lamond 2018; Ryan and Wamsley 2008)
	Appeal to aesthetic interests.	(Chen et al. 2018; Miller and Montalto 2019; Schmidt et al. 2014)
	Appeal to educational interests.	(Chen et al. 2018; Miller and Montalto 2019; Schmidt et al. 2014)
	Appeal to place (e.g., sense of community) interests.	(Chen et al. 2018; Schmidt et al. 2014)
	Appeal to people's sense of self-efficacy.	(Everett and Lamond 2018)
Communicate Effectively		
Clear and consistent Communication should foster understanding and knowledge transfer.	Make communication strategies anticipatory and adaptive.	(Davis and Cole 2004; Schernewski et al. 2017)
	Design communication strategies to increase awareness of the measure and justify the rationale behind the measure (e.g., why here?; why now?).	(Esteves and Thomas 2014; Schernewski et al. 2017)
	Maintain close and regular contact with the media and prepare outreach materials and articles.	(Schernewski et al. 2017)
	Stay on message.	(Esteves and Thomas 2014)
	Open communication channels already in the planning stage and sustain them.	(Kuo et al. 2016; Schernewski et al. 2017)
	Use plain language, particularly for risk communication.	(Chou 2016; Davenport et al. 2010; Kuo et al. 2016)
	Include relevant time-frames and targets so people know what to expect and when.	(Esteves and Thomas 2014; Everett and Lamond 2018; Myatt et al. 2003a)
Two-way and multi-path Communication both to and from project managers fosters learning, but only through accessible channels.	Create opportunities for communication that are active and dialogic.	(Everett et al. 2018; Everett and Lamond 2018; Howgate and Kenyon 2009)
	Establish trust, common understanding, and social capital through collaborative and goal-oriented dialogues.	(Biswas et al. 2008; Calvello et al. 2016; Howgate and Kenyon 2009; Triyanti et al. 2017)

Success criteria	Recommendations/examples	Example citations
	Facilitate sustained access to two-way dialogue.	(Holstead et al. 2017; Kuo et al. 2016)
	Make use of formal and informal communication pathways, since highly structured formats can limit involvement.	(Davenport et al. 2010; Scholte et al. 2016)
	Use a wide range of communication channels (e.g., internet, social media, radio, newspaper).	(Chen et al. 2018; Chou 2016; Howgate and Kenyon 2009; Schernewski et al. 2017)
	Use trusted and established networks for information dissemination.	(Bihari and Ryan 2012; Calvello et al. 2016)
Value-framed Communication (not just to increase awareness of benefits) can be framed in a way that appeals to the public and follows important (contextually dependent) public narratives.	Emphasize mutual attachment to community and place, fostering a sense of altruism and shared responsibility.	(Beery 2018; Bihari and Ryan 2012; Brink and Wamsler 2019; Holstead et al. 2017)
	Appeal to environmentally conscious citizens with environmental information.	(Beery 2018; Buchecker et al. 2015; Chou 2016)
	Highlight quality of life concerns if these are preeminent, as is often the case.	(Chou 2016; Godschalk et al. 2003; Miller and Montalto 2019)
	Make use of targeted messaging when possible, since the 'public' is not a homogenous entity.	(Myatt et al. 2003a)
Place-based Communication should be grounded with local relevance.	Provide information at the most understandable and relevant scale possible.	(Myatt et al. 2003a)
	Describe how spatial scales interact (e.g., how the measure fits into a larger context).	(Holstead et al. 2017)
	Link outreach to existing community groups and established networks.	(Bihari and Ryan 2012; Davenport et al. 2010; Tanaka et al. 2011; Triyanti et al. 2017)
	Make use of testimonies from in-groups and locally trusted intermediaries.	(Bihari and Ryan 2012; Holstead et al. 2017)

Success criteria	Recommendations/examples	Example citations
	Explain any short- and long-term changes and impacts to place.	(Davenport et al. 2010; Groot and Groot 2009; Kienker et al. 2018)
	Describe the history of hazard events as a reminder and a justification for the measure.	(Chou 2016; Godschalk et al. 2003)
	Be sensitive to and consider integrating local causal explanations (e.g., for hazard events).	(Neef et al. 2013)
	Consider local subjective risk tolerance rather than assuming risk to be a motivating factor.	(Calvello et al. 2016)
Promote Participation and Collaboration		
Early and sustained Efforts should be based on public input and foster a sense of both self-determination and trust with project managers.	Involve citizens already in the design and planning phase (e.g., co-determine goals and indicators).	(Davenport et al. 2010; Davis and Cole 2004; Schmidt et al. 2014)
	Devote resources to gaining early acceptance by e.g., integrating local knowledge, which can also increase measure effectiveness.	(Pueyo-Ros et al. 2019)
	Demonstrate commitment to long-term benefits with sustained public-project manager interactions.	(Davenport et al. 2010; Herringshaw et al. 2010; On-prom 2014)
Broad and inclusive Members of the public are diverse and have different skills and capabilities.	Craft many different opportunities and options for the public to get involved and to volunteer.	(Chou 2016; Davenport et al. 2010; Scholte et al. 2016)
	Tailor outreach for collaboration to a broad swath of the public, including relevant private stakeholders to prevent or alleviate conflicts.	(Koutrakis et al. 2011; Kuo et al. 2016)
Meaningful and active	Support the establishment of ad-hoc local institutions, offices, committees, or citizen-based advisory groups.	(Davenport et al. 2010; Davis and Cole 2004; Everett and Lamond 2018; Myatt et al. 2003a)

Success criteria	Recommendations/examples	Example citations
Meaningful participation gives real voice and decision-making power to the public (van den Hoek et al. 2014), while personal experiences can strongly influence attitudes.	Explore the use of creative and fit-to-purpose plans for collaboration (e.g., thematic working groups led by informed local stakeholders).	(Schernewski et al. 2017; Schmidt et al. 2014)
	Consider interactive, hands-on and experiential participatory activities such as workshops, field trips, or volunteer stewardship programmes.	(Bihari and Ryan 2012; Chou 2016; Schmidt et al. 2014)
Educational and capacity-building Participation and collaboration, such as co-management or stewardship schemes, may require that certain knowledge and skills first be acquired (Barbier 2006; On-prom 2014).	Provide capacity building when needed in relation to acquisition of co-benefits, for example how to take advantage of nature-based tourism for local businesses.	(Davenport et al. 2010)
	Consider residents' personal experiences (e.g., past environmental/risk management).	(Bihari and Ryan 2012)
	Involve relevant institutions, fostering bi-directional learning to and from citizens.	(Santoro et al. 2019)

2.4 Discussion

Our review leads to three broad insights.

1. In line with key NbS literature, we find that NbS involve distinct social interactions across project phases compared to traditional grey infrastructure measures for reducing risk. Moreover, the long-term success of NbS consistently relies on a broader range of public acceptance outcomes.

2. Given their reliance on public acceptance, a number of interconnected factors related to the measure itself, the individual, and the societal context are crucial for the success of NbS. These factors are highly contextual in their strength of influence, but broad in their potential applicability and therefore worthy of systematic consideration.

3. Strategies for providing benefits, increasing public awareness of benefits, communicating effectively, and promoting participation and collaboration are suggested for leveraging the identified factors and increasing public acceptance of NbS.

To provide NbS practitioners and researchers a basis for structured consideration of how to increase public acceptance, we graphically represent the relevant review findings to create the Public Acceptance of Nature-based Solutions framework (PA-NbS) (Figure 2-8). The PA-NbS thus provides a starting point for the design and testing of strategies to increase NbS acceptance. When possible, the four interdependent principal recommendations and four corresponding success criteria that form the base of the framework should be met (Table 2-4). Moving from the bottom to the top of the framework, these recommendations act on and are modulated by influencing factors for public acceptance within the nexus of the individual, the society, and the NbS. The factors provided are illustrative examples (taken from Table 2-3) positioned within the triangle in accordance to their relevance to the individual, society, and the NbS. The flow of ecosystem services from the NbS to individuals and society represents the most commonly cited underlying factor for public acceptance - perceived benefits. In the framework, if the recommendations are acted on and appropriately adapted to the context found at this nexus, they lead to public acceptance of the NbS.

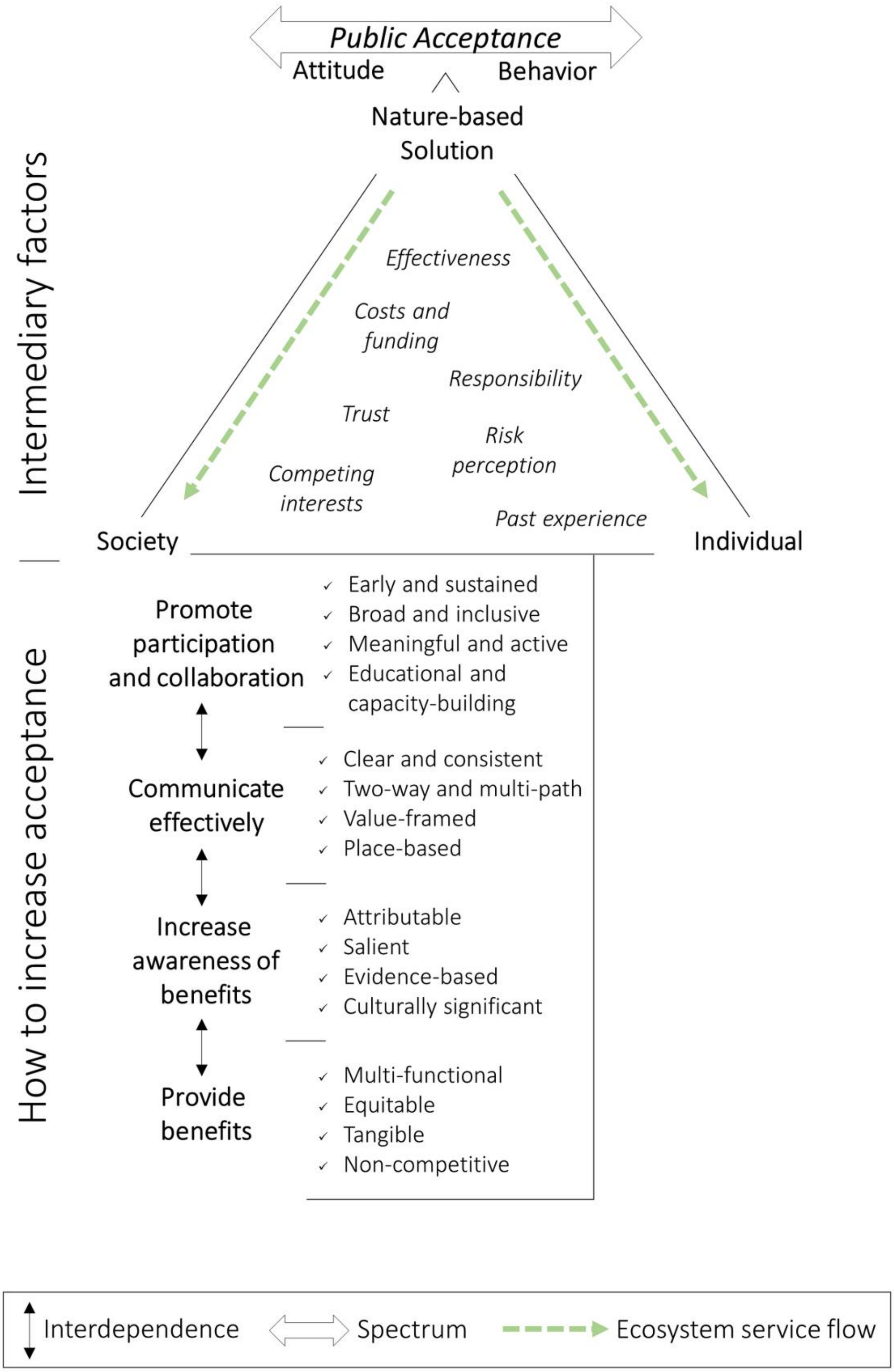


Figure 2-8 The Public Acceptance of Nature-based Solutions framework (PA-NbS). The PA-NbS depicts recommendations and corresponding success criteria. These act on and through contextual factors at the nexus of the individual, the society, and the NbS. Ecosystem services represent the crucial factor of benefits and trade-offs. These flow within this nexus from the NbS and are perceived (or not) by individuals and society. Public acceptance is case-specific, exists on a spectrum, and is manifested by attitudes and behaviours, which also act on each other causally.

Acceptance is manifested in positive public attitudes and/or behaviours. Attitude can shape behaviour just as behaviour can shape attitude (Spence and Pidgeon 2009), but the precise definition of public acceptance should be case-specific and ideally co-determined using goals and indicators with the public itself.

We mostly find a high degree of overlap between the recommendations in the PA-NbS that are directly related to the measure (providing benefits and promoting participation and collaboration) and NbS principals (Cohen-Shacham et al. 2019) and the Global Standard for NbS outlined by the IUCN (IUCN 2020b). Principle 4, for example, calls for producing “societal benefits in a fair and equitable way in a manner that promotes transparency and broad participation” (Cohen-Shacham et al. 2016, p. 6) while Criterion 6 of the Global Standard provides indicators for assessing whether benefits and trade-offs are equitable (IUCN 2020b). Stakeholder involvement, recognizing and limiting trade-offs, ensuring public understanding and incorporating public values are all key elements of the documents. However, whether benefits are tangible to the public (or not) is lacking. Similarly, the principles and Global Standard fail to emphasize the importance of not only providing benefits, but also promoting awareness of them. Increasing awareness was highlighted as one of four key overarching recommendation in the reviewed literature. Because NbS rely more heavily on public acceptance for success than grey measures and are often perceived as novel, complex, and value-laden, we recommend that the criteria regarding increasing awareness of benefits be addressed in the core principles.

The importance of aesthetics of NbS has been demonstrated in other contexts and should be a point of emphasis in designs and planning, as well as communicating co-benefits and trust (Frantzeskaki 2019). Our findings also corroborate those of a recent review on NbS perceptions by Han and Kuhlicke (2019). In particular, they also find a focus in the literature on co-benefits, risk-reduction efficacy, participation, environmental attitudes, and uncertainty surrounding NbS for forming perceptions. Likewise, they discuss the seemingly negative association between threat-appraisal and trust in NbS. This lends credence to the importance of risk (in)tolerance as well as perceived effectiveness in relation to acceptance as presented in our RP-MAM model (see the ‘Risk Perception’ section). The RP-MAM model should be considered a first step towards understanding the interconnections among the key factors of risk perception, risk (in)tolerance, perceived effectiveness, and perceived co-benefits in relation to NbS acceptance. The model is currently being tested with data from NbS sites in the OPERANDUM project[12].

Societal acceptance and sustained success of NbS is not limited to the perception of citizens living in and around NbS, but also determined by a host of legal, governmental, economic and technical factors (Nesshöver et al. 2017; Wamsler et al. 2019). Some of the factors identified in our review exist within such spheres and could be difficult to act on. For example, costs and funding and effectiveness of the measure may be constrained by non-negotiable requirements. However, even practical constraints and quantifiable characteristics are perceived differently and can influence attitudinal and behavioural public acceptance.

Although participation is generally desirable, it may be inappropriate in contexts where decisions have necessarily already been made, past failures have occurred, insufficient resources are available (e.g., for capacity building), or there is no civic culture. Here, effective communication and consultation may form the basis of more appropriate goals (Reed et al. 2018). Additionally, public engagement can be risky and not always beneficial, depending particularly on the history, flexibility, and capacities of the institutions involved (Wamsler et al. 2019). This underscores the idea that there is effective and ineffective public engagement, and ineffective engagement may lead to worse outcomes than no engagement at all.

Positive attitudes often do not lead to positive behaviours and behavioural motivators may differ greatly (Wachinger et al. 2013). However, to disaggregate the factors on this basis would require a larger dataset and more experimental evidence in the literature. The factors we identify are relevant for promoting positive attitudes and behaviours, since the success of NbS projects often relies on both and they are interconnected. Indeed, increasing awareness of benefits and fostering engagement are key considerations for behaviour change, which may or may not be mediated by effects on attitude change (Spence and Pidgeon

[12] www.operandum-project.eu

2009). For broad practicality, the factors and recommendations are therefore useful as a starting point for research to determine their relevance, strength and specific contextual characteristics.

Such studies should follow the principle of segmentation, recognizing that the public is not a homogeneous entity. Contradictory public values should be identified since their interplay is key for acceptance (Reed et al. 2018). For example, Scholte et al. (2016) found that biodiversity was a more important factor for farmers than other residents. Several studies also highlight that aesthetics, although important, is subjective among members of the same public (Evans et al. 2017; Myatt et al. 2003b). Using social norms can be a powerful motivator but relevant norms must already exist and it has been shown to backfire depending on in- and out-group dynamics (Bicchieri and Dimant 2019). Likewise, the use of economic incentives may be very effective for some, but have negative externalities such as competing with altruistic or moral motivation (Beery 2018) or raising expectations too high in others (Biswas et al. 2008).

2.5 Conclusions

Using nature to address societal challenges like risk from natural hazards is often highly effective and can deliver a wide range of co-benefits. However, the approach is still perceived as novel compared to traditional grey measures, common for practitioners and the public to rely on in contexts of risk. In many cases, public acceptance of NbS for risk reduction will have to be earned. Along with effectiveness and co-benefits, we identified a number of factors that can influence public perceptions and be leveraged by practitioners and researchers to encourage greater acceptance. Generic education campaigns are a popular recommendation for increasing awareness of benefits. However, it has become increasingly obvious that the presentation of scientific evidence alone can have a very weak influence on public attitudes and behaviours. Further research into alternative approaches to leveraging these factors for acceptance is needed. Moreover, efforts towards establishing principles and standards for NbS should be accompanied by more research into interactions among individuals, societies and NbS for risk reduction. Public perceptions determine acceptance, which is crucial for the success and continued uptake of NbS.

Chapter 3 Public acceptance of nature-based solutions for natural hazard risk reduction: Survey findings from three study sites in Europe

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Abstract:

Climate change is one factor increasing the risk of hydro-meteorological hazards globally. The use of nature-based solutions (NbS), and more specifically ecosystem-based disaster risk reduction measures (Eco-DRR), has become a popular response for risk reduction that also provides highly-valued co-benefits. Public acceptance is of particular importance for NbS since they often rely on local collaborative implementation, management, and monitoring, as well as long-term protection against competing societal interests. Although public engagement is a common goal of NbS projects, it is rarely carried out with a sufficient understanding of the (de)motivating factors tied to public perceptions. Successful collaboration demands consideration of societal attitudes and values in relation to risk, nature, and place. However, existing research does not sufficiently explore these themes together, their interactions, and their implications for the public acceptance of NbS. This may lead to misaligned public expectations and failed participatory initiatives, while jeopardizing the success of NbS projects and their continued funding and uptake. We conducted citizen surveys within local NbS ‘host’ communities to determine the degree of pro-NbS attitudes and behaviours, associated variables, and how these may be leveraged to increase acceptance. We compared results across sites, relying primarily on correlations and regression models along with survey comments and expert knowledge. Three distinct rural NbS being implemented within the OPERANDUM project aim to reduce risk from (socio-)natural hazards in Scotland (landslides and coastal erosion; n=66 respondents), Finland (eutrophication and algal blooms; n=204) and Greece (river flooding and water scarcity; n=84). Our research thus centres on rural NbS for risk reduction within a large EU project. Trust in implementers is a consistent factor for defining attitudes towards the NbS across the sites, and attitudes are strongly associated with respondents’ commitment to nature and behavioural acceptance (i.e., willingness to engage). Behavioural acceptance is most consistently predicted by connectedness to place and the extent of expected future impacts. Scepticism of NbS effectiveness leads to high public demand for relevant evidence. To increase public acceptance, we recommend greater framing of NbS in relation to place-based values as well as demonstration of the effectiveness of NbS for risk reduction. However, distinct hazard types, proposed NbS, and historical characteristics must be considered for developing strategies aimed at increasing acceptance. An understanding of these characteristics and their interactions leads to evidence-based recommendations for our study sites and for successful NbS deployment in Europe and beyond.

Keywords: nature-based solutions, climate change, public acceptance, public perceptions, local participation, stakeholder engagement, hydro-meteorological hazards, community action

3.1 Introduction

Public attitudes and behaviours are central to tackling the greatest social and environmental issues of our time (Reid et al. 2010; World Bank 2015). The importance of public attitudes and meaningful participation has long been recognised for environmental protection (Blake 1999; Reed 2008) and within the broader context of sustainable development (Chambers 1994). Over the past several decades, the field of disaster risk reduction has undergone a learning process and generally taken up these calls for increasing local and community involvement (Begg et al. 2018; La Tozier de Poterie and Baudoin 2015; Macherera and Chimbari 2016; Maskrey 1989), spurred on by an understanding of interconnections among environmental protection, sustainable development, disaster risk, and climate change (Birkmann and Teichman 2010; Turner, II et al. 2003; UNDRR 2015; United Nations 2015).

Phrases such as “integration of local stakeholder knowledge”, “bottom-up approach”, and any number of verbs following the prefix “co-”, to describe public actions within risk management projects are commonplace. The ubiquity of this terminology is indicative of the shift towards increased reliance on public support (i.e., non-state actors and individuals) (Begg et al. 2018; Bubeck et al. 2017; Kuhlicke et al. 2020; Mees et al. 2012; Penning-Rowsell and Johnson 2015; Puskás et al. 2021; Zingraff-Hamed et al. 2020) that has also been codified in relevant policy such as the European Water Framework Directive (European Commission 2000). Indeed, this shift has been most prominently manifested in the context of flood risk management in Europe (Bark et al. 2021; Begg et al. 2011; Begg et al. 2018) and promoted as a departure from a “decide, announce, defend” practitioner-public interaction model to an “engage, deliberate, decide” approach (Daly et al. 2015). An increasing reliance on the public for addressing environmental risk has been attributed to, among other reasons, a decline in trust in policy-makers (van der Vegt 2018), a push for increased legitimacy and democratic decision-making, a recognition of improved outcomes (Begg et al. 2018; Zingraff-Hamed et al. 2020), the ability to break gridlock and prevent litigation (Irvin and Stansbury 2004), and the extra burden on disaster risk managers due to climate change and land-use conflict (Wamsler et al. 2019).

However, public acceptance and the expected resulting positive outcomes are uncertain and highly predicated on context (Euler and Heldt 2018; Godschalk et al. 2003; Irvin and Stansbury 2004; Wamsler et al. 2019). Additionally, the success of scientific innovations for sustainable development is often determined by public perceptions rather than scientific consensus (Hopkins et al. 2012). Nature-based solutions (NbS) that aim to reduce risk from natural hazards while also providing a wide range of ecosystem services, or benefits, to people (Cohen-Shacham et al. 2016) can be considered one such innovation. NbS encompass measures for ecosystem-based disaster risk reduction (Eco-DRR) and ecosystem-based adaptation to climate change (EbA) (Cohen-Shacham et al. 2016). We focus on Eco-DRR in this study. The substantial funding for NbS research and its ongoing implementation across Europe is indicative of the increasing political and scientific consensus for these measures (European Commission 2021b; Faivre et al. 2017; Zingraff-Hamed et al. 2020).

A greater reliance on local stakeholders for cooperation with NbS during implementation, maintenance, management, and monitoring phases means public acceptance is crucial for their success (Anderson and Renaud 2021; Bark et al. 2021; Ferreira et al. 2020; Puskás et al. 2021). The multi-functionality of NbS entails greater opportunity for stakeholder participation but also greater risk of conflict (Connop et al. 2016; European Commission 2021b; Naumann and Kaphengst 2015). Additionally, in the short-term NbS can be less effective than other measures and can require increased long-term protection (e.g., conservation) when faced with competing societal interests within their ‘host’ communities (i.e., the groups of local citizen stakeholders living and interacting with NbS) (Anderson and Renaud 2021; Kabisch et al. 2016). Negative public perceptions are commonly considered a potential barrier to NbS uptake (Connop et al. 2016; Han and Kuhlicke 2019; Heldt et al. 2016; Raymond et al. 2017) and the centrality of local stakeholder engagement is reflected in policy-oriented NbS guidelines (IUCN 2020a).

Although public participation is a common goal of NbS projects and a prominent feature of relevant guidelines (IUCN 2020a), it is rare that stakeholder engagement processes are based on a thorough understanding of the motivating and conflicting factors related to public perceptions (Zingraff-Hamed et al. 2020). Research aimed at increasing the success of NbS has focused more on its physical implementation rather than local public attitudes and supportive behaviour, although a recognition of the latter is increasing (Buchecker et al. 2013; Ferreira et al. 2020; Howgate and Kenyon 2009; Kabisch et al. 2016; Triyanti et al. 2017). There is also increasing attention on stakeholder preferences within NbS projects, although the focus of this research generally involves the weighting of criteria for instrumental project outcomes (Giordano et al. 2020; Pugliese et al. 2020; Ruangpan et al. 2020), rather than a broader analysis of relevant perceptions and values. This lack of background social science research on NbS for risk reduction can lead to misaligned expectations (Verbrugge et al. 2017) and communities being blamed for the failure of participatory initiatives (Barthélémy and Armani 2015; Biswas et al. 2008). If facilitated without proper intentions and a rich contextual understanding, local participation may be viewed as performative rather than contributory and lead to both negative perceptions and unsatisfactory project outcomes (Begg et al. 2018; Euler and Heldt 2018; Irvin and Stansbury 2004; Wamsler et al. 2019). In contrast, effective risk or project-related communication and meaningful participation is more likely to be successful with an understanding of individuals' perspectives and values (Brink and Wamsler 2019; Moser and Dilling 2011; Raymond et al. 2017; Simon et al. 2013). Transparent participation and framing of communication can enhance identification of shared goals and improve engagement (Buijs 2009; Everett et al. 2018; Moser and Dilling 2011; Simon et al. 2013), even in contexts of inherently misaligned public-practitioner objectives (Pfadenhauer 2001; Williams et al. 2017).

Perspectives and values vary greatly both across and within the contexts of NbS sites and should be explored on a case-by-case basis but with systematic consideration of relevant variables. In their review of 99 articles related to public acceptance of NbS for disaster risk reduction, Anderson and Renaud (2021) identified the variables found to influence acceptance and their frequency in the literature. The variables are classified as being most relevant to the individual, the society, or the NbS approach itself, and the most frequently cited include perceived benefits and trade-offs, effectiveness of risk reduction, cost, risk perception, place attachment, and trust in the responsible party. Many of the variables can also be classified into the general themes of perceptions of risk, nature, and place, the relevance of which is also suggested by prior research. For example, perceived concern for hazards (Ding et al. 2019; Fordham et al. 1991) or their negative impacts (Böhm and Pfister 2000; Bubeck et al. 2012b; Schernewski et al. 2017; Sjöberg 1999, 2000a) are widely cited as potential (context-dependent) motivators of (support for) protective action. Similarly, individuals' 'acceptance' or intolerance of risk can determine whether they support risk reduction and its required personal or community resources (e.g., time or money) (Baird 1986; Buchecker et al. 2015; Chowdhury 2002; Fischhoff et al. 1978; Holstead et al. 2017).

Since both using natural elements and supporting ecosystems are central to NbS, the long-standing and well-established research on determinants of pro-environmental attitudes and behaviours is also highly relevant (Steg and Vlek 2009; Stern 2000; van Liere and Dunlap 1980). Cleaner air (Groot and Groot 2009; Miller and Montalto 2019) and water (Koutrakis et al. 2011; Schaich 2009) and greater biodiversity (Everett et al. 2018; Howgate and Kenyon 2009; Jones et al. 2012b; Miller and Montalto 2019; Roca and Villares 2012; Schaich 2009; Scholte et al. 2016) and wildlife habitat (Beery 2018; Evans et al. 2017; Herringshaw et al. 2010; Kenyon 2007) can be crucial for public acceptance of NbS. The perceived importance of positive environmental outcomes as motivators is related to individuals' sense of interdependence and commitment to nature (Davis et al. 2011).

Lastly, whether NbS are seen to enhance or degrade local history, identity and place can influence the degree of public acceptance (Bihari and Ryan 2012; Brink and Wamsler 2019; Buijs 2009; Roca and Villares 2012). Individuals' connectedness to place may determine whether shifts away from the status quo or the idealised environment face opposition (Buijs 2009; Jacobs and Buijs 2011; Pueyo-Ros et al. 2019) or if NbS that enhance local values find support (Brink and Wamsler 2019; Schmidt et al. 2014). Recent literature reviews on the subject have also found risk, nature, and place to be key themes of variables that influence perceptions of NbS across diverse geographic and hazard contexts (Anderson and Renaud 2021; Han and Kuhlicke 2019).

These research streams from disaster risk reduction and risk perception, environmental attitudes and behaviours, and attachment/connectedness to place provide fertile ground for explaining public acceptance of rural NbS (projects) for risk reduction. However, the associated variables from these fields have only very rarely been considered within the same studies on public acceptance (Buijs 2009). Our research addresses the resulting insufficient understanding of what determines public attitudes and behaviours in this context.

The ongoing EU-funded OPERANDUM project[13] is implementing NbS in Europe to reduce risk from hydro-meteorological hazards. We conducted surveys with residents of three rural OPERANDUM NbS host communities across Europe (Scotland, Finland and Greece). By a) assessing public attitudinal and behavioural acceptance of NbS and b) determining what variables define and are related to acceptance, we aim to address the outlined knowledge gaps and help ensure successful NbS within the study sites while also identifying more general lessons and recommendations for NbS.

We define public acceptance broadly to encompass, for example, cooperation, engagement, satisfaction, and buy-in while avoiding conflict, opposition, and a lack of participation (Anderson and Renaud 2021). It thus describes both attitudes and behaviours toward NbS while recognizing their potentially distinct motivators. We use a comparative research approach to identify similarities and divergence across the sites (Lijphart 1975; Mills et al. 2006; Przeworksi and Teune 1970). Our research compares three rural sites that were all in the mature planning stage prior to deploying NbS for risk reduction. However, within the limits of the OPERANDUM project, our study site selection then seeks to maximise contextual differences across sites in terms of social and environmental systems. This research design can be described as the “most different system” approach (Przeworksi and Teune 1970). Divergence in results across sites demands a systematic exploration of contextual characteristics, while similarities across sites leads to cautious inferences regarding generalisability of the independent variables in contexts of rural and externally initiated NbS projects for risk reduction. Based on the risk, nature, and place literature described above, we set out with the hypothesis that these variables

[13] https://www.operandum-project.eu

will be influential for public acceptance of each NbS across the sites, testing this using maximally different contexts.

We are not aware of any similar studies that compare results across distinct rural study sites with different natural hazards, social and cultural characteristics, and proposed NbS with the primary objective of disaster risk reduction. We combined the comparative approach with psychometric methods since these are suitable for measuring individuals' perceptions through standardised survey items and composite scales (Borsboom 2005) for bivariate and multivariate statistical analyses.

We first provide a brief background on the study sites and detailed description of survey sampling, survey design, and data analysis. Next, results are structured based on the following research questions:

RQ1) What is the degree of public acceptance within the NbS sites and how does this differ across the sites?

RQ2) What variables define attitudinal acceptance, what is their strength within and across sites, and are perceptions of risk, nature and place associated with them?

RQ3) What variables define, correlate with, and explain behavioural acceptance (i.e., willingness to engage), and do attitudes towards NbS moderate their strength?

We then discuss key findings across the sites, their relation to prior research, and corresponding recommendations for increasing public acceptance of NbS within the sites and beyond. This is followed by a reflection on the study's limitations, the direction of further research needed, and a conclusion.

3.1.1 Study sites

Our three European study sites are Catterline, Scotland, UK; the Lake Puruvesi area in Eastern Finland, and the Spercheios River Basin in Stereá Elláda, Central Greece (Figure 3-1). All three sites are rural and have relatively low-density populations living nearby who are exposed to hydro-meteorological hazards.

Additionally, the sites were all at similar points in their project timeline – the NbS had not yet been deployed by the project, but the stakeholder engagement process had begun and NbS planning was at a mature stage. Because contact had already been made with residents during limited prior outreach activities, there was a baseline level of awareness of the OPERANDUM NbS work among the respondents. These three sites were selected within the OPERANDUM project to cover a diverse set of social and environmental contexts, including spatial scales (Catterline is much smaller than the other sites), as well as diverse hazards and NbS. In this way, the survey variables are tested for both their site-specific and general relevance.

(A)

(B)

Study Site	Study site area	Hazard	Primary NbS	Primary aim of NbS
Catterline	0.4 km^2	Landslide	Live cribwall, live grating, live pole drain	Slope protection and erosion control
Puruvesi	73 km^2	Eutrophication and algal blooms	Continuous cover forestry (CCF)	Erosion control and reduction of runoff
Spercheios	92.4 km^2	River flooding and water scarcity	Natural water retention basins	Excess surface runoff storage and groundwater recharge

Figure 3-1 Three European NbS study sites. Three European NbS study sites (A) and their characteristics, including hazard type and primary NbS being implemented within the OPERANDUM project (B). Map: European Commission, Eurostat, https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/countries. Photo credits: Catterline, Dr. Karen Munro; Puruvesi, Pro Puruvesi ry; Spercheios, KKT-ITC S.A.

3.1.2 Catterline, Scotland, United Kingdom

Catterline is a small, rural, and scenic seaside village in Northeast Scotland with important historic and cultural relevance. The community has a long history of landslides, soil erosion, and related coastal hazards (Gonzalez-Ollauri and Mickovski 2017). Prolonged periods with heavy rainfall, surface water accumulation, fluctuations in groundwater, spring tides, storm surge, and high winds are all long-standing issues that contribute to landslides in Catterline. The last major landslide event, before the surveys were conducted in September 2019, occurred in October 2012.

Along with a detraction from the scenic beauty, the impacts of landslides in the community are most frequently road closures that can inhibit both the residents' recreational opportunities and access to essential services. There is also a fear of property damage or personal injury since past landslides have come within meters of residences.

Recent work to mitigate landslide risk has involved live ground anchor systems and live drainage systems making use of locally available willow branches, as well as the (re)planting of woody seedlings and cuttings along some sections of the slopes. These measures, including live cribwalls and grating, were being planned for deployment by the OPERANDUM project when the surveys were carried out. Additionally, a stabilisation effort using geogrid mesh with vegetation was completed in August 2019 by members of a community group – the Catterline Braes Action Group (CBAG[14]). The group was formed following the landslides during the winter of 2012/2013. Most members live in the village and it is supported by voluntary resident engagement, with several highly engaged residents and many others supportive.

3.1.3 Lake Puruvesi area, Finland

Lake Puruvesi and its surroundings in South-eastern Finland are rural, scenic, and culturally significant. Puruvesi is particularly well-known for its water clarity. While most of the 416 km^2 lake is in excellent ecological condition, the frequency of blue-green (cyanobacterial) algal blooms related to eutrophication has increased within portions of the lake, particularly in its north-western extent near the Lake Kuona-Vehkajärvi sub-catchment area.

The dominant land-use in the Lake Puruvesi catchment is forestry (92% of the catchment land area) and the remainder mostly agricultural (7%)[15]. Runoff from rainwater and snowmelt carries sediment and agricultural inputs to the lake. Forestry practices underlie the issue, while the hydro-meteorological conditions for the processes are exacerbated by climate change. Eutrophication occurs when the water is overly enriched with nutrients, often indicated by blue-green

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[14] https://www.cbag.org.uk

[15] https://www.syke.fi/en-US/Open_information/Spatial_datasets

algal blooms, lower water clarity, sliming, higher quantity of mud and reeds on the beaches, as well as reduced oxygen levels for plants and fish. Ecological degradation, in turn, impacts recreational activities such as swimming and fishing as well as livelihoods dependent on the water quality of the lake (tourism and fishing). Additionally, adverse health effects can occur, including skin and eye irritation.

The focus of OPERANDUM NbS work in Puruvesi is on continuous cover forestry (CCF), a sustainable resource management practice involving selective timber harvesting to maintain a forest canopy and vegetation density to reduce runoff while also maintaining forest ecosystem structure and habitat. However, other NbS including constructed wetlands, peak flow control structures, sedimentation ponds and pits and surface runoff fields were also being planned at the time of the survey, as communicated to respondents.

3.1.4 Spercheios River Basin, Greece

The steep slopes of the Spercheios River Basin, present within approximately two-thirds of the total length of the river, form a mountainous topography with crucial flooding peaks and very intense sediment yield. In the last downstream part of the Spercheios course, the topography gradually changes into a lowland relief, discharging into the Maliakos Gulf connected to the Aegean Sea. Our research concentrates on the mouth of the Spercheios River near the city of Lamia, the area with the largest population exposed to flooding. Topography, soil properties and climate are conducive to seasonal flash-flooding and high sedimentation. Along with some tourism, agriculture is the most common livelihood in the area.

Flood events occur on an almost yearly basis that damage property – both residential and agricultural – and can block access roads. Most recently, flash flooding in 2018 caused extensive damage and disruption for several weeks. Tourism and agricultural livelihoods are thereby affected in addition to transportation and recreation. There are no recorded deaths from flooding.

A system of canals and trenches, most of which have been in place since the 1950s, are the primary flood protection measures in the basin. Berms are also in place to provide protection near settlements. These measures have been maintained and extended in the past decades with varying degrees of (mostly limited) success.

NbS in Spercheios are natural water retention measures (NWRM). Drainage basins using natural materials are being implemented to reduce the risk of flooding by absorbing excess water while also providing wildlife habitat and contributing to groundwater recharge and irrigation needs. In parallel, measures such as dam height reduction and the removal of some longitudinal barriers are being taken to increase river connectivity and support downstream wetlands.

3.2 Methods

3.2.1 Survey sampling

Self-administered surveys of residents living near NbS deployment sites in the OPERANDUM project were conducted between September 2019 and April 2020. The Covid-19 pandemic had not yet affected the study areas at the time of data collection. Ethical clearance for data collection was granted by a dedicated review board at the University of Glasgow and all responses were voluntary and treated anonymously. Due to time and financial constraints, the sampling approaches in the three sites were non-random and aimed to maximise the number of responses rather than ensure representative samples. Due to different contexts and capacities of local collaborators, this meant data collection methods across the sites were distinct (Table 3-1).

In Catterline, the geographic boundary was set to include residences beyond the dense village, extending out to the A92 highway to the west, north to Cloak Caravan Park, and south to Glasslin Burn (i.e., approximately 1km in each direction). In Puruvesi, all residents in postal code 58200 were targeted. The boundary for Spercheios included the entire basin, from Lamia and Komma upstream to Makrakomi. However, 32 responses are from Lamia (37.6%) and the next highest count is from Kompotades (n=9). In all sites, all residents above 18 years of age were targeted. Gender and age of the samples moderately reflect population percentages. Most notably, females are underrepresented in Puruvesi with a difference of 10% compared to the population while the sample population of Catterline and Puruvesi is older than the population in each site. Lastly, the sample in Spercheios has a higher percentage of middle-aged repsondents than the population (Table 3-2).

Table 3-1 Survey data collection process. Characteristics of the data collection process and outcomes for each of the three study sites.

Study Site	Survey date	Format	Collection method	Detailed description	Response rate[1]	Survey count	Survey count after pre-processing
Catterline	September 2019	Paper-based	Door-to-door	Seventy-two residences were included in the study area and contacted by the lead author, first with a survey notification letter one week prior to visiting the community. The lead author went door-to-door to every residence and all over 18-year-old residents were invited to complete the survey. Surveys were left with residents to be self-administered and collected within several days at the respondents' convenience. Surveys were completed at 60 residences.	51.6%[2]	67	66
Puruvesi	March-April 2020	Online (eHarava[3])	Postcard with online survey link	First, all 1662 households within the most affected postal code area (also where the NbS are planned) were contacted with a postcard describing the NbS work and inviting participation in the survey through a URL link. Next, 900 members of a local action group of lake users, ProPuruvesi, were also sent a survey notification email with invitation (an estimated 20% of whom were already contacted through the postcard). A short article in a free local newspaper was published in March 2020 that introduced the project and the NbS as well as informing/reminding readers of the ongoing survey.	10.3%	228	205
Spercheios	October 2019-January 2020	Paper-based	Focus group, convenience	First, surveys were distributed at the end of a public outreach focus group organised within the context of the OPERANDUM project in the town of Kompotades in October 2019. Thirty surveys were collected from the focus group, to which all surrounding residents were invited. In November 2019, 70 additional paper or electronic versions of the survey were distributed to residents by project partners representing the municipality of Lamia using existing institutional mailing lists and contacts.	79%	85	84

[1]The response rate is the number of completed surveys (i.e., 'responses') divided by the total number of surveys distributed. In Catterline, because the method was door-to-door and all households were approached, the response rate reflects the number of completed surveys divided by the number of over 18-year-olds in the study area. All distributed surveys in Catterline were completed.
[2]Based on Scottish Census (2011) output area S00091368; https://www.scotlandscensus.gov.uk/ods-web/area.html
[3] www.eharava.fi.

Table 3-2 Gender and age of the survey samples compared to the population.

	Catterline[1]		Puruvesi		Spercheios[2]	
	Sample[3]	Population[4]	Sample	Population	Sample	Population
Characteristic	n=66	N=128	n=205	N=2,694	n=84	N/A
Percent						
Male	52.54	54.30	60.11	49.80	53.52	49.90
Female	47.46	45.70	39.89	50.20	46.48	50.10
Age 19-24	1.69	7.44	0.00	4.86	2.50	8.38
Age 25-34	3.39	14.05	3.28	7.76	16.25	17.80
Age 35-44	11.86	21.49	8.20	11.36	37.50	20.44
Age 45-54	25.42	26.45	15.85	14.22	23.75	17.88
Age 55-64	32.20	14.88	26.78	18.19	17.50	13.63
Age 65-74	22.03	13.22	37.70	23.57	2.50	11.12
Age 75+	3.39	2.48	8.20	20.04	0	10.75

[1]Surveyed age group data ranges in Catterline do not match census data. Data are approximated by taking a fraction of census ranges, assuming an equal age distribution within the range.
[2]2011 census data from Lamia and Makrakomi are used to average gender and age population percentages.
[3]Missing response data for each gender and age omitted to calculate percentages in all sites.
[4]Only includes over 18-year-olds for all sites. The geographic extent of Catterline includes homes within 1km of the village. Puruvesi includes all residents in postal code 52800. The Spercheios River Basin has many villages and is not a political geographic unit, therefore it is difficult to estimate its total population. The city of Lamia alone has some 50 000 residents.
Data sources: Catterline: Based on Scottish Census (2011) output area S00091368, https://www.scotlandscensus.gov.uk/ods-web/area.html; Puruvesi: Tilastokeskus statistical database, https://pxnet2.stat.fi/PXWeb/pxweb/en/Postinumeroalueittainen_avoin_tieto/; Spercheios: Hellenic Statistical Authority, https://www.statistics.gr/en/statistics/-/publication/SAM03/-

Comparing across the sites, the samples included mostly even distributions of gender in Catterline and Spercheios and about 60% more males than females in Puruvesi. The sample in Puruvesi was also older, while the sample in Spercheios was younger than the other sites (Figure 3-2).

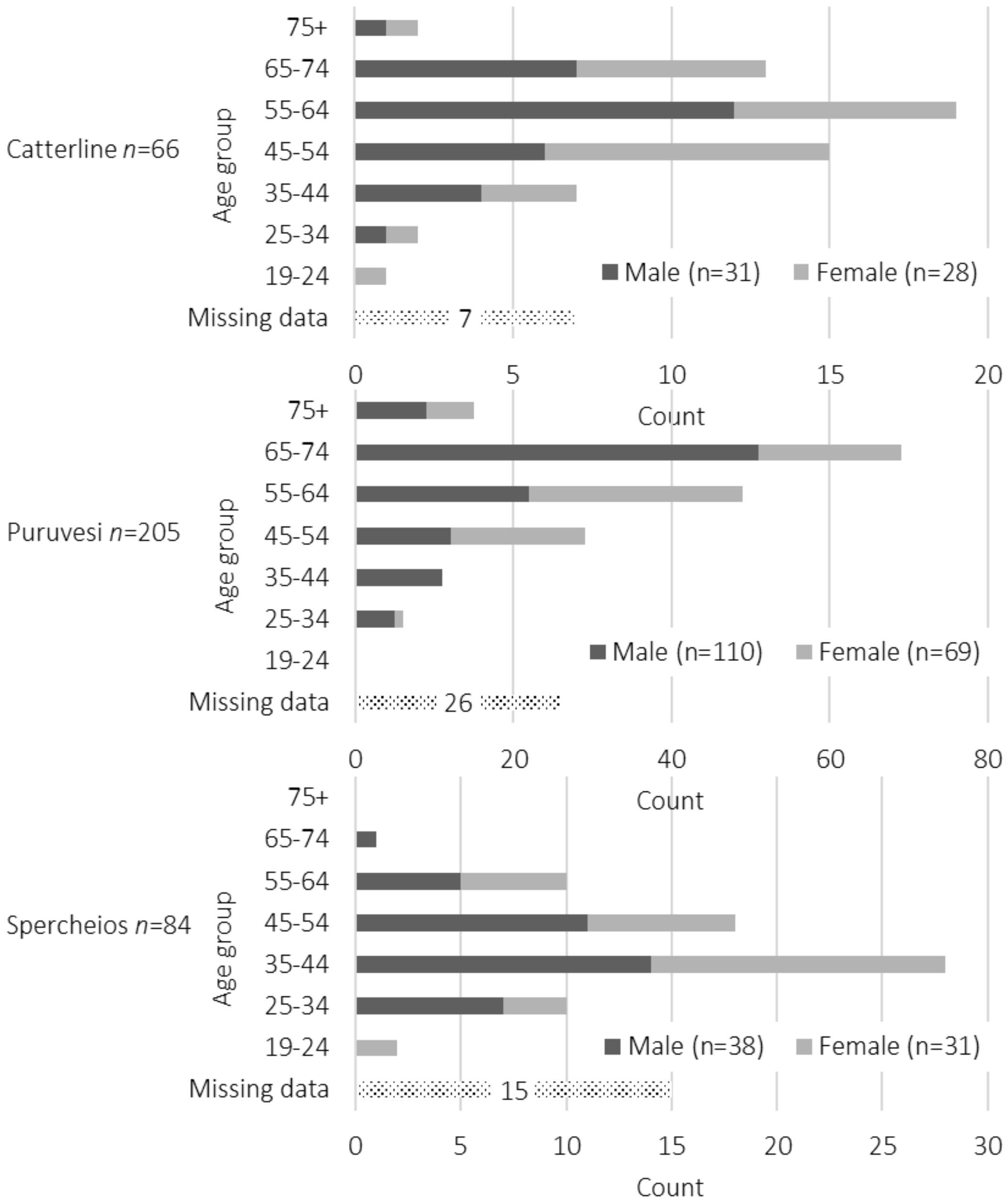


Figure 3-2 Survey respondents by age and gender. Distribution of male and female respondents in the three study sites by age group. Respondents were explicitly instructed to skip this survey item if they preferred not to respond.

3.2.2 Measured variables

We used exploratory factor analyses (EFA) to derive measured variables for *attitudinal acceptance*, *behavioural acceptance*, and variables related to the themes of risk, nature, and place.

The survey primarily included 1-9 Likert items and several yes/no items (the full Catterline survey is provided in the appendix as Text. A-3). This Likert range was selected since acceptance is a bipolar construct (i.e., rejection is also possible) (Boateng et al. 2018) and to capture more variation in responses past the mid-point response, given evidence of generally high acceptance of the measures in the sites through past outreach. We used EFA with promax rotation to interpret oblique factors (Abdi 2003) and generate weighted sum factor scores for scales based on Likert items (Boateng et al. 2018; Briggs and Cheek 1986; DiStefano et al. 2009; Fabrigar et al. 1999) while yes/no responses were coded as 1/0 and summed.

We assessed *attitudinal acceptance* with 13 items due to its lack of established relevant scales and multi-dimensionality based on the five themes of 1) trust in implementers, 2) competing societal interests, 3) sense of personal responsibility, 4) perceived effectiveness of NbS, and 5) acceptance of NbS cost. We also included two general items related to whether the NbS is perceived as “good” and whether the respondent is “satisfied with [ongoing] implementation.” The *attitudinal acceptance* themes and all risk, nature and place variables were drawn from Anderson and Renaud’s (2021) review on public acceptance of NbS. Variables were selected that are a) the most frequently cited as influencing public acceptance of NbS, b) broadly relevant for distinct NbS contexts, including our study sites, and c) can be assessed using nonintrusive citizen surveys (e.g., do not test for or require extensive NbS knowledge). Additionally, we relied on consultation with local project managers at each of the study sites to ensure the relevance of the variables.

For *behavioural acceptance*, we used six items to reflect the most relevant forms of both passive and active engagement in the sites. These started with the phrase *“I would like to…”, under which were the items: “learn about NbS”, “attend* *meetings", "implement and maintain", "monitor", "fundraise or source supplies"* (not applicable in Spercheios), or *"volunteer in other ways"*. These items were designed to capture the wide range of potential forms of acceptance identified in Anderson and Renaud (2021). They were determined in consultation with local project managers to a) include the full range of past supportive actions of residents, b) include potential future actions that would be instrumentally useful for the project managers (i.e., more than merely performative), c) be relevant across NbS contexts (i.e., not overly specific to the sites), and d) capture a range of knowledge, skill, and physical capacities of residents. This latter criterion was particularly important given the substantial elderly population in the Catterline and Puruvesi sites.

We use scales, i.e., internally reliable compositions of multiple survey items that measure a single concept (Borsboom 2005), for *attitudinal acceptance* (13 items) and *behavioural acceptance* (6), as well as for variables within the themes of risk, nature, or place. These include: *risk perception* (5), *risk intolerance* (4-6), *past impacts* (5-8), *future impacts* (5-8), *commitment to nature* (4), and *connectedness to place* (4) (Table 3-3). Risk scales (excluding *risk perception*) vary in number of items due to the number of relevant hazard impacts identified per site (Text. A-3). To capture the environmental aspect of an item related to attitudinal acceptance, "*sense of responsibility for risk reduction*", we included the additional single item *responsibility for nature* (Blake 1999). We use the term 'variables' to refer to all survey items and scales, with the exception of EFA results for *attitudinal acceptance*, which we refer to as 'factors'.

The *commitment to nature* scale is based on Davis et al.'s (2011) commitment to the environment scale and the *connectedness to place* scale on Jorgensen and Stedman (2001). These were truncated due to space constraints (Buijs 2009) and to prevent respondent fatigue and/or criticism of seemingly irrelevant survey material. Risk perception scales relevant to natural hazards in academic literature have historically focused primarily on hazard characteristics (Fischhoff et al. 1978; Siegrist and Árvai 2020; Slovic et al. 1985). Perceived vulnerability and concern (or 'worry') have also been associated with risk perception and protective behaviour and engagement (Gifford and Comeau 2011; Peters et al. 2006; Rundmo 2002;

Terpstra 2011). We combined items related to perceived hazard, vulnerability, and concern and created additional scales of summed binary past impacts (experienced) and future impacts (expected). The *risk intolerance* scale was inspired by Finlay and Fell (1997), who applied the concept to individual perception of landslide risk, Maynard et al. (1976), who assessed acceptability of risks associated with nuclear waste disposal, and Haynes et al. (2008), who assessed tolerability of volcanic risk.

Table 3-3 Composition and computation of variable scales. For scales composed of 1-9 Likert items, processing and reliability testing was conducted by assessing Cronbach's alpha (α), corrected-item-total correlations (CITC), and exploratory factor analysis (EFA) using principal axis factoring. The 'original' Cronbach's α is a measure of the internal reliability of all scale items per site (C=Catterline, P=Puruvesi, and S=Spercheios), while the 'final' Cronbach's α results from removing items from the scales to increase their reliability, based on the processing steps described. Factor scores using weighted averages were calculated for further analysis.

Scales[1]	*Risk perception*	*Risk intolerance*	*Past impacts*	*Future impacts*	*Commitment to nature*	*Responsibility for nature*	*Connectedness to place*
Item count	5	4-6	5-8	5-8	4	1	4
Agg. method	Factor score	Factor score	Sum	Sum	Factor score	N/A	Factor score
Themes / item structure	Coping capacity Susceptibility Hazard frequency Hazard magnitude Concern	*"It is okay if [exposed element] is/are affected by [hazard] once every [time span]."*	*"In the past, [hazard] has affected my [exposed element] in [place]."*	*"In the future, I believe [hazard] will affect my [exposed element] in [place]."*	Well-being Attachment Feel good Best interests	*"As a resident of [place], I feel responsible for protecting its natural environment."*	Identity Attachment Dependence Pride
Original Cronbach's α	C= .491 P= .630 S= .576	C= .864 P= .854 S= .851	N/A	N/A	C= .887 P= .587 S= .564	N/A	C= .734 P= .668 S= .724
Final Cronbach's α	C= .550 P= .653 S= .728	C= .864 P= .854 S= .839	N/A	N/A	C= .887 P= .759 S= .695	N/A	C= .771 P= .651 S= .776
Final % variance explained	C= 69.2 P= 51.1 S= 56.0	C= 72.6 P= 81.2 S= 62.3	N/A	N/A	C= 75.4 P= 68.0 S= 63.1	N/A	C= 72.8 P= 59.5 S= 69.9

Scale processing steps:

1. Compute Cronbach's alpha scores, alpha if item deleted and corrected-item-total correlations (CITC).
2. In parallel, run EFA using principal axis factoring (100 iterations max), eigenvalues 1, and promax rotation (100 iterations max).
3. Remove items from each EFA model until the following criteria are met, in this general order of importance: alpha maximised; no CITC <0.3; no communality <0.3; no cross-loading factors, low loadings on all factors, or stand-alone large negative loadings; percent variance maximised; adequate KMO and Bartlett's test.
4. Rerun this process iteratively, removing one variable at a time.
5. Calculate weighted averages (non-refined factor score method) to use for further analysis.

[1]*Responsibility for nature* is a single item.

Generally, the scales yielded appropriate alpha scores. Truncating the scales decreased their reliability and necessitated, in some cases, the iterative exclusion of items on a site-by-site basis (see Table. A-4 for a list of retained/excluded variables per site) (Boateng et al. 2018). The *risk perception* scale showed the lowest reliability scores. Due to several low scores, we conducted a final analysis using all underlying single items in addition to the survey scales.

Space was provided periodically for respondents to write in “survey comments”, which we assessed to help interpret the results. Translations were carried out by the authors.

3.2.3 Data pre-processing and analysis

Data pre-processing was carried out using Excel and analysis carried out using SPSS (v. 26). Responses with high missing data counts (n=14 in Puruvesi) or with lack of expressed consent were removed (n=5 in Puruvesi; n=1 in Spercheios). Due to small sample sizes in Catterline and Spercheios, single missing values for scale items were imputed using the median of other items for the same scale and respondent (Bernaards and Sijtsma 2000). Additionally, “I don’t know” responses, included on Catterline and Spercheios surveys, were treated as mid-point responses (5) on the scales for *risk perception*, *risk intolerance*, and *attitudinal acceptance*. Items with greater than 5% imputed data per site are shown in the appendix, along with data imputation for binary hazard impact items (Table. A-5).

The data analysis process was guided by the three research questions and required defining *attitudinal acceptance* and *behavioural acceptance* and then running correlation and regression analyses to determine their relation to risk, nature, and place variables. The results subsections are organised based on the three research questions and corresponding analyses (Figure 3-3).

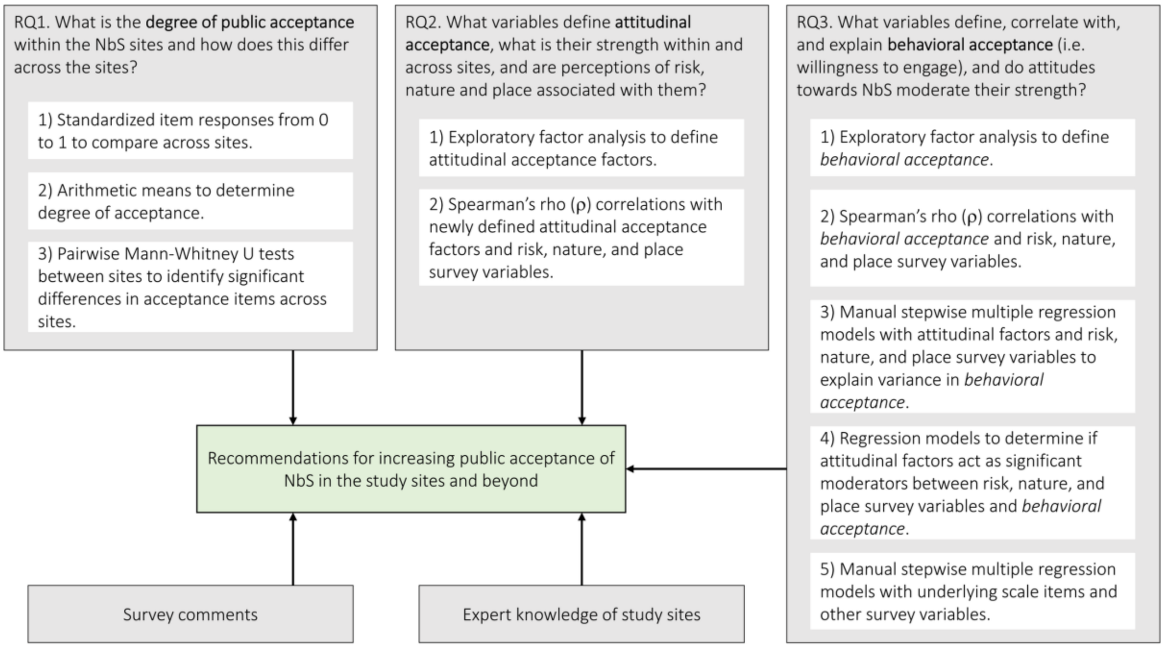


Figure 3-3 Research questions (RQ) and corresponding methods. Statistical results, combined with survey comments and expert knowledge of the sites, lead to recommendations for increasing public acceptance of NbS both within the study sites and for NbS generally.

Responses to *attitudinal* and *behavioural acceptance* items were divided by the max Likert response (9 for Catterline and Spercheios, 7 for Puruvesi) and arithmetic means calculated to compare the standardised degree of acceptance within and across the sites. Pairwise Mann-Whitney *U* tests were used to determine any significant differences in means between sites ($p<.05$).

First, we used exploratory factor analysis (EFA) to determine the items that best define the constructs of *attitudinal* and *behavioural acceptance* towards NbS in the sites (see Table 3-3 for EFA methodology; Table. A-6 and Table. A-7 for detailed outputs). We then conducted Spearman's rho (ρ) correlations between both *attitudinal* and *behavioural acceptance* and the survey variables related to risk, nature, and place. The correlation analyses allowed us to explore independent associations between acceptance and individual variables. We only report correlations at significance levels of $p<.10$, $p<.05$, and $p<.01$ to simplify visual interpretation of tables.

Multiple linear regression models, in contrast to the correlations, are affected by interrelations among the variables. These were also created using each of the risk, nature, and place variables per site as well as models including all survey variables per site to explain variance in *behavioural acceptance*. For the latter, we included only predictors with the strongest correlations with *behavioural acceptance*, maximum one predictor per eight observations (VanVoorhis and Morgan 2007). We followed a manual stepwise procedure of iteratively removing (step-down) the most non-significant predictors until all remaining predictors were significant to at least $p<.05$. This is preferred in contrast to relying on automated stepwise regression with biased selection criteria and overemphasis on overall model fit indices (Thompson 1995). It is important to note that excluded predictors are not necessarily insignificant in simple regression models (and therefore relevant) but rather, taken together, do not explain additional variance. Since this method increases the chance of Type I errors within final models, despite all predictor variables grounded in theory as relevant for public acceptance of NbS, we interpreted findings also using correlation outputs, expert knowledge of the sites and qualitative survey comments. The risk, nature, and place variables may be considered underlying personal values and related to affective reactions to NbS, whereas attitudes towards NbS are more analytically driven (i.e., arrived at through reasoning) (Homer and Kahle 1988; Jacobs and Buijs 2011; Slovic et al. 2004). Therefore, attitudinal acceptance of NbS may moderate the strength of the risk, nature, and place variables on behavioural intention. We created moderating regression models using the PROCESS macro for SPSS (Hayes 2017) with *attitudinal acceptance* factor scores as moderating variables for all risk, nature, and place variables.

3.3 Results

3.3.1 RQ1. What is the degree of public acceptance within and across the sites?

Standardised mean responses across the sites show a positive perception of the NbS generally in that their implementation is considered “good” ($M_{Catterline}$=0.92/1, SE=.022; $M_{Puruvesi}$=0.93/1, SE=.010; $M_{Spercheios}$=0.86/1, SE=.023). However, there were lower responses for the degree of satisfaction with how the measures are being implemented ($M_{Catterline}$=0.75/1, SE=.027; $M_{Puruvesi}$=0.79/1, SE=.016; $M_{Spercheios}$=0.66/1, SE=.025) and their perceived effectiveness ($M_{Catterline}$=0.71/1, SE=.024; $M_{Puruvesi}$=0.56/1, SE=.024; $M_{Spercheios}$=0.72/1, SE=.023) (Figure 3-4).

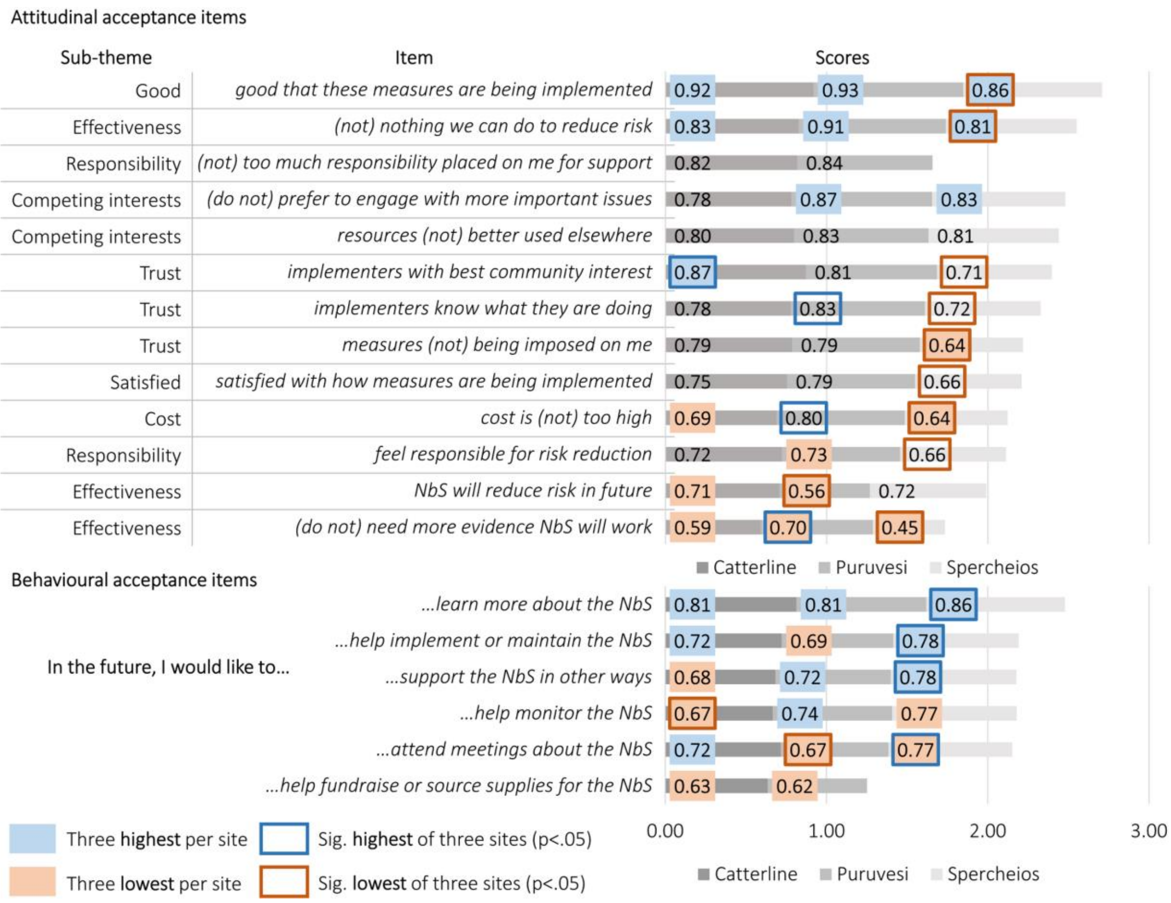


Figure 3-4 Standardised average responses for survey items that represent *attitudinal acceptance* and *behavioural acceptance* in the three study sites. Response averages are standardised by dividing by the maximum Likert response (9 for Catterline and Spercheios and 7 for Puruvesi), so that 1 is the new maximum value and 0 the minimum. Attitudinal and behavioural items are ordered from top to bottom by highest sum of the average responses across the sites. The top three highest average responses for each site for each form of acceptance are highlighted in blue and the three lowest highlighted in red. Using Mann-Whitney *U* tests, the items that are significantly higher in one site compared to each of the other two sites (*p*<.05) are outlined in blue and those significantly lower in red. The third *attitudinal acceptance* item from the top regarding responsibility and the last *behavioural acceptance* item were excluded from surveys conducted in Spercheios since they were not applicable.

Spercheios stands out as a unique study site among the three regarding acceptance, with nine *attitudinal acceptance* items significantly lower than the other two sites and four *behavioural acceptance* items significantly higher than the other two sites (Mann-Whitney *U* $p<.05$). There is generally greater scepticism surrounding the measures and implementers in Spercheios but more willingness to actively support them. The discrepancy in acceptance values in Spercheios demonstrates the important distinction between the two forms of acceptance.

Greater scepticism in Spercheios is likely in part due to past failed flood protection measures in the region and a mistrust of authorities (Georghiou 1996). This may play a role in the perceived importance of cost as well – a significantly stronger potential limiting variable for acceptance among residents of Spercheios (M = 0.64/1, SE=.026; Mann-Whitney *U* p<.05) and significantly less of a barrier to acceptance in Puruvesi (M = 0.80/1, SE=.017; Mann-Whitney *U* p<.05). Two items related to effectiveness, *"NbS will reduce risk in the future"* and *"(do not) need more evidence NbS will work"*, have the two lowest average standardised scores across the sites. The other item related to effectiveness describes fatalist or agentic views of the risk, *"risk can be reduced"*, and had the second highest average scores summed across the sites. This indicates that the scepticism regarding effectiveness of risk reduction originates from the specific nature-based solutions rather than from a sense of hopelessness or inevitability.

In both Catterline and Spercheios, there were also a high number of mid-point responses on the Likert item regarding satisfaction in implementation (Catterline n=14; Spercheios n=14) and items related to trust, particularly "*implementers know what they are doing*" (Catterline n=20; Spercheios n=23). This most likely represents either a lack of information and/or a "wait and see" mind-set, since all NbS were in the pre-implementation phase when the surveys were completed. This mind-set has been prominent in past community outreach activities in Catterline. Items for *behavioural acceptance* show high public demand for both more passive and active forms of engagement with the NbS project. Full descriptive statistics of acceptance items are provided in the appendix (Table. A-8).

3.3.2 RQ2. Attitudinal acceptance

3.3.2.1 What defines attitudinal acceptance?

The composition of *attitudinal acceptance* of NbS in the three case studies is defined using principal axis factoring. Based on factor loadings, three distinct dimensions of attitudes emerge from the data across the sites. Based on the highest loading factors, we named these: *trust in implementers, benefits outweigh costs,* and *good and satisfied* (Table 3-4).

Table 3-4 Rotated structure matrix output (promax) from principal axis factoring to determine latent variables of attitudinal acceptance in each of the three study sites. Items were standardised for direction when necessary so that increasing scores equated to increasing acceptance. All items were first included and iteratively removed one-by-one from the analysis to maximise reliability and percent variance explained within each site. Two dimensions of *attitudinal acceptance* best explain the variance in each site. Only the higher factor loading between each of the two factors (F1 and F2) per item is shown here, since these were used to derive weighted average factor scores for further analyses. For full scale reliability and EFA outputs (initial and final, after iterative item removal) see Table. A-6 in the appendix.

		Catterline		**Puruvesi**		**Spercheios**	
	Analysis *n*	66		181		84	
	Total percent variance explained	62.21		73.85		79.18	
	Cronbach's alpha (α)	.840		.747		.704	
	Lowest corrected item-total correlation (CITC)	.406		.442		.427	
	Lowest communality	.404		.350		.501	
	Factor	**F1**	**F2**	**F1**	**F2**	**F1**	**F2**
	Factor percent variance explained	46.03	16.18	50.53	23.32	53.15	26.04
Theme	**Item**						
Good	*It is good that these measures are being implemented.*	.724					.707
Satisfied	*I am satisfied with how these measures are being implemented.*	.761					.762
Trust	*I believe the people implementing the measures know what they are doing.*	.657			.921	.742	
Trust	*I believe the people implementing the measures are doing so in the best interest of the community.*	.635			.741	.819	
Trust	*I [do not] feel that the measures are being imposed on me.*			.629			
Competing interests	*I believe resources would [not] be better used for other community concerns.*		.686	.909			
Competing interests	*I would [not] prefer to engage with more important community issues than (hazard) risk reduction in (place).*	.608					
Effectiveness	*I [do not] need more evidence that the natural measures will reduce risk of (hazard).*		.725				
Effectiveness	*I believe that when (storms) come in the future, these measures will reduce the chance of (hazard).*	.712					
Cost	*I believe the financial cost of these measures is [not] too great.*		.667	.591			

	Factor 1	**Factor 2**
Catterline	*Good and satisfied*	*Benefits outweigh costs*
Spercheios	*Trust in implementers*	*Good and satisfied*
Puruvesi	*Benefits outweigh costs*	*Trust in implementers*

The factor composition and item loadings are mostly divergent across the sites. It is likely that the unique attributes of each rural NbS site for risk reduction led to differences in the strength of the *attitudinal acceptance* themes and their interrelations. A more comprehensive list of survey items for these themes, and the inclusion of additional themes, may have consistently captured unique dimensions of *attitudinal acceptance*. However, the reasonable percent variance explained (Catterline 62.21%; Puruvesi 73.85%; and Spercheios 79.18%) and the emergence of three unique factors with similarly loading items when considering all three sites suggests that perceptions in relation to *trust in implementers*, *benefits outweigh costs*, and *good and satisfied* with the NbS should be considered when assessing *attitudinal acceptance*.

The first two items related to trust in the implementers were retained together within a factor for all three of the sites. Trust is a particularly large component of acceptance in Spercheios, where the factor composed of these two items explains 53.15% of the variance in attitudes. Different past experiences with flood risk reduction measures and the authorities responsible for them is likely to be crucial here, also supported by the highest standard deviation of scores for these items in Spercheios at SD=0.24 for each (compared to $SD_{Catterline}$ = 0.18; $SD_{Puruvesi}$ = 0.19, 0.21). Results suggest that a) trust towards the implementers of NbS is a unique dimension of acceptance (Spercheios and Puruvesi), and b) trust is a consistently important factor for attitudes towards NbS.

Respondents' views regarding competing societal interests, the cost of the NbS, and whether the NbS are "good" and respondents are "satisfied" with their implementation are each retained in two of the three sites. In Puruvesi, perceptions of whether *benefits outweigh costs* explain just over 50% of the variance in attitudes (factor 1; 50.53%). An item *a priori* linked to trust in implementers ("*measures being imposed on me*") loads with the themes competing interests and cost in Puruvesi (.629), suggesting it is also more related to a cost/benefit judgement of the measures.

Both items designed to capture respondents' sense of responsibility for risk reduction and an item related to an agentic vs. fatalistic view of risk (*a priori* grouped with effectiveness variables; “*risk can be reduced*”) were excluded based on low scores for alpha, CITC, and communality (Table. A-6).

3.3.2.2 What correlates with attitudinal acceptance?

Spearman’s rho (ρ) correlations show consistently moderate significant correlations of most variables in Catterline and Puruvesi and only *risk intolerance* and *commitment to nature* in Spercheios (Table 3-5). We show here only correlations of at least p<.10 to ease interpretation of the findings.

Table 3-5 Spearman’s rho (ρ) correlation coefficients of attitudinal acceptance factors and risk, nature, and place survey variables in the three study sites. Only correlations significant to at least *p*<.10 are shown.

	Good and satisfied		***Benefits outweigh costs***		***Trust in implementers***	
	Catterline	Spercheios	Catterline	Puruvesi	Spercheios	Puruvesi
Risk						
Risk perception	.345***			.340***		.304***
Risk intolerance	.261**	.426***		.193***	.257**	.125*
Past impacts (sum)	.401***			.142*		
Future impacts (sum)	.489***			.212***		.178**
Nature						
Commitment to nature	.319***	.231**	.229*	.518***	.207*	.301***
Responsibility for nature	.308**			.324***		.179**
Place						
Connectedness to place	.425***			.225***		.240***

$^{*}p$<.10, $^{**}p$<.05, $^{***}p$<.01

Commitment to nature is a significant correlate across all three *attitudinal acceptance* factors and sites. It is particularly associated with respondents’ perception of benefits versus costs in Puruvesi (ρ=.518, p<.01), as is *responsibility for nature* (ρ=.324, p<.01). This is unsurprising since the hazard of eutrophication is itself a degradation of the natural environment. However, the correlation of ρ=.340 (p<.01) with *risk perception* also indicates the intersection between risk and nature in relation to acceptance at the site.

Risk intolerance is also consistently significant and the strongest correlate of any risk, nature, and place variable for Spercheios, associated there with the factor *good and satisfied* at ρ=.426 (p<.01). Puruvesi likely has the most significant correlates due to the larger sample size, serving as an important reminder to triangulate correlation results with other statistical outputs as well as expert knowledge and survey comments.

Testing demographic categorical variables of age and gender using simple linear regression, we found that in Puruvesi, gender and age are predictive of positive attitudes in terms of *benefits outweigh costs* ($F(1,181)=5.75$, $p=.018$; $R^2=.031$; $\beta=.192$, $p=.018$) and gender is also predictive of *trust in implementers* ($F(1,181)=6.46$, $p=.012$; $R^2=.035$; $\beta=.186$, $p=.012$). There, female respondents have significantly more positive attitudes toward the NbS for *benefits outweigh costs* and for *trust in implementers* (Mann-Whitney U $p<.05$) and increasing age predicts increasing positive attitudes of *benefits outweigh costs* ($F(1,181)=6.39$, $p=.012$; $R^2=.034$; $\beta=.185$, $p=.012$).

3.3.3 RQ3. Behavioural acceptance

3.3.3.1 What defines behavioural acceptance?

Based on principal axis factoring, a single factor captures most of the variance in *behavioural acceptance* with high internal reliability in all three sites (Catterline: 75.83% variance explained, Cronbach's $\alpha=.933$; Puruvesi: 66.29%, $\alpha=.898$; Spercheios: 63.81%, $\alpha=.856$). We therefore retained all items and calculated weighted factor scores for further analyses of a single *behavioural acceptance* variable for each site (Table. A-7).

3.3.3.2 What risk, nature, and place survey variables correlate with and predict behavioural acceptance?

Both the *attitudinal acceptance* factors and risk, nature, and place variables are consistently and significantly correlated with behavioural intention across the sites. The attitudinal factor *good and satisfied* has the second strongest correlation of any variable in Catterline ($\rho=.492$, $p<.01$) and the attitudinal factor *trust in the implementers* has the strongest correlation in Spercheios ($\rho=.369$, $p<.01$) (Table 3-6).

Table 3-6 Spearman's rho (ρ) correlation coefficients of attitudinal acceptance factors and risk, nature, and place survey variables with *behavioural acceptance* in the three study sites. Only correlations significant to at least *p*<.10 are shown here. N/A (not applicable) is used when the factor did not define *attitudinal acceptance* in that site.

	Behavioural acceptance		
	Catterline	Puruvesi	Spercheios
Attitudinal acceptance			
Good and satisfied	.492***	N/A	.297***
Benefits outweigh costs		.327***	N/A
Trust in implementers	N/A	.223***	.369***
Risk			
Risk perception	.436***	.276***	.252**
Risk intolerance		.254***	.264**
Past impacts (sum)		.319***	.354***
Future impacts (sum)	.510***	.385***	.286***
Nature			
Commitment to nature	.324***	.395***	
Responsibility for nature	.396***	.410***	.219**
Place			
Connectedness to place	.465***	.284***	.330***

*p<.10, **p<.05, ***p<.01

Although both *risk perception* and *future impacts* are significant correlates across the three sites, the latter is more strongly correlated (Catterline ρ=.510, p<.01; Puruvesi ρ=.385, p<.01; Spercheios ρ=.286, p<.01). This is in line with past risk perception research showing that perceived consequences are more associated with mitigative or adaptive behaviour than hazard characteristics (Bubeck et al. 2012a; Sjöberg 1999).

In Catterline and Puruvesi, respectively, *behavioural acceptance* (like *attitudinal acceptance*) is shown to be associated with respondents' *commitment to nature* (ρ=.324, p<.01; ρ=.395, p<.01) and *responsibility for nature* (ρ=.396, p<.01; ρ=.410, p<.01). Landslides in Catterline and eutrophication in Puruvesi are both seen as threats to the ecosystem, in contrast to Spercheios where, despite also being an area of high scenic beauty, the impacts of flooding and drought are felt more in relation to the social system. These results suggest that perceptions of risk *to* nature from the hazards is worth considering for acceptance, in addition to the appreciation of ecosystem services from the NbS.

Connectedness to place is significant across the three sites and particularly strong for Catterline (ρ=.465, p<.01**)**. A related item on the surveys in Catterline, *"landslides are a threat to our history and culture"*, is also strongly correlated with *behavioural acceptance* at ρ=.480 (p<.01). In regression models using *attitudinal acceptance* factors and risk, nature, and place variables, *connectedness to place* is one of only three variables retained in two of the sites (along with *good and satisfied* and *past impacts*) (Table 3-7). It is not retained in the Catterline model despite its strong correlation, likely due to also having strong correlations with the remaining predictors (ρ=.435, p<.01 with *good and satisfied* and ρ=.443 , p<.01 with *risk perception*). The models explain 27.7% (Catterline), 31.7% (Puruvesi), and 37.7% (Spercheios) of the variance in *behavioural acceptance* in each of the three sites and all three models are significant at p<.01 (Catterline $F(2,65)=12.09$, p=.000; R^2=.277; Puruvesi $F(5,180)=16.22$, p=.000; R^2=.317; Spercheios $F(4,82)=11.76$, p=.000; R^2=.377).

Table 3-7 Multiple linear regression model results using attitudinal factor scores and risk, nature, and place variables as initial independent variables and *behavioural acceptance* scores as the dependent variable in each study site. Variables are removed from the model in a step-wise manner in order of least significant *beta* per model, until only *beta* (β) coefficients at *p*<.05 remain.

Model	Predictors	β	R^2	Adj. R^2	*F*	df	DW
Catterline			.277	.254	12.09***	65	1.85
	Risk perception	.382***					
	Good and satisfied	.256**					
Puruvesi			.317	.297	16.22***	180	1.92
	Responsibility for nature	.211***					
	Benefits over costs	.208***					
	Future impacts (sum)	.173**					
	Past impacts (sum)	.162**					
	Connectedness to place	.144**					
Spercheios			.377	.345	11.76***	82	1.71
	Connectedness to place	.297***					
	Past impacts (sum)	.287***					
	Trust in implementers	.263***					
	Good and satisfied	.241**					

**p<.05, ***p<.01

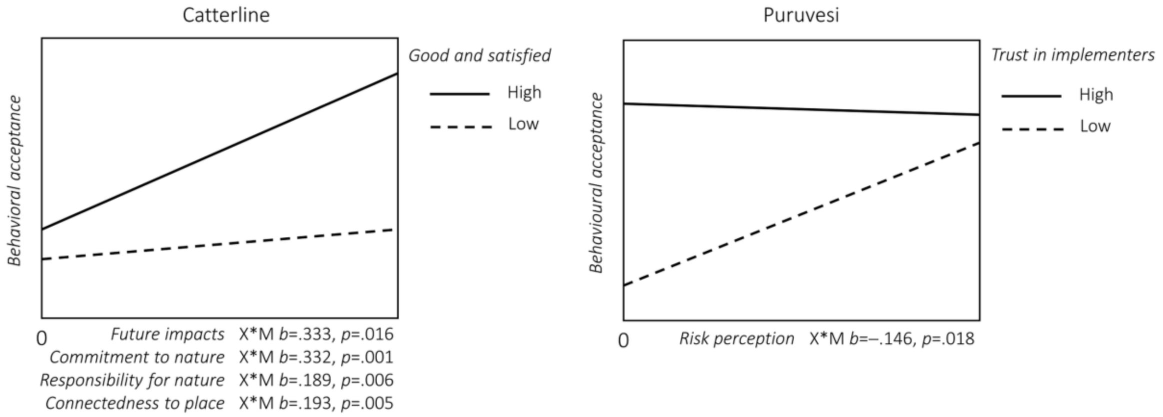
Risk perception is the strongest predictor of *behavioural acceptance* for any of the sites, at β=.382 (p<.01) in Catterline. In Puruvesi, items related to all three themes of risk, nature and place are significant predictors, as well as the attitudinal factor *benefits over costs*. There, experience of *past impacts* as well as the perceived potential for *future impacts* are unique significant predictors (β=.162, p<.05; β=.173, p<.05). In Spercheios, attitudes emerge as being particularly important for predicting *behavioural acceptance* (*trust in implementers* β=.263, p<.01; *good and satisfied* β=.241, p<.05), along with *past impacts* (β=.287, p<.01) and *connectedness to place* (β=.297, p<.01). This finding for Spercheios suggests that strategies aimed at increasing positive attitudes towards the NbS may translate into increased public engagement. Appealing to public pride in place is warranted, a theme returned to in the discussion.

Also noteworthy is the absence of *risk intolerance* from any of the models. Its lack of explanatory ability beyond *risk perception* and impact scales may be in part due to low variation of skewed right responses for its items (generally risk of listed impacts was not at all tolerated by respondents; see Table. A-9 for descriptive statistics of risk, nature, and place variables). Using simple linear regression, we found that neither age nor gender is a significant predictor of *behavioural acceptance* in the sites.

3.3.3.2.1 Do attitudes towards NbS act as moderating variables?

We assessed attitudes as moderating the influence of risk, nature, and place variables on *behavioural acceptance* in each site. After testing for moderation effects of the two attitudinal factors per site, we found one significantly moderating variable ($p<.05$) in Catterline (*good and satisfied*) and one in Puruvesi (*trust in implementers*) (Figure 3-5). In Catterline, the factor *good and satisfied* moderates variables related to all three themes of risk, nature and place - *future impacts*, *commitment to nature*, *responsibility to nature* and *connectedness to place*. As "*good and satisfied*" attitudes towards the NbS increase, each of these variables are significantly more predictive of behaviour (full output in Table. A-10). This suggests that strategies for increasing behavioural acceptance based on the public's perception of future impacts and relation with nature and place may only be successful if they are also able to improve these attitudes towards the NbS.

A)



B)

Model	Predictor	Moderating attitudinal factor	R^2	*F*	P	df1	df2
Catterline_1	*Future Impacts*	*good and satisfied*	.294	8.61	.000	3	62
Catterline_2	*Commitment to nature*	*good and satisfied*	.343	10.80	.000	3	62
Catterline_3	*Responsibility for nature*	*good and satisfied*	.258	6.97	.000	3	60
Catterline_4	*Connectedness to place*	*good and satisfied*	.277	7.92	000	3	62
Puruvesi_1	*Risk perception*	*trust in implementers*	.126	8.58	.000	3	179

Figure 3-5 Schematic representations of moderation models in Catterline and Puruvesi. Statistically significant (*p*<.05) moderating attitudinal acceptance factors in Catterline and Puruvesi (A) and model statistics (B). These factors (M) moderate relations between the risk, nature, and place predictor survey variables (X) and *behavioural acceptance*. For example, in Puruvesi there is a significant positive relation between *risk perception* and *behavioural acceptance*, but this relation is significantly stronger when respondents' scores on the attitudinal factors *trust in implementers* is low. These are schematic representations of relations - further statistical output and graphs are provided in Table. A-10 in the appendix.

In Puruvesi, the attitudinal factor *trust in implementers* significantly reduces the effect of *risk perception* on *behavioural acceptance* (F(3,179)=8.58, *p*=.000; R^2=.126; X*M *b*=-.146, *p*=.018). Significant relations between risk perception and public trust are well-established, albeit contextual (Siegrist et al. 2005; Siegrist 2019; Slovic 1999; Viklund 2003), but less so as interacting variables for risk management demand and corresponding behaviour (Bronfman et al. 2008). One explanation for our finding is that residents who do not perceive the implementing authorities as capable of risk reduction (low trust) are more motivated by perceived risk and a desire to reduce it through engagement with the NbS. This is supported by many survey comments suggesting alternative measures to reduce eutrophication, including: reducing variation in water level, implementing and monitoring wastewater regulation, banning fertilizers, and supporting beaver dams (see full survey comments in Table. A-11). The finding suggests that risk framing will not increase acceptance of NbS without parallel gains in trust – both in the implementers and (confidence) in the effectiveness of the NbS (the item *“NbS will reduce risk in the future”* received the lowest standardised average response score in Puruvesi of all *attitudinal acceptance* items at 0.56/1; Figure 3-4).

3.3.3.3 What other survey variables predict behavioural acceptance?

As expected, when considering all survey variables the regression models increase in explanatory power. An item to assess the perceived social norm of risk intolerance – *“other residents believe risk must be reduced”* - in Spercheios emerges as the strongest predictor for any site at β=.487 (p<.01) (Table 3-8).

Table 3-8 Multiple linear regression model results using all survey variables as initial independent variables and *behavioural acceptance* scores as the dependent variable in each study site. Results (A) and standardised *beta* (β) coefficients (B) using all attitudinal acceptance and risk, nature, and place survey variables as independent variables and *behavioural acceptance* scores as the dependent variable in each study site.

(A)

Model	R^2	Adj. R^2	*F*	df	DW
Catterline	.519	.475	11.86***	48	1.98
Puruvesi	.411	.390	20.33***	181	1.94
Spercheios	.467	.453	33.764***	79	1.57

(B)

Model	Theme	Predictors	β
Catterline			
	Acceptance	*Past acceptance (sum of past actions)*	.363***
	Place	*Connectedness to place*	.281**
	Risk	*Future impacts (sum)*	.267**
	Risk	*“landslides a threat to history and culture”*	.251**
Puruvesi			
	Cost	*“financial cost too great”*	-.235***
	Connectedness to place / Dependence	*“enjoy spending my free time at Puruvesi”*	.209***
	Nature	*Commitment to nature*	.189***
	Responsibility	*“feel responsible for risk reduction”*	.177***
	Risk	*Future impacts (sum)*	.168**
	Risk	*Past impacts (sum)*	.151**
Spercheios			
	Risk intolerance (social norm)	*“other residents believe risk must be reduced”*	.581***
	Connectedness to place/Identity	*“sense of who I am tied to Spercheios”*	.275***

*p<.10, **p<.05, ***p<.01

Considering all survey variables as independent variables, multiple regression models explain 51.9% (Catterline), 41.1% (Puruvesi), and 46.7% (Spercheios) of the variance in *behavioural acceptance* in each of the three sites and all three models are significant at $p<.01$ (Catterline $F(4,48)=11.86$, $p=.000$; $R^2=.519$; Puruvesi $F(6,181)=20.33$, $p=.000$; $R^2=.411$; Spercheios $F(2,79)=33.76$, $p=.000$; $R^2=.467$).

Both *connectedness to place* ($\beta=.281$, $p<.05$) and *threat to history and culture* ($\beta=.251$, $p<.05$) are significant predictors in Catterline. This supports prior findings of individuals' relation to place for acceptance of NbS approaches (Bihari and Ryan 2012; Brink and Wamsler 2019; Buijs 2009; Roca and Villares 2012) while also demonstrating that behavioural acceptance can be uniquely motivated by both a connection to place and perceived threat to that connection.

In Catterline, past supportive behaviour of NbS was the strongest predictor of intention to support the measures ($\beta=.363$, $p<.01$). This indicates that targeting residents who have already engaged will likely see the greatest uptake. Perhaps more importantly, having residents actively support the measures in some way may lead to further engagement and foster a sense of responsibility for risk reduction (this had a correlation of $\rho=.445$, $p<.01$ with behaviour).

The importance of perceived cost for *attitudinal acceptance* in Puruvesi was highlighted as also important for *behavioural acceptance* ($\beta=-.235$, $p<.01$), along with *past* and *future impacts* ($\beta=.151$, $p<.05$; $\beta=.168$, $p<.05$).

3.4 Discussion

Shared findings across the sites lead to three key recommendations to increase public acceptance of rural, project based NbS for risk reduction. The recommendations, along with corresponding relevant findings, are first listed below. Strategies and site-specific results related to the key themes are then provided in more detail.

1) Demonstrating the effectiveness of NbS for risk reduction should be prioritised and linked to building trust.

There is scepticism among the public regarding the effectiveness of NbS. *Trust in implementers* is consistently an important factor for defining attitudes towards NbS and there is a high public willingness to actively engage.

2) The public's sense of place, despite being highly context-dependent, should be considered within NbS projects for their successful uptake.

Public *connectedness to place* is tied to the importance of the beauty, reputation, history, and culture of the sites and is related to *behavioural acceptance*.

3) In line with the benefits provided by NbS, both perceptions of risk and nature, as well as their interactions, are important for acceptance.

Perceptions of nature are consistently associated with *attitudinal* and *behavioural acceptance* across the sites. Perceived risk and particularly the threat of multiple *future impacts* is an important predictor of *behavioural acceptance*.

Commonalities across the sites suggest that these general recommendations are warranted, while site-specific findings must also be considered for acceptance within the OPERANDUM project and taken up in similar contexts (Figure 3-6).

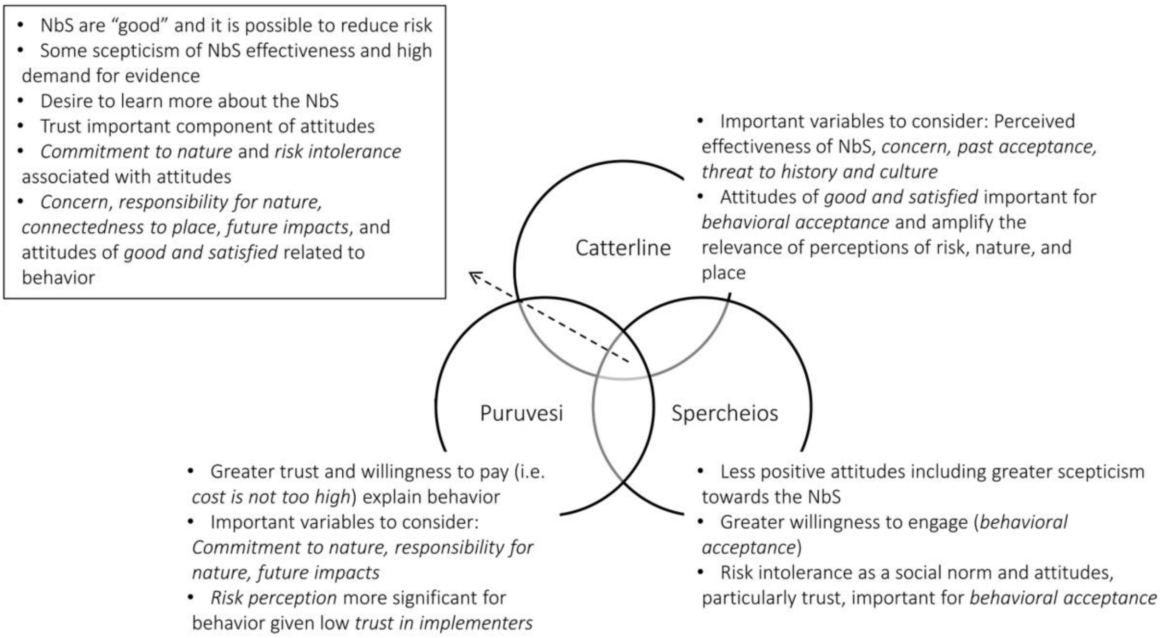


Figure 3-6 Venn diagram of main findings shared across the study sites and specific findings within each site.

3.4.1 Key themes and recommendations for increasing public acceptance

3.4.1.1 Effectiveness of NbS and trust in implementers for public acceptance

We found high public demand for evidence of NbS effectiveness for risk reduction. While most respondents believe risk can be reduced and the NbS will have reasonable success, a range of attitudes between cautious optimism and outright scepticism were expressed. Results suggest that the surveys were conducted at a crucial time in the project lifespan in which most residents have cautious positive perceptions. This presents an opportunity to improve acceptance but also a risk of not fulfilling expectations.

Scepticism of NbS effectiveness is likely to be related to both NbS characteristics and broader context. Potential drivers of hesitant attitudes regarding effectiveness include the complexity and novelty of NbS (Schernewski et al.

2017; Seddon et al. 2020), their effects often being less visible to the public (e.g., rainwater absorption in Catterline and Puruvesi) (Duan et al. 2018; Miller and Montalto 2019), and their duration in implementation with a time lag for effectiveness (e.g., dependence on plant growth) (Anderson and Renaud 2021; Kabisch et al. 2016; Shah et al. 2020). Contextual characteristics such as the history of hazard events in the area, climate change and increasing impacts despite the measures, and zero-risk bias mean that managing NbS expectations is crucial. Therefore, adapting to, rather than solely mitigating, risk should be a priority of NbS projects and clearly communicated to the public.

Ongoing efforts at collecting evidence of NbS effectiveness are well-positioned to increase public acceptance (Chausson et al. 2020; Davis and Naumann 2017; Faivre et al. 2018). However, perhaps the most powerful way to provide such evidence is through participatory citizen science initiatives in which residents can see for themselves the positive results of the NbS (Holstead et al. 2017) – not just risk reduction but also, e.g., biodiversity gains (Davenport et al. 2010; Pueyo-Ros et al. 2019). Findings show a very high willingness to actively engage in the NbS projects. Resources should be devoted to capacity building and involvement in implementation and monitoring, where appropriate. There is a discrepancy in public willingness to engage and the ability of relevant projects to capitalise on this, particularly for monitoring (Doswald et al. 2014; Puskás et al. 2021).

Although the evidence base for NbS is increasing, there is still substantial work to be done in this regard (Chausson et al. 2020; Davis and Naumann 2017; Doswald et al. 2014; Kabisch et al. 2016). Until NbS are well-established and there exists ample evidence of their contextual effectiveness, *trust in implementers* as a consistent attitudinal determinant of acceptance will be even more heavily relied on and must be maintained and/or strengthened (Howgate and Kenyon 2009). Trust-building should be a continuous priority, since it can be hard to gain but easy to lose in contexts of risk (Slovic 1999).

3.4.1.2 Connectedness to place for public acceptance

In Puruvesi, the strong connectedness to place and the many comments regarding the importance of the reputation of Puruvesi are linked to the NbS and can be leveraged for improving acceptance (Table. A-11). As one resident wrote, *“If eutrophication is not controlled, Puruvesi's reputation as Finland's cleanest lake may have been lost. People may also lose hope that eutrophication could be brought under control and stop doing their part for control measures”* (P140). Past research suggests that if NbS are able to enhance highly-valued local natural features, they are more likely to attain public support (Brink and Wamsler 2019; Schmidt et al. 2014). Conveying the importance of the NbS work, not only for improving lake quality but also for the sake of Puruvesi in its context as a highly respected Finnish lake, could be well-received by the public. This act of both localising the issue and zooming out to the wider implications of NbS efforts will likely be more relevant and motivating for the residents (Bihari and Ryan 2012; Buijs 2009; Goeldner-Gianella et al. 2015; Groot and Groot 2009). Connecting Puruvesi’s reputation with eutrophication and its impacts, it may be possible to appeal to the public’s pride in- and sense of responsibility for- the natural area.

Connectedness to place was also strongly associated with behaviour in Catterline. A related variable, *“perceived threat to history and culture”* was strongly correlated with *behavioural acceptance* and also with the general risk intolerance item of *“risk must be reduced”* (ρ=.566, p<.05). This is in line with Buijs (2009), who found that a threat to the perceived historical and cultural setting diminished support for NbS in the context of river restoration. Emphasizing landslides as a threat to place and community, as defined by cultural elements and practices, will likely resonate with residents. For example, amplifying the voices of long-time residents of Catterline in the form of narrative histories of landslide risk in relation to culture could increase knowledge on the issue and promote its position as a communal threat. Crucially, any such efforts must causally link the NbS as an effective actionable solution to the threat to avoid promoting a sense of despair or inevitability (O'Neill and Nicholson-Cole 2009).

Also in Spercheios, *connectedness to place* was related to acceptance, likely due to regional pride and rural identity. Providing tangible economic benefits in the form of increased tourism or otherwise may improve acceptance of the NbS (Davenport et al. 2010; Kenyon 2007; Roca and Villares 2012). However, this must be approached carefully since not everyone benefits from tourism and a sense of inequity of benefits could be fostered, reducing acceptance (Beery 2018; Otto et al. 2018).

The strongest correlate of *behavioural acceptance* in Spercheios was the item "*other residents believe risk must be reduced*". The perceived social norm of risk reduction is linked to both place and responsibility. Further research should aim at determining whether this is more a function of a moral norm (i.e., "we should act") or a social dilemma (i.e., "I won't act unless others do"), although survey results point more strongly to the former. This finding suggests that strategies for increasing acceptance may be successful by demonstrating that other residents are a) concerned about natural hazard risk and b) supporting the NbS work as a result. Testimonials, for example of well-respected and long-standing community members affected by flooding who support the NbS, could be trialled along with publicizing strong attendance at NbS-related activities. Also, pictures of engaged community members or "engagement days" in which locals come out to support the NbS together could be piloted.

3.4.1.3 Perceptions of risk and nature for public acceptance

The consistent significant relations between nature-related variables and acceptance reflect the importance of NbS co-benefits and how these measures are framed to the public, i.e., as more than just interventions to reduce risk. One quotation from Catterline captures the recognition of NbS as multi-functional, but primarily intended for risk reduction: *"I think if the measures are as natural as possible this is best for [the] environment and residents. If [they were] manmade prevention methods, I'd be less inclined to support them unless guaranteed benefits"* (C9). Anecdotal evidence from the site also points towards peaks in public engagement in the aftermath of landslides that wanes over time, underscoring temporal fluctuations in the salience of risk and impacts in relation to engagement.

The importance of perceived cost for *attitudinal acceptance* in Puruvesi was highlighted as also important for *behavioural acceptance*, together with the number of *past*- and *future impacts* experienced by respondents. Many comments from respondents in Puruvesi reflect varying degrees of perceived severity of the issue of eutrophication (Table. A-11), for example: *"...Is there now a fuss about something that can be influenced, when in reality the effect is non-existent?"* (P96); *"Blue-green algal blooms occur in small and predictable areas"* (P193); *"There have hardly been any of them at my cottage beach"* (P205). In this case it seems that the unequal spatial distribution and ephemerality of impacts play an important role in determining whether residents believe the ongoing NbS efforts against eutrophication are worth the resources invested. This is supported by an item for general risk intolerance – *risk must be reduced* – showing a correlation of $\rho=.327$ ($p<.01$) with the factor *benefits outweigh costs* in Puruvesi. The relatively invisible causal mechanisms behind eutrophication (e.g., rainwater runoff vs. infiltration), may exacerbate this effect. Past research on infrequent hazards and climate change also shows that when threats are perceived as distant in space and time there is less willingness to take action against them (Brink and Wamsler 2019; Everett et al. 2018; Rambonilaza et al. 2016).

The importance of proving the effectiveness of NbS (Chausson et al. 2020; Miller and Montalto 2019), as well as its cost-effectiveness (Davis and Naumann 2017; Faivre et al. 2017; Reguero et al. 2018), is reiterated here. Strategies to demonstrate the negative effects of eutrophication to a greater public than those who are affected by any one algal bloom event are worth considering. Water clarity is a simple and easily relatable indicator of water quality and therefore may be useful for developing persuasive and memorable communication material. It also ties into the importance of the reputation of Puruvesi in Finland as a benchmark for water quality and the strong connectedness to place.

Perceptions of risk are motivators for acceptance and the primary NbS aim of risk reduction should not be detracted from, despite co-benefits being potential additional motivators for NbS acceptance. Nevertheless, natural co-benefits of the NbS are important for increasing acceptance among the wider community and for outreach to residents who may benefit less from risk reduction.

3.4.1.4 Limitations and future outlook

Our survey variables reflect the characteristic of this study as interdisciplinary and exploratory. Many of the variables most strongly related to acceptance are in line with Protection Motivation Theory (Rogers 1975), while the importance of social norms for risk reduction in Spercheios, for example, supports more thorough inclusion of variables and testing also for the Theory of Planned Behaviour (Ajzen 1991). Further research should systematically test these theories and others (Kuhlicke et al. 2020) including well-established variables such as self-efficacy for public acceptance of NbS, while also incorporating our findings regarding the importance of nature and place-based perceptions. Although the *behavioural acceptance* scale was highly reliable in all sites (high validity as well since significantly more high acceptance respondents provided contact information; Mann-Whitney *U* $p<.05$), research is also needed to advance the scale(s) for assessing attitudinal acceptance of NbS.

Other variables, such as awareness and understanding of the measures, although found to be important for public perception of NbS in recent literature reviews (Anderson and Renaud 2021; Han and Kuhlicke 2019), were excluded from this research. The surveys were self-administered, and we aimed to prevent respondents from feeling ‘tested’ on their knowledge. The OPERANDUM project was ongoing at the time of the surveys and these were carefully designed to not detract from public acceptance by eroding trust or creating stakeholder fatigue. Since our study sites were rural, exposed to hydro-meteorological risk, and the projects externally led, the variables may not apply to other NbS contexts and should be further tested where appropriate. It is possible that *connectedness to place* is more associated with acceptance where deeply rooted rural identities are prevalent (indeed, segmenting Spercheios data supports this hypothesis) (Buijs 2009). Beyond the internal variables we tested for, research should continue to support the success of NbS through a deeper understanding of the wide range of external considerations (e.g., financial and governmental) (Nesshöver et al. 2017; Seddon et al. 2020; Wamsler et al. 2019), as well as social contexts and issues of practicality that can also determine engagement (Blake 1999). Future public perceptions of NbS depend on their overall success.

We recognise the limitations of our non-randomized single point sampling approach. Additionally, the response rate for Puruvesi was quite low at 10.3%. It is likely that these results show higher acceptance than the population, given that the motivation to complete the survey may represent a certain level of acceptance. However, opposition is also a powerful motivator and it may be that polarized views were over represented, since the written-in comments on the surveys also expressed complaints about the NbS work. The broad range of comments and Likert responses bolsters confidence in the surveys having captured more than a specific subsection of the population. Our findings provide baseline evidence for developing strategies to increase public acceptance of NbS. However, all such efforts should first be piloted and segment the public as much as possible. Further segmentation of results presented here are not reported due to space constraints (see Appendix section A.4.1). Our use of multiple statistical tests combined with expert knowledge and survey comments increases confidence in the interpretation and recommendations. However, questions around contextual objectives such as “Should we aim to improve the most negative attitudes towards NbS?” or “Do we need to ensure at least limited public collaboration?” are crucial considerations for further actionable research.

Experiments to test the effects of risk, nature and place framings on acceptance, for example, would help establish causal, rather than just correlate, relations and advance the field (Kuhlicke et al. 2020). Moreover, these designs could overcome the current limitation of assessing behavioural intention rather than actual engagement (Sheeran 2002). The importance of perceptions of nature and benefits versus costs supports the systematic study of perceived ecosystem services of NbS and their relation to public acceptance, including the primary aim of risk reduction (Doswald et al. 2014; Kabisch et al. 2016). Follow-up research to examine these interactions more closely is currently being carried out by the lead authors.

3.5 Conclusions

Understanding what drives public acceptance of NbS for risk reduction is essential for the success of NbS projects and a first step towards their continued uptake in Europe and beyond. Additionally, public outreach should frame NbS not based on what is assumed to be important to public stakeholders, but rather what is evidenced as being highly valued. Our findings support the importance of perceptions of nature and place in contexts of NbS, along with effective risk reduction.

Despite current support, actively investing in campaigns to improve attitudes and behaviour towards NbS rather than assuming continued public acceptance is crucial. Providing benefits through effective NbS is essential, but the burden of proof through evidence is a subsequent hurdle, particularly in the context of increasing risk due to climate change. Our findings not only have immediate practical implications for stakeholder engagement within OPERANDUM study sites but also broader lessons for European and global NbS

Chapter 4 Green, hybrid, or grey disaster risk reduction measures: What shapes public preferences for nature-based solutions?

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Abstract:

Nature-based solutions (NbS) contrast with grey infrastructure measures to reduce risk from natural hazards. Using natural and sustainable measures (green) or combining green with grey elements (hybrid) can provide important co-benefits beyond risk reduction. Thanks to their co-benefits and flexibility across a range of possible climate change futures, NbS are sometimes referred to as ‘win-win’ or ‘no-regret’ measures. The success of NbS and associated projects often relies on the public for co-creation, co-implementation, and long-term sustainable use, monitoring, and management. However, the relative importance of NbS benefits is defined by the perceptions and underlying values of stakeholders with potentially divergent interests.

It is unclear what measures at-risk individuals may prefer on the green-hybrid-grey spectrum and what shapes their preferences, including perceived benefits and potential regret. Identifying public (mis)perceptions, expectations, objectives, and what underlies these can inform communication and project framing, engagement, and ultimately increase public acceptance and continued uptake of NbS. We use citizen surveys at three distinct European sites where NbS are being planned and in-depth focus groups as a follow-up in the site at risk of landslides (Catterline, Scotland). Preferences and their drivers for measures on the green-hybrid-grey spectrum are assessed, focusing on public perceptions of NbS effectiveness, risk, and nature.

We find that although wildlife habitat and aesthetics as co-benefits are important, reducing risk is of primary concern. Uncertainty in the strength and effectiveness of NbS, as one of 13 qualitative factors we identify, drives public preferences towards hybrid measures - seen as balancing green and grey trade-offs. Misperceptions and a demand for NbS information should be addressed with experiential learning, combined with transparent two-way communication of expectations. We urge caution and further research regarding emphasizing co-benefits and the ‘natural’ framing of NbS when risk reduction is the primary public objective.

Keywords: Nature-based solutions (NbS); public acceptance; public perception; stakeholder engagement; hydro-meteorological hazards; disaster risk reduction

4.1 Introduction

Despite the increased use of nature-based solutions (NbS) to reduce risk from natural hazards, there remains barriers to its continued uptake (Kabisch et al. 2016; Seddon et al. 2020; Thorne et al. 2018). Along with governmental, financial, and technical issues, another barrier is the mixed and scarce evidence for the effectiveness of NbS at reducing risk in different contexts when compared to traditional ‘grey’ infrastructure (Chausson et al. 2020; Depietri and McPhearson 2017; Sudmeier-Rieux et al. 2021; Sutton-Grier et al. 2015). NbS must be designed with a greater consideration of surrounding (and embedded) social-ecological systems, the associated diversity and complexity makes a standardised approach to their design and implementation, along with evidence-basing, more difficult (Papathoma-Koehle and Glade 2013; Sudmeier-Rieux et al. 2021). Many ongoing projects aim to address this issue, and there is a rapidly growing body of knowledge and evidence for the effectiveness of NbS across European risk contexts (Chausson et al. 2020; Dushkova and Haase 2020; Faivre et al. 2017; Faivre et al. 2018; Sudmeier-Rieux et al. 2021). In addition to satisfying researchers, engineers, and risk managers, a greater reliance on public ‘host communities’ of NbS for their co-design, implementation, monitoring, and long-term protection means public perceptions and degrees of *acceptance* (Anderson and Renaud 2021) are crucial for their success (Anderson et al. 2021; Giordano et al. 2020; Seddon et al. 2021; Triyanti et al. 2017; Wamsler et al. 2019).

NbS is considered an umbrella concept for many approaches to addressing societal issues using nature (Cohen-Shacham et al. 2016). We focus on NbS with the primary intended function of disaster risk reduction (DRR) from natural hazards, most closely aligned with the concepts of ecosystem-based disaster risk reduction (Eco-DRR) and ecosystem-based adaptation (to climate change; EbA). NbS are often contrasted with traditional ‘grey’ infrastructure measures such as dams or dikes (Gray et al. 2017; Onuma and Tsuge 2018; Poratelli et al. 2020). However, the breadth of concepts under the NbS umbrella includes ‘hybrid’ measures or approaches; i.e., those that use a combination of green and grey (natural and non-natural) elements and offer related co-benefits (e.g., sea walls that are designed synergistically with ecosystem restoration and/or provide wildlife habitat) (Depietri and McPhearson 2017; Naylor et al. 2017; Sutton-Grier et al. 2015; Turkelboom et al. 2021). Here, we use ‘green’ as synonymous with ‘NbS’ and refer to a spectrum of green-hybrid-grey measures (that can be *greener* or *greyer*) (Choi et al. 2021; Davies et al. 2006; Davies and Lafortezza 2019; Raymond et al. 2017).

From this perspective, and with contextual variation, potential negative characteristics of greener measures have been identified as: greater time lag for effective risk reduction (Kabisch et al. 2016; Shah et al. 2020; Verbrugge et al. 2017), more uncertainty regarding place-based DRR effectiveness (Cheong et al. 2013; Onuma and Tsuge 2018), and greater reliance on a broader range of stakeholders (Bark et al. 2021; Nesshöver et al. 2017; Schernewski et al. 2017). Potential positive characteristics have been identified as: lower cost or more cost-effective (Depietri and McPhearson 2017; Kabisch et al. 2016; Poratelli et al. 2020; Sutton-Grier et al. 2015), less long-term maintenance (Cheong et al. 2013; Gray et al. 2017), greater adaptive capacity to climate change (Choi et al. 2021; Kim et al. 2020; Ruangpan et al. 2020; Stafford et al. 2021), and, crucially, greater provision of co-benefits as ecosystem services (Pauleit et al. 2017). These include aesthetics, wildlife habitat and increased biodiversity, livelihood support, and carbon sequestration, among others (Cohen-Shacham et al. 2016; Seddon et al. 2020).

The first criterion and corresponding indicator of the IUCN’s Global Standard for NbS (2020b) state that NbS should seek to address specific societal challenges while prioritizing the most urgent ones. Nevertheless, NbS provide co-benefits beyond any one objective, which has several important implications. The most relevant here is that NbS often rely on a wide range of public stakeholders with different interests, objectives, and values in relation to their (subjective) benefits, with “local human communities at the heart of NBS” (Eggermont et al. 2015, p. 244). NbS are generally well-regarded among European citizens (European Commission 2015a), likely due to values that align with the perceived importance of nature and environmental protection (European Commission 2014), and the attraction of a 'natural' and 'green' framing (i.e., a positive connotation) (Osaka et al. 2021). A review by Anderson and Renaud (2021) on public acceptance of NbS for risk reduction identified the most frequently cited positive outcomes of public acceptance, demonstrating their importance compared to grey measures. In addition to active collaboration for NbS, they showed that public acceptance was more frequently cited as leading to protection against competing societal interests (e.g., for land), sustainable use of NbS sites, and upscaling and repetition when compared to grey measures.

Because NbS generally provide more co-benefits, have a lower opportunity cost, and have a greater adaptive capacity than grey measures, they are often framed as 'win-win', 'low-regret' or 'no-regret' solutions (CBD 2019; IPCC 2012; Kaufmann et al. 2021; Renaud et al. 2013a). In other words, these robust measures will produce net benefits despite, for example, a potentially catastrophic climate change scenario, with more natural and societal (co-)benefits provided than are needed to justify their cost (IPCC 2012).

Although NbS characteristics generally garner positive public sentiment, it is less clear whether individuals living in contexts of risk from natural hazard consistently *prefer* NbS over grey measures (Mallette et al. 2021) or indeed perceive them as 'low-regret' or 'no-regret' options. Public (mis)perceptions of NbS have been identified as one barrier to NbS uptake (Kabisch et al. 2016; Ramírez-Agudelo et al. 2020; Waylen et al. 2018). Additionally, stakeholders must value the co-benefits for these to increase support for NbS (Anderson et al. 2021; Giordano et al. 2020; Hagedoorn et al. 2021) and move preferences away from grey measures (Gray et al. 2017; Loos and Rogers 2016; Ruangpan et al. 2020; Tompkins et al. 2008). Along with many diverse factors (Anderson and Renaud 2021; Han and Kuhlicke 2019; Mallette et al. 2021), past research highlights three key themes that can influence support for NbS: public perceptions of 1) effectiveness, 2) risk (i.e., risk perception), and 3) the importance of nature and natural co-benefits.

Perhaps most commonly, the effectiveness of NbS for reducing risk has been called into question by public stakeholders (Anderson and Renaud 2021; Fuchs et al. 2017; Gray et al. 2017; Mallette et al. 2021). A perceived lack of evidence (Bark et al. 2021; Esteves and Thomas 2014; Evans et al. 2017; Howgate and Kenyon 2009) and higher confidence in grey measures are common (Chou 2016; Mallette et al. 2021; Roca and Villares 2012). This has been attributed to the novelty and complexity of NbS compared to conventional options (Bark et al. 2021; Schernewski et al. 2017; Seddon et al. 2020). A recent review of public acceptance of measures for coastal adaptation by Mallette et al. (2021) supported findings from reviews on public perceptions of NbS by Anderson and Renaud (2021) and Han and Kuhlicke (2019), highlighting risk perception as a frequently cited influential variable. However, the reviews also found that risk perception is highly contextual and can shape preferences in unexpected ways, be mediated by other variables, or indeed have very little effect at all. Lastly, co-benefits can promote support for NbS, such as aesthetic beauty (especially important for NbS in Europe) (Anderson and Renaud 2021; Buijs 2009; European Commission 2015a; Mallette et al. 2021) and increased wildlife habitat (Evans et al. 2017; Pueyo-Ros 2018). Similarly, NbS citizen surveys conducted by Anderson et al. (2021) showed that public commitment to nature and responsibility for nature were significantly correlated with positive attitudes and behaviours towards NbS.

There are several relevant gaps in the literature cited above. Most importantly, there is a lack of studies that 1) assess the same public's preferences for risk reduction measures considering the full spectrum of green-hybrid-grey, 2) assess perceptions of NbS effectiveness, risk, and nature with the same subjects, despite evidence of relevant interconnections, and 3) go beyond aggregated ratings or rankings and use open qualitative methods to capture individuals' perceptions in this context. Additionally, the 'no-regret' framing of NbS from a risk management perspective has not been thoroughly explored from the perspective of local public stakeholders (Kaufmann et al. 2021; Osaka et al. 2021). Research is needed to understand the reasons behind preferences (Mallette et al. 2021) and how the public frame these in contexts of risk. Understanding (mis)perceptions is a first step towards improving communication and bridging knowledge gaps (Gray et al. 2017) while fostering needed support (Mallette et al. 2021) and preventing conflict (Everett et al. 2021; Holstead et al. 2017; Schernewski et al. 2017).

To address these gaps, we carried out citizen surveys in three NbS study sites in Europe - Catterline, Scotland (landslides and coastal erosion; n=66), Lake Puruvesi area, Finland (eutrophication and algal blooms; n=204) and the

Spercheios River Basin, Greece (river flooding and water scarcity; n=84). Survey results from Catterline, described in Anderson et al. (2021), showed that residents highly value the NbS co-benefits of wildlife habitat and aesthetics, along with having a high risk perception and strong demand for effective measures. Because these characteristics provide a suitable context to address our research questions, in this study we follow up our survey results in the Catterline site with in-depth focus group discussions (FGDs). All study sites are part of the ongoing Horizon 2020 OPERANDUM project[16], which has the primary aim of reducing risk from hydro-meteorological hazards using NbS across Europe.

Using the surveys and FGDs, this study is guided by three primary research questions:

RQ1) To what degree do residents in communities with planned NbS (green) prefer grey measures in addition to green measures (hybrid approach) or grey measures instead of green measures?

RQ2) Are perceptions of NbS effectiveness, risk, and nature associated with these preferences?

RQ3) What other factors, including the perceived importance of NbS benefits, influence preferences for measures to be greener or greyer?

a) Are nature and risk-related benefits perceived as complementary or non-complementary (conflicting)?

b) Are green measures perceived as 'no-regret' given their co-benefits even if they fail to prevent future landslides?

As detailed in the subsequent methods section, research questions 1 and 2 are addressed using all three study sites, albeit with more in-depth data from qualitative FGDs in Catterline, while RQ3 relies only on Catterline FGD data.

[16] https://www.operandum-project.eu

4.2 Methods

We conducted surveys in three European study sites within the OPERANDUM NbS project: Catterline, Scotland, UK; the Lake Puruvesi area in Eastern Finland; and the Spercheios River Basin in Stereá Elláda, Central Greece. The surveys and study sites are described in more detail in Anderson et al. (2021), who relied entirely on the surveys and focused on attitudinal and behavioural acceptance of NbS. Here, we explore survey items in relation to preferences for hybrid or grey measures instead of green NbS. Following analysis of survey results, we then held four small online FGDs with residents of Catterline, Scotland to qualitatively explore underlying reasons for preferences for green, hybrid, or grey measures and perspectives on associated attributes of each measure type. Both data collection methods were approved by a dedicated ethical committee at the University of Glasgow and carried out following GDPR guidelines with written or verbal participant consent. The surveys were conducted between September 2019 and April 2020 and the focus groups were held in April 2021. For both methods, the NbS were at a mature planning stage but had not yet been implemented by the OPERANDUM project. Therefore, public perceptions are not based on actual benefits and trade-offs from these measures, but rather on their expected benefits and trade-offs. Surveys were carried out before the Covid-19 pandemic affected the sites, and focus groups were held online due to the ongoing pandemic and related restrictions in the UK. We primarily rely on descriptive statistics and Spearman’s rank correlations for the survey data and thematic coding of transcriptions for the FGDs (Figure 4-1).

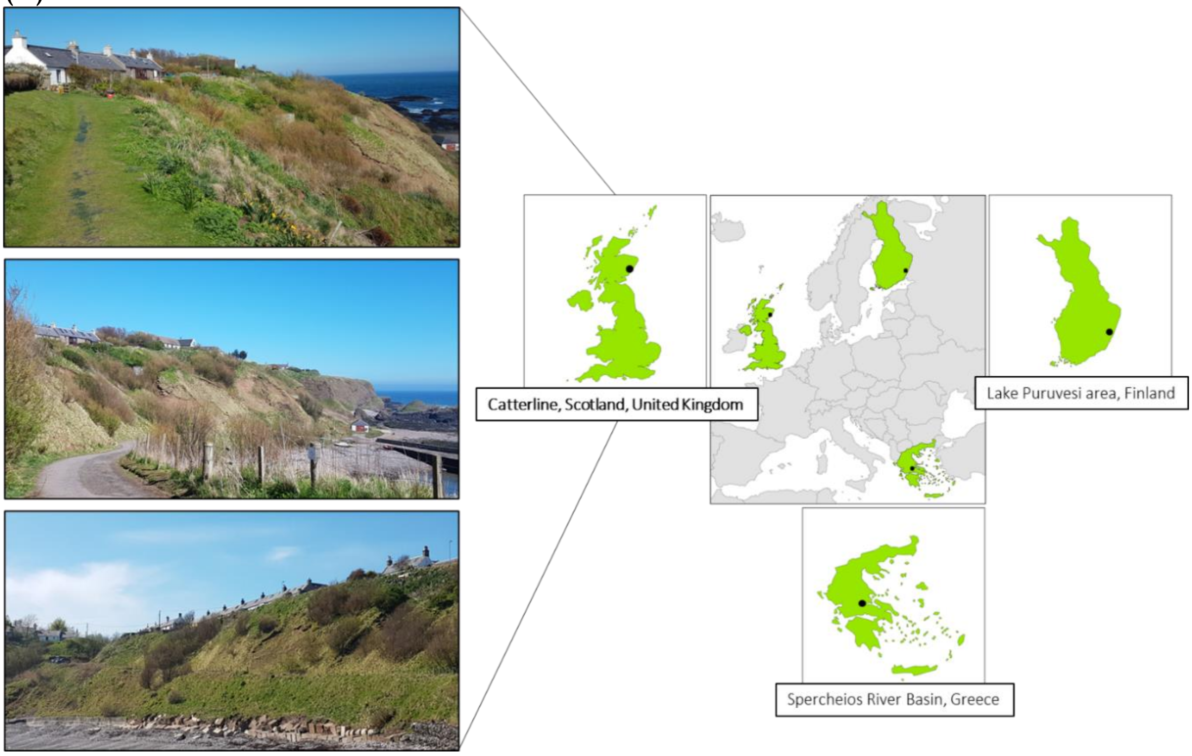
	RQ1. To what degree do residents in communities with planned NbS (green) prefer grey measures in addition to green measures (hybrid approach) or grey measures instead of green measures?	**RQ2:** Are perceptions of NbS effectiveness, risk, and nature associated with these preferences?	**RQ3:** What other factors, including the perceived importance of NbS benefits, influence preferences for measures to be greener or greyer? a) Are nature and risk-related benefits perceived as complimentary or non-complementary (conflicting)? b) Are green measures perceived as "no-regret" given their co-benefits even if they fail to prevent future landslides?
Surveys in Catterline (n=66), Puruvesi (n=204), and Spercheios (n=93)	1) Descriptive statistics of Likert responses	1) Spearman's rank correlations of Likert responses	N/A
Focus groups in Catterline (4 groups, n=10 [2x2, 2x3])	2) Deductive coding of transcription for group preferences for green, hybrid, or grey measures in Catterline	2) Thematic deductive coding of transcription for the influence of perceptions of NbS effectiveness, risk, and nature on preferences for green, hybrid, or grey measures	1) Thematic inductive coding of transcription for influential factors behind preferences for green, hybrid, or grey measures 2) Stated group preferences for degree of benefit for a) wildlife habitat and aesthetics and b) risk reduction
Study sites used to answer research questions	Catterline, Scotland, UK; Lake Puruvesi area, Finland	Spercheios River Basin, Greece	Catterline, Scotland, UK

Figure 4-1 Research questions with the corresponding study sites and methods applied to address them. The third research question (RQ3) has two sub-questions, a) and b), and is addressed only with the focus group discussions carried out in Catterline, Scotland. The study sites are shown as black points within the outline of their countries of location (Scotland, Finland, and Greece).

4.2.1 Study sites

We provide only a brief description of the surveyed NbS sites in Finland and Greece and describe in more detail the Catterline, Scotland site, since this study relies heavily on FGD findings from Catterline to answer our research questions. We selected sites within the OPERANDUM project to 1) maximise differences in environmental and social systems in order to test survey variables and compare outputs while 2) ensuring the constant characteristic of rural sites in a mature planning stage prior to deploying NbS (Figure 4-2).

(A)



(B)

Study Site	Area	Hazard	Potential impacts	Primary NbS	Primary aim of NbS
Catterline	0.4 km^2	Landslide and surface erosion	Injury or death; Damage to residential property, access roads; Loss of recreation, aesthetics	Live cribwall, live grating, live pole drain	Slope protection and erosion control
Puruvesi	73 km^2	Eutrophication and algal blooms	Negative human and animal health impacts; Loss of tourism, fishing, aquatic recreation, aesthetics	Continuous cover forestry (CCF)	Erosion control and reduction of runoff
Spercheios	92.4 km^2	River flooding and water scarcity	Injury or death; Damage to residential and agricultural property, access roads; Loss of recreation, livelihood	Natural water retention basins	Excess surface runoff storage and groundwater recharge

Figure 4-2 Study site locations and characteristics. (A) Location of the three European NbS study sites and (B) their characteristics, including hazard type, potential impacts, and primary NbS being implemented within the OPERANDUM project. Three photos from the Catterline site show (*from the top*) sea-facing residences exposed to landslides, the access road to the pier and signs of past landslide events, and the beach, concrete blocks and gabions as past coastal defence measures with evidence of landslides on the slopes. Adapted from Anderson et al. (2021). Photo credit: Dr. Karen Munro. Map: European Commission, Eurostat, https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/countries.

Lake Puruvesi is culturally significant in Finland and well-known for its water clarity (Tienhaara et al. 2017). However, the frequency of blue-green (cyanobacterial) algal blooms related to eutrophication has increased within portions of the lake. Recreational activities in particular, but also fishing and tourism livelihoods and health (e.g., skin and eye irritation), are documented negative impacts (Anderson et al. 2021). Continuous cover forestry (CCF) as an NbS was planned near the Lake Kuona-Vehkajärvi sub-catchment area to address eutrophication. This sustainable resource management practice involves selective timber harvesting to maintain a forest canopy and vegetation density to reduce runoff while also preserving forest ecosystem structure and wildlife habitat. Other planned NbS included constructed wetlands, peak flow control structures, sedimentation ponds and pits and surface runoff fields, as communicated to survey respondents.

The topography, soil properties and climate of the Spercheios River Basin in Central Greece are conducive to seasonal flash-flooding and high sedimentation. We carried out the surveys at the mouth of the Spercheios River near the city of Lamia, Greece, the area with the largest population exposed to flooding. Flood events occur on an almost yearly basis that damage residential and agricultural property and block roads, thereby affecting livelihoods, tourism, and recreation. NbS in Spercheios are natural water retention measures (NWRM). Drainage basins using natural materials were being planned to reduce the risk of flooding by absorbing excess water while also providing wildlife habitat and contributing to groundwater recharge and irrigation needs.

Catterline is a small seaside village in Northeast Scotland with important national historic and cultural relevance as well as natural scenic beauty. Soil erosion and landslides are long-standing issues in the community (Gonzalez-Ollauri and Mickovski 2017) related to prolonged periods of heavy rainfall, surface water accumulation, fluctuations in groundwater, spring tides, and storm surge. Although shallow landslides occur relatively frequently, the most recent major landslide event prior to the surveys (September 2019) occurred in October 2012. Shortly before the FGDs (April 2021), a moderate landslide blocked the road to the harbour following heavy rainfall in February 2020 (Figure. A-3) and another similar event occurred in February 2021 (Gonzalez-

Ollauri and Mickovski 2021). The process of restoring the slope and unblocking the road was led by residents affiliated with a voluntary community group (CBAG; Catterline Braes Action Group[17]) dedicated to slope protection and stabilisation. CBAG was formed following a collective response to landslide events over the winter of 2012/2013. Although depth of knowledge is variable, both CBAG members and non-member residents are generally aware of landslide risk and slope stabilisation work in the community.

CBAG has supported the OPERANDUM NbS plans and research. Before OPERANDUM, CBAG led stabilisation efforts, including the (re)planting of woody seedlings and cuttings along some sections of the slopes (green measure), the installation and maintenance of plastic drainpipes (grey measure), and in August 2019, the deployment of a geogrid mesh (erosion blanket) with ground anchors and vegetation (hybrid measure). Small-scale efforts have also been supported by Glasgow Caledonian University researchers and student volunteers for nearly a decade, and the Aberdeenshire Council (mostly clean-up or reconstruction). These measures have aimed at improving drainage and physically reinforcing/stabilizing the slopes. Notably, they have not sought to directly address wave erosion from tides and storm surge. For this, there are only small gabions from the 1970s and cement blocks from the 1940s (Figure 4-2, bottom photo) that have been damaged and are considered wholly insufficient, though community-led efforts are underway to address this as well (Mickovski et al. 2021).

4.2.2 Survey design and analysis

Due to time and financial constraints, different sizes of the sites, and the capacities of local collaborators, we used non-random and distinct survey data collection approaches across the sites that aimed to maximise the number of responses rather than obtain representative samples. In Catterline, the lead author went door-to-door with paper-based surveys and in Puruvesi postcards were mailed to inform residents of the online survey version. In Spercheios, surveys were facilitated by OPERANDUM partners during a focus group and

[17] https://www.cbag.org.uk

institutional mailing lists were then used to reach additional residents (Table. A-12).

The surveys were designed to determine the degree of public acceptance of NbS by nearby residents and how risk, nature and place variables are associated with and predict acceptance, as described in Anderson et al. (2021). In this study, we use only two 1-9 Likert items to represent our dependent variables and assess respondents' preferences for grey (non-natural) measures 1) instead of NbS (preference for grey) and 2) in addition to NbS (preference for hybrid). Because the surveys were conducted while the OPERANDUM project was ongoing and NbS were at a mature planning stage, these items were understood by participants as alternate preferences to the general plan. A description of the proposed NbS was provided on the surveys immediately prior to these dependent variable items. On all three surveys, NbS are described as natural measures that can reduce risk and provide additional benefits. We determine how independent variables in relation to perceived effectiveness of NbS (n=3) and perceptions of risk (n=6) and nature (n=3) correlate with these preferences (Table. A-13).

Effectiveness items were created using findings from Anderson and Renaud (2021) to capture unique dimensions of how public perceptions may influence acceptance of NbS. The *risk perception* scale combines items related to perceived hazard characteristics (Fischhoff et al. 1978; Siegrist and Árvai 2020; Slovic et al. 1985) and vulnerability and concern (Gifford and Comeau 2011; Peters et al. 2006; Rundmo 2002; Terpstra 2011) (see Table. A-14 for all underlying items for the *risk perception* scale and others). We created additional scales of summed binary past impacts (experienced) and future impacts (expected) and risk intolerance (Finlay and Fell 1997; Haynes et al. 2008; Maynard et al. 1976). The *commitment to nature* scale is a truncated version based on Davis et al.'s (2011) *commitment to the environment* scale. Sense of responsibility and pride were highlighted in Anderson and Renaud (2021) in relation to acceptance of NbS and past research on human-environment relations has identified their significance in determining attitudes and behaviour. Processing and reliability testing was conducted by assessing Cronbach's alpha (α), corrected-item-total correlations (CITC), and exploratory factor analysis (EFA) using principal axis factoring (Table. A-14). We determine Spearman's rank correlations between preferences for grey or hybrid measures and all variables related to perceptions of effectiveness, risk, and nature.

4.2.3 Focus group discussion (FGD) design and analysis

The FGDs were held in April 2021 using the video/audio software Zoom, approximately one month prior to the implementation of NbS in Catterline and after an extended hiatus of stakeholder engagement activities in the OPERANDUM project due to restrictions brought by the Covid-19 pandemic. Invitations to sign up for FGDs using an online scheduling platform were sent via email to 33 residents on April 8, 2021, and a reminder sent on April 19. Due to probable overlap in email lists and data protection law (inability to share lists), we estimate that 45 residents were invited to participate. Several time slots were available every day between April 25-28, 2021. Eleven residents signed-up (24.4% response rate) and were randomly assigned to groups based on their availability. In total, ten residents attended four 1.5-hour sessions, with two groups of two residents and two groups of three. Three females and seven males participated, with one female in groups one, two, and three. Age data were not collected, but no younger residents attended and most participants were middle-aged. Small groups were used to maximise the depth of individuals' insight and corresponding amount of transcribable data, and because answering our research questions does not directly rely on intra-group interactions.

Along with data collection, the FGDs were designed to present to the residents the summarised results of the 2019 survey they had completed. We first assessed characteristics of FGD participants based on 2019 survey items using a five-item Zoom poll. To contextualize results, as presented in the following methods subsection, these established the participants' degree of perceived risk and perceived importance of nature (and natural co-benefits). Three discussion activities were held at planned intervals, occasionally relying on presented results to generate discussion (Table. A-15). However, questions, comments, and discussion were encouraged from participants throughout the sessions.

The first and most extensive discussion activity involved deciding where measures should fall on the green-hybrid-grey spectrum, first regarding direct slope stabilisation, and then improving drainage. Before this, a definition and examples of a green, hybrid, and grey measure in the context of coastal erosion were explained (mangrove planting, artificial coral reef, concrete seawall) and participants were informed that “this categorization can also be applied to slope stabilisation measures”. We used pictures, described only as examples, to help elicit discussion on green-hybrid-grey measures for landslide risk reduction. A numeric scale of 1-2-3, corresponding to green-hybrid-grey, with intervals of 0.2 was overlaid on the example images. This gave participants the opportunity to discuss and express preferences for positions between green (1), hybrid (2), and grey (3).

Other activities involved group decisions on the importance of two benefits of potential measures - *wildlife habitat and aesthetics* and *risk reduction* (Table 4-1). The FGD content was piloted and amended based on feedback from University of Glasgow researchers and the fourth author of this article, who has worked for nearly a decade on slope stabilisation in Catterline.

Table 4-1 Three primary focus group discussion activities. Although most relevant data were collected during these activities, dialogue was generated with participants during the presentation of 2019 community survey results (see Table. A-15 for full FGD schedule).

Discussion activity 1
As a group, please decide where (ideally) the measures for Catterline [1. slope stabilisation and 2. drainage] would fall on this spectrum [green-hybrid-grey].
Five years later, a series of major landslides has occurred, some of the worst Catterline has ever seen. How do you feel about your decision? Do you regret it? [follow-up] Does the continued issue of landslides make you consider moving to a new home? leaving Catterline?
Discussion activity 2
Measures have different attributes like *wildlife habitat and aesthetics* and *risk reduction*. You can have minimum benefit of each of these (0%) and maximum possible benefit of each of these (100%). Where would you like each of these attributes to be? [follow-up] Do you think this is realistic?
Discussion activity 3
You have 20 “Catterline pounds” to invest in a hypothetical measure for Catterline. The more you spend on an attribute of the measure (*wildlife habitat and aesthetics* and *risk reduction*), the more of that benefit you get. As a group, how would you like to distribute your 20 “Catterline pounds”?

Discussion activities were carried out before presenting most survey results to limit their influence on any subsequent stated opinions and preferences. However, since participants were encouraged to comment and ask questions throughout, some discussion did occur during phases of the FGDs in which the moderator (lead author) was presenting survey results (Table. A-15). We considered the advantages of presenting survey results, i.e., generating targeted discussion relevant to the research questions in a context of two-way knowledge exchange, outweighed any potential bias. We also reversed the order of presented survey results during ‘Part 1. Landslides and risk’ and ‘Part 2. Catterline and nature’ (Table. A-15) in two of the sessions, to not bias aggregate attitudes towards survey results on risk more than those on nature, or vice versa.

Sessions were recorded on Zoom, manually transcribed by the lead author using f4transkript software[18], and coded using NVivo Pro v.12. Codes were created to categorise responses to discussion activities across groups as well as to identify the primary themes of 1) influencing factors for green, hybrid, or grey preferences; 2) attribute interrelations of measures; 3) objective of measures; and 4) description of measures.

[18] https://www.audiotranskription.de/en/f4transkript/

4.3 Results

4.3.1 Survey respondents' preferences for grey measures and associated variables

On average, surveys showed that respondents in Spercheios and Puruvesi were slightly in favour of a hybrid approach (deploying *grey measures in addition to NbS*). In Catterline, the median response was at the mid-point (5) and the mean just slightly below. There is more resistance to using purely *grey measures instead of NbS,* but mean responses on this item are only just below the mid-point of the Likert range in all three sites (Figure 4-3).

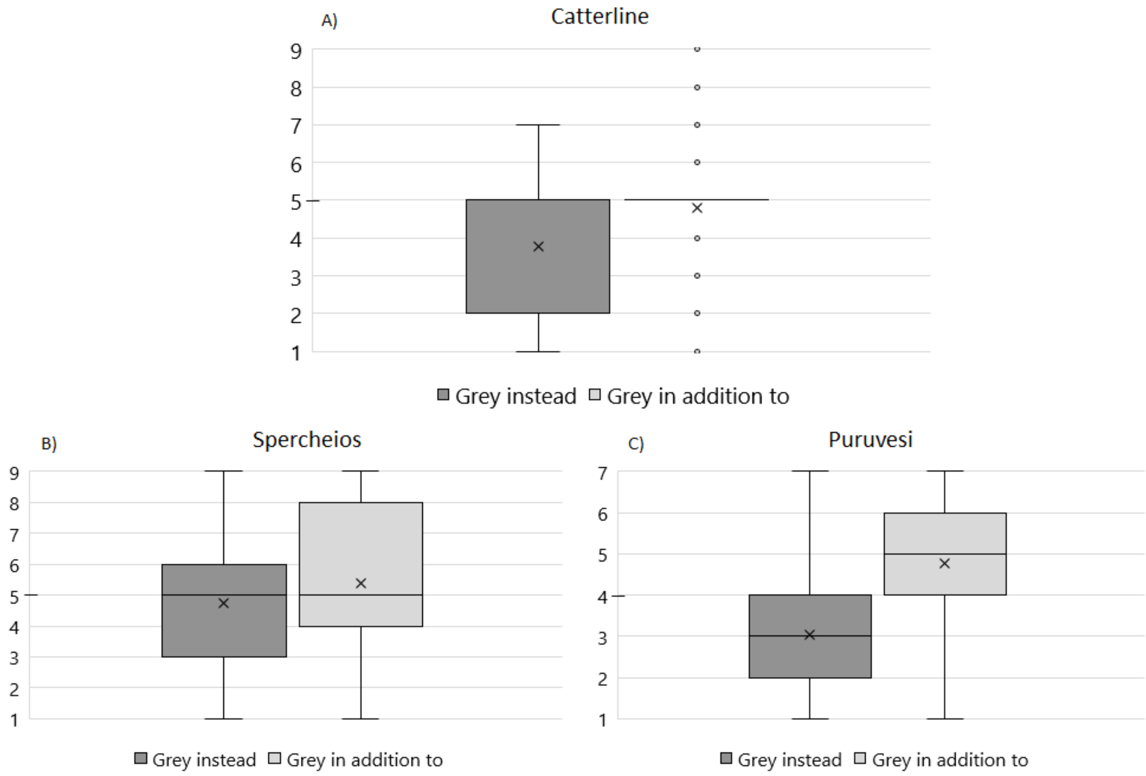


Figure 4-3 Likert survey item responses for preferences for grey or hybrid measures. Box plots of two Likert survey items: 1) degree of preference for grey measures instead of NbS (grey) and 2) degree of preference for grey measures in addition to NbS (hybrid) in the three study sites: A) Catterline, B) Spercheios, and C) Puruvesi). The strongest preference for grey/hybrid is 9 and the weakest 1. The 'x' marks the mean, the horizontal line the median, the edges of the box the interquartile range, and the extended vertical lines (whiskers) the minimum and maximum responses. Beyond the whiskers, here only in the case of Catterline (A), dots represent outliers. In Catterline, in response to "grey in addition to", there were 33 responses at the mid-point (5) and a range of responses at all other Likert choices, making all non-mid-point responses outliers. "I don't know" responses are excluded. Note that the Likert range is 1-9 for A) and B), and 1-7 for C).

The results show a wide range of responses for each of the two items, with some respondents strongly opposed to hybrid/grey measures and others strongly in favour. However, most responses are at (or close to) the mid-point of the Likert ranges for the three sites (Table. A-16).

Mid-point responses can be interpreted as ambivalence, uncertainty, or a moderate perspective (Kulas and Stachowski 2009). There were also nine (13.6%) "I don't know" responses for each item in Catterline. In Spercheios, there were eleven (13.1%) "I don't know" responses for preferring grey instead of NbS and eight (9.5%) for "in addition to". Because these are among the survey items with the highest number of "I don't know" responses, it is likely that many of the mid-point responses demonstrate uncertainty. Nevertheless, results suggest no immediate opposition to- or strong preference for- using grey measures.

Preferences for hybrid and grey measures are significantly correlated with each other in all three sites, but strongly correlated in Catterline and Spercheios and only weakly correlated in Puruvesi (Table 4-2, Part A). Significant correlations were expected, since a demand for additional grey elements (hybrid) should be related to, but not equivalent to, a demand for only grey elements. In Puruvesi, residents were more accepting of hybrid but more strongly rejected grey (Table 4-2, Part A; Figure 4-3). Survey items and variables in relation to NbS effectiveness, risk, and nature mostly show insignificant or weak correlations with hybrid and grey preferences across the sites. There was, however, one notable exception. Items related to perceived effectiveness of NbS and perceptions towards nature show mostly significant correlations with preferences for *grey measures instead of NbS* across the sites, with the strongest correlations in Catterline (Table 4-2, Part B).

Table 4-2 Spearman's rank correlations between measure preferences and effectiveness, risk, and nature variables. Spearman's rank correlations between the two items related to preferences for grey measures instead of NbS (grey) or grey measures in addition to NbS (hybrid) (A) and with variables related to perceptions of effectiveness of NbS, risk, and nature in the three study sites (B). Single item variables are shown in quotation marks and multi-item scales in italics. Missing data and "I don't know" responses are excluded from the analysis. Correlations at significance levels of *p*<0.10, *p*<0.05, and *p*<0.01 are shown in bold.

A)

	Grey instead of NbS		
	Catterline	Puruvesi	Spercheios
Grey in addition to NbS	.541***	.282***	.579***

$^{*}p<.10$, $^{**}p<.05$, $^{***}p<.01$

B)

	Grey instead of NbS			Grey in addition to NbS		
	Catterline	Puruvesi	Spercheios	Catterline	Puruvesi	Spercheios
Effectiveness						
"Need more evidence for NbS"	**.307****	**.258*****	**.292****	.076	.109	**.263****
"NbS will reduce risk"	**-.368*****	-.118	-.188	-.169	-.128	-.138
"Nothing can reduce risk"	**.331****	**.251*****	**.201***	**.241***	.010	.066
Risk						
Risk perception	-.166	-.097	**.292****	-.011	-.091	**.264****
Risk intolerance	**-.220***	.092	-.030	**.304****	-.045	-.051
"Risk must be reduced"	-.084	-.085	-.085	-.125	-.038	**.209***
"Concerned about impacts"	-.029	-.099	.161	.133	-.048	**.275****
Past impacts (sum)	-.098	.043	-.045	-.029	**.126***	.102
Future impacts (sum)	**-.230***	-.065	.032	-.026	-.032	.147
Nature						
Commitment to nature	**-.468*****	**-.231*****	-.062	**-.271****	**-.125***	.126
"Responsible for nature"	**-.344*****	**-.127***	-.052	-.148	-.050	.111
"Not proud of natural area"	**.349*****	**.133***	**.256****	**.282****	.031	**.255****

$^{*}p<.10$, $^{**}p<.05$, $^{***}p<.01$

In Catterline, confidence in the effectiveness of NbS (i.e., "NbS will reduce risk") is highly negatively correlated with preference for using *grey measures instead* (ρ=-.368, *p*<.01), along with perceptions of nature and especially *commitment to nature* (ρ=-.468, *p*<.01).

4.3.2 *Focus group discussion (FGD) results from Catterline, Scotland*

Polls carried out at the start of the FGDs showed that participants generally had both a high risk perception and demand for risk reduction as well as high commitment to nature and appreciation of the natural NbS benefits (Table. A-17). All responses on the 1-9 range Likert poll items are above the range's mid-point of 5. However, five of the ten respondents listed only five of the nine potential future impacts (Table. A-18; Item 2). There is low variation in responses among groups, although Groups 3 and 4 expected slightly fewer future impacts, while Group 1 is slightly more concerned and has higher demand for risk reduction. Because these group characteristic responses show very little variation, we do not systematically present the qualitative FGD results on a group-by-group basis. We do, however, always refer to individuals by their group number when quoted (e.g., G1P1 = Group 1 Participant 1).

4.3.2.1 Preferences for landslide risk reduction and natural co-benefits

When FGD participants were asked to what degree they would like each attribute to provide minimum (0%) or maximum (100%) benefit on the two primary attributes of *wildlife habitat and aesthetics* and *risk reduction*, nearly all groups sought to maximise both, and no group implicitly considered these two attributes to be entirely non-complementary. This was reinforced with the direct follow-up question from the moderator (lead author): "Do you think this [simultaneous maximization] is realistic?". Here, responses mostly confirmed the non-complementary implication of the percentages provided; for example, "It has to be! Otherwise, if we don't think it's realistic, we're not going to continue trying to do it, are we?" (G1P1); "It only becomes a real issue if there's a trade-off between the two… I don't know if that's necessarily the case" (G4P1); "I don't think there's a dichotomy here" (G3P1). Two of the groups proposed that stabilizing the slopes, and thereby focussing on risk reduction, would directly benefit wildlife and aesthetics. However, short-term versus long-term trade-offs of prioritizing the attributes also emerged: "There's always going to be a cost, you just try and mitigate [it]. But, if the village is on board that they don't want to find their houses at sea level in the probably not-too-distant future, some intervention has to take place and there *will* be an impact visually, to their lives while that work is going ahead, to any local wildlife" (G3P2).

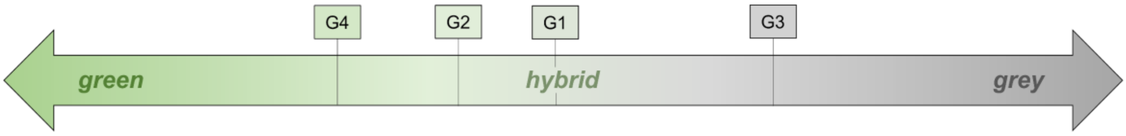
We then implied non-complementarity by asking groups to allocate 20 "Catterline pounds" (imaginary money) between the two attributes (every pound allocated to one attribute equates to one fewer for the other). In this case, *risk reduction* was allocated at least 50% more by all groups, and on average 74.4% of the 20 pounds (Table. A-19).

Nearly all participants' preferred allocation was approximately 5/15 (25% *wildlife habitat and aesthetics* and 75% *risk reduction*). This shows that the primary objective is risk reduction, but the natural co-benefits are still an important aspect of the work.

4.3.2.2 Preferences for green, hybrid, or grey measures

Nearly all participants expressed a preference for measures that are as green as possible, but only if such measures are not subject to unacceptable trade-offs. Only Group 3 (G3) expressed a general preference for measures closer to the grey end of the spectrum, although they considered hybrid to be "ideal" and that different types of measures were required at different times and in different areas. This perspective, along with the perceived trade-offs of both green and grey measures, meant that group preferences tended to coalesce around hybrid measures (Figure 4-4).

A)



B)

	n	Dominant rationale for group preference
G1	2	*Depends on where in the community and for what purpose. Closer to the sea requires greyer measures, on the braes [cliffs] in some places green is adequate, but hybrid is ideal.*
G2	3	*Hybrid made the most sense with prior work for slope stabilisation, but green was used for drains and green is generally preferable. It may be that greyer measures could be implemented at first and then afterwards greener measures.*
G3	2	*Hybrid is ideal, but some things can and should be done with grey measures. The issue must be broken down into many small problems and many different solutions should be used in different areas, but possibly best to start with grey and then later start to move towards green.*
G4	3	*Green is the best but only assuming the measure is sufficiently effective, while there are trade-offs to consider with any measure.*

Figure 4-4 Group preferences on a spectrum of green-hybrid-grey. Group preferences for the approximate position of the "ideal measure for Catterline" on a spectrum of green-hybrid-grey (A) and corresponding primary rationale synthesized from the group discussions (B).

The emphasis on risk reduction as the primary objective led to a 'success/failure' framing of the measures. In response to whether participants would 'regret' their chosen measure in the scenario that major landslides hit Catterline five years after implementation, group responses referred to the need for cost-benefit analyses to aid in decision-making and ex-post assessments to determine why and how things went wrong. Participants who viewed the implementation of NbS as an experiment were more willing to accept the perceived risk of failure involved in opting for green measures: "An experiment is not necessarily going to work... Let's see if this works, if this doesn't work then we try something else" (G1P1). No responses referenced co-benefits of green measures, implying that the appreciation of co-benefits may not atone for inadequate risk reduction.

A quote from Group 2 summarises the perspective of most participants that green measures are preferable, but any trade-offs in terms of the primary objective of risk reduction are not:

"…if it was a green solution and it lasted longer than I expected, then I'd be very, very happy. But if it didn't last so long, then yes, I don't think I'd be as happy as I would have been if I had an identical cost and effort model on the greyer side that could have been used…" (G2P1).

4.3.2.3 Influential factors for green, hybrid, or grey preferences

We identified 13 factors of aggregated perspectives from the FGD transcripts that influenced preferences for greener or greyer measures. Prior quotes have already demonstrated several of these, including *effectiveness for risk reduction*; *time*; *aesthetics*; *habitat*; *evidence base*; *awareness, knowledge, and skills*; *past experience*; and *suitability for context*. The remaining factors are *cost*; *effort*; *risk perception*; *visibility of benefits*; and *unintended consequences* (Table 4-3).

Table 4-3 Factors that influence preferences for green, hybrid, or grey measures. Thirteen factors (*left*) composed of perspectives (bullet points) that influence preferences for green, hybrid, or grey measures among focus group participants. Perspectives with check-mark (✓) bullet points indicate a positive influence on preference towards the corresponding measure type, while x-mark (✗) bullet points indicate a negative influence. Factors are listed by number of references in transcribed focus groups from high to low. All unique perspectives are provided. Blank cells indicate that no perspective was relevant for that measure type.

	Green	Hybrid	Grey
Effectiveness for risk reduction	✓ Prevents shallow slips, helps stabilise slopes ✓ May be more effective long-term if self-reinforcing ✗ Cannot stop energy from the sea ✗ Scepticism and uncertainty; more of a gamble ✗ Ineffective/less effective for drainage ✗ Supplementary measure to be done “on top” ✗ Status quo is an ineffective natural system	✓ Prevents deep slips ✓ “Compromise” choice; sufficient ✓ “Engineering solution” with strength ✓ Allows for acquisition of house insurance	✓ Strength against the sea; necessary for coastal defence ✓ If needed, then necessary ✓ Confidence and understanding ✓ Reduces risk ✓ Best for water management ✗ Not highly effective for groundwater outflow ✗ Not always needed/required
Time	✓ Stabilises over time for less maintenance ✗ Willow drains clog over time ✗ May not last as long ✗ Ecosystems take a very long time to stabilise ✗ Takes time for effectiveness, situation could get worse ✗ Takes time for aesthetics	✓ Stabilises over time for less maintenance ✓ Lasts longer ✓ Shorter time frame for risk reduction than green ✓ Green can establish after grey ✓ Eventually covered by vegetation	✓ Lasts longer, will stabilise long term ✓ Immediately effective against urgent issue ✓ Unavoidable short-term impact on species for implementation of any measure ✗ May not last “30 years”, prone to break since man-made ✗ Long-term maintenance necessary ✗ Initial impact on species, but not long-term

	Green	Hybrid	Grey
Aesthetics	✓ Supports tourism ✓ Should not be undervalued in relation to DRR ✓ More visually pleasing ✓ Fits in with environment × Trees may change landscape	✓ Pipe can be buried, vegetation grows on top ✓ Invisible or fits in with environment ✓ Eventually covered by vegetation ✓ "Compromise" choice × Less pleasing than green	✓ Stabilise slope effectively to improve aesthetics ✓ Concrete pump house already there, more won't detract × Can be done in harmony with surroundings × Doesn't fit in with environment × Ugly
Cost	✓ Lower cost, cheapest	✓ Slightly cheaper than grey ✓ Addressing landslips from underground water supply cheaper	× Costly × Expensive to repair × Requires "a lot more cost" than green × Much more expensive to address sea erosion
Habitat	✓ Better for nature and wildlife ✓ Supports tourist industry ✓ Supports a varied ecosystem ✓ More important than aesthetics ✓ Should not be undervalued in relation to DRR × Must not support rabbit population × Current unstable slope/ecosystem has a negative impact		✓ Stabilises slope quickly and effectively to support habitat × Initial impact, species may need to be reintroduced later × Wildlife tends not to establish over man-made features
Evidence base	× Need to be convinced and assess risks of the measure × Poorly understood × Not sure how long they will last × Uncertainty about effectiveness × Should be tested and evaluated over time	✓ Expected to last a long time	✓ Expected to last a long time ✓ Understanding of how it works ✓ More confidence in effectiveness
Effort	✓ Natural system stabilises over time		× Difficult to implement

	Green	Hybrid	Grey
	✓ Least amount of work × Natural system may revert to prior ineffective state × Manually intensive × Requires some maintenance × Requires active community support		× Difficult to repair × Difficult to maintain drains; regular maintenance needed × Manually intensive × Requires “a lot more work” than green × Requires more planning/mapping than green
Awareness, knowledge, and skills	× Drains and their (potential) benefits are hidden × Difficult to find information about/ educate oneself × Fewer case studies available × Lack of knowledge leads to assumptions		✓ Easier to find information about/ educate oneself ✓ Easier to understand how it works
Risk perception	× Too much energy from the sea and storms combined with tide for plants to stop	✓ Reduces risk of property damage ✓ Reduces anxiety (re. ground anchors under vegetation) ✓ Clay soil quickly turns to slurry when saturated	✓ Reduces risk of property damage ✓ The closer to the sea, the more important to implement ✓ 500-year storm surge event hasn’t happened recently, but will ✓ Coastal erosion creates more anxiety
Past experience	✓ Effectiveness and aesthetic benefits witnessed elsewhere	✓ Effectiveness and aesthetic benefits witnessed elsewhere	✓ Failure to maintain past measures means more invasive measure needed ✓ Experience and understanding of how concrete works × Past measures have not lasted × Concrete drains in nearby town poorly maintained
Suitability for context	✓ Not too rocky, rather clay with topsoil × Requires certain conditions to be feasible and practical	✓ Not too rocky, rather clay with topsoil	

	Green	Hybrid	Grey
Visibility of benefits	× Water can accumulate with clogged willow drains		
Unintended consequences			× Inevitable with man-made structures

Although some perspectives among participants were contradictory (e.g., under *time* and *effort*; Table 4-3), each factor tended to consistently push all participants towards the same end of the green-hybrid-grey spectrum. Determining the strength of influence of each factor on preferences is subjective, but can be judged based on their frequency of occurrence in the FGD transcription, across groups, and across participants, as well as the strength of conviction with which they were mentioned (Figure 4-5).

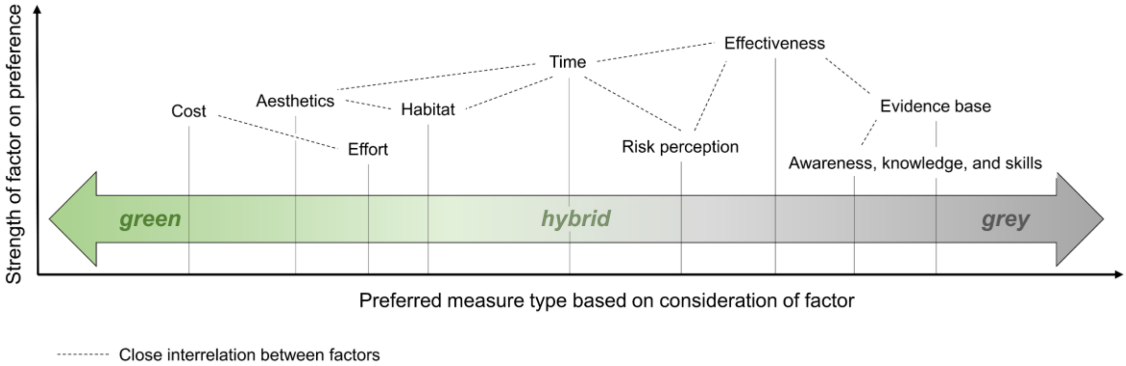


Figure 4-5 The nine most frequently mentioned factors that influence preferences towards green, hybrid, or grey measures in Catterline. The estimated strength of each factor is displayed by its position on the y-axis, based on its total number of mentions, the number of groups and participants that mention it, as well as its stated importance across groups. Close interrelations among factors indicate that they are often mentioned together as influencing preferences and are shown with dashed connecting lines. We omit the last four factors from Table 4-3 (*past experience, suitability for context, visibility of benefits,* and *unintended consequences*) since they were rarely mentioned and do not contain enough data to indicate a general preference among participants regarding this spectrum.

4.3.2.3.1 Factors contributing to support for green measures

Considerations in relation to the factors *cost*, *aesthetics*, *effort*, and *habitat* tended to push participants' preferences towards greener measures. There were no conflicting views among participants regarding greener measures being lower cost and greyer measures being more expensive to implement and maintain. The amount of effort required was often but not always related to cost by the participants. Most participants thought that grey measures would require "a lot more work" (G2P1) and "a lot of mapping" (G2P3), although one participant (G1P2) stated that the green measures were likely lower cost but "look like more effort" and may be more "manually intensive" due to digging, moving soil around, and heavy logs.

Maintenance was also a common concern in relation to effort and particularly for drainage options. A consideration mentioned by several participants was that grey measures could “break” and need to be repaired as well as require regular maintenance, which would increase their cost over time. This perspective was reinforced by past experience. Residents had seen that concrete blocks (a makeshift seawall) in Caterrline were scattered due to wave erosion over time. Others also had knowledge of the nearby town of Stonehaven, where a concrete drainage system was constructed that has been deemed ineffective in recent years due to major flooding. In contrast, it was perceived as highly preferable to create “a natural system that becomes stable” or “a natural solution that maintains itself” (G4P1), since “…nature takes care of itself a lot of the time…” (G2P1), and this would mean less effort for the community members.

Aesthetic considerations mostly led to support for greener measures and were related to the measure “fitting in” with the natural environment and the ugliness of concrete measures. However, Group 3 was more in favour of grey measures, with respondents noting that there is already a concrete pumphouse on the slope and “a little bit more concrete won’t detract from it” (G3P2) and that “concrete done well, and in harmony with the situation around it, can be very valuable” (G3P1). Additionally, hybrid measures were viewed favourably in terms of aesthetics, since “the green would grow and mask it [grey features] massively” (G4P2). The geo-mesh with ground anchors that was recently deployed on the slopes was also chosen in part for this characteristic:

“…the idea is that the longer [time] it is, the more the vegetation comes through, then you don’t actually see any of the anchors or any of the mesh, but obviously you know that, in the back of your mind, ...they all are there and they should all last for at least 25 years” (G1P1).

The green measures were seen to be better for nature and wildlife habitat, which were also important to the residents based on the polls conducted (Table. A-17) and the 2019 survey (Anderson et al. 2021). However, there were several important contradictory perspectives to this more immediately apparent one. One crucial point was that the status quo is seen as a largely natural and green slope, while also being completely unacceptable in terms of risk. Additionally, because landslides negatively impact wildlife and aesthetics, green measures were not immediately perceived as preferable to all participants even in relation to natural co-benefits. Rather, an additional burden of proof regarding their effectiveness emerged: “I'm yet to be convinced that the current unstable nature of the slope isn't in itself having an impact on wildlife habitat and aesthetics. So if you stabilise the slope, does the environment recover to the way that it's meant to?” (G3P1). The overabundance of rabbits in Catterline is exemplary in this case – wildlife that is perceived as undesirable and should be eliminated to achieve the primary objective of risk reduction, rather than supported (Table 4-3).

4.3.2.3.2 Factors contributing to support for hybrid measures

The factor *time* most directly led to preferences for hybrid measures, while *risk perception* led to preferences for hybrid or grey. *Time* is closely related to other factors that involve short-term versus long-term trade-offs, mostly concerning the requirement for anything planted to grow and establish despite the immediate need for slope stabilisation. This perceived urgency promoted the use of greyer measures immediately to enable greener measures thereafter, as well as the use of greyer measures in areas that require more strength and greener elsewhere.

“…there is a harmony point… where these two things come together and work together. Concrete to give you the short-term solution to allow the slope to stabilise to bring the habitat back… there's probably a mixture of solutions…” (G3P1).

The more immediate effectiveness of hybrid and grey measures is recognised and preferred, but generally hybrid measures with elements of grey and green are seen as best at balancing the range of both short-term and long-term benefits.

“…ideally, green would be the best solution for me personally just because… I personally don't like the look of grey, but then if you've got some areas which require more stability than what the green option could offer, then you've got a good mixture hopefully with the hybrid” (G4P3).

This was also provided as the rationale for prior slope stabilisation work done in the community using mesh stabilisation nets with ground anchors (a hybrid measure): "…we did very much think about the balance between having something that is invisible, but had strength. So, it's an engineering solution that's actually in fitting with what's there" (G1P2).

A preference for hybrid was also reinforced by the perspective of having a current natural system that is unacceptable: "…there is a natural system there at the moment, it's just not working" (G4P1). However, as mentioned previously, most respondents agreed that if green measures and associated ecosystems can stabilise over time, it would reduce the long-term cost and high-maintenance (*effort*) characteristic of grey measures. The hybrid option emerges as preferable since hybrid measures don't necessarily embody this negative characteristic of grey measures in relation to time, but are able to reduce risk and eventually also provide the co-benefits of habitat and aesthetics.

The participants' risk perception is closely linked with perceived effectiveness of the measures. This pushes them away from green measures and towards hybrid and grey, especially in relation to wave erosion due to storm surge: "…the closer we get to the sea, the more important it is to have the grey area. I sometimes wonder if people understand just how bad the weather can be" (G1P2); "You're dealing with so much energy and no plant or anything is going to stop that" (G1P2). Again, the primary objective of risk reduction and preventing the most serious potential impacts influences preferences: "it's people's property that could be at risk at the end of the day. So, we need to think about... the best for that as well" (G2P2). Two groups (G3 and G4) note that hybrid or grey measures may be necessary for residents at risk of property damage to get their homes adequately insured. Lastly, participants in G3 implied that concern should lead to a preference for grey measures (rather than NbS). For example, "…you would go for the killer grey, this-fixes-it-once-and-for-all solution, if that [landslides] was truly the thing you were most concerned about" (G3P2).

4.3.2.3.3 Factors contributing to support for grey measures

Similar to *risk perception*, the perceived primary objective of the NbS, *effectiveness for risk reduction,* tended to push preferences towards greyer measures. This was also the case with *evidence base* and *awareness, skills, and knowledge*. Many participants were explicit in their lack of knowledge regarding whether grey is more effective than green. However, with this important caveat, the common underlying assumption at the time of the FGDs was that grey measures were more effective and the burden of proof fell on green. This was reflected in the phrasing of preferences. Green measures became viable in “an ideal world” (G2P1) and only when grey measures were referred to as being “not needed” or “required” (G1P2; G2P2):

“…because of where we live and because of the sea, somewhere we need to have something more robust than just the green measures…we're not necessarily in favour of it [grey], but we're also not against it. If it's needed, it's needed, for the risk reduction piece” (G1P2).

The implication is that if more strength is required to withstand the geophysical forces that can result in landslides, then greyer measures should be the default. Similarly, the green measures were seen as something that could be done in addition to hybrid or grey, particularly considering their perceived limitations for effective drainage: “… So I think… the nature-based [solutions], yeah, they will help, but on its own it's not the solution… if we can do this [NbS] on top, fantastic, it all helps” (G1P2). As mentioned previously, the green measures proposed as part of the project (described as NbS) were also understood by some as experiments.

The perceived need by both the participants and the OPERANDUM project to test and collect evidence for different kinds of NbS is indicative of the current lack of evidence, which in turn pushes preferences towards greyer measures: “… I’m not against it, the branches in the trench [willow branches as NbS], but I just… I need to be convinced of that one myself” (G1P2); “...if there is a green solution here then fine, sell it to me!” (G3P1). One exchange between participants reflected the reliance of the measures on the community and the resultant influence of this factor on greyer preferences:

G2P3: “…community led volunteer efforts… highly rest, almost one hundred percent on the competency of that community, the skills you have, the confidence you have to execute that piece of work...”

G2P1: “Yeah, very true… because when somebody does their research on the internet and they discover, oh look at this option on the right [grey], which is the one that we all see the most often, that's kind of the way that we're pushed towards, because we're thinking right, that's how we're going to do it, that will stabilise the slopes long term, everyone's happy. But the one on the left [green] is one that we don't see available online if you Google it. Unless you're very specific, you won't come across it.”

The exchange also demonstrates the connection between a lack of available evidence and insufficient *awareness, knowledge, and skills*. This leads to greater uncertainty and, in turn, less acceptance of the perceived inherent risk in implementing green rather than grey measures: “… They [residents] see a bunch of people putting in sand banks and wooden trellising and planting willow trees and 10 years down the line it all just falls down and we're actually in a worse position, so they see an implicit risk in doing that” (G4P1).

4.4 Discussion

4.4.1 Grey over uncertain green if necessary for risk reduction

The FGD results were in line with the survey results from Catterline regarding preferences for grey measures, which were negatively associated with perceived effectiveness of NbS and *commitment to nature* (in the FGDs the importance of natural co-benefits). Therefore, one plausible interpretation of the survey findings from the perspective of a typical Catterline resident might be:

I like the green measures, but I don't know if they are effective, so if greyer measures are (also) needed, then I would prefer these be implemented.

One discrepancy between the surveys and FGDs was the importance of risk perception on greyer preferences - insignificant or low correlations on the survey but a positive relation in the FGDs. The residents who are most at risk in Catterline live on the slopes and also derive the most benefit from the scenic views and wildlife of the village. These benefits likely moderate preferences for grey measures despite higher risk perception. Additionally, both the surveys and FGDs highlighted the importance of perceived effectiveness, which may act as an intermediary variable between risk perception and preferences for green-hybrid-grey measures (Anderson and Renaud 2021; Kim and Petrolia 2013). In other words, high risk may be perceived, but more information is needed to draw the conclusion that grey is therefore necessary to reduce risk instead of NbS. When asked to choose a position on the green-hybrid-grey spectrum based on their current understanding, Catterline residents selected the option with the least perceived risk of failure to sufficiently reduce risk. The burden of proof therefore falls on the green measures in this context of insufficient evidence, positioning grey measures as a persistent 'default option' for risk reduction that must be overcome (Gifford 2011; Wood and Rünger 2016; World Bank 2015).

The current information deficit acknowledged by the participants is a common issue with NbS projects, given their novelty, specificity to local contexts, and non-obvious or invisible mechanisms for reducing risk (Bark et al. 2021; Schernewski et al. 2017; Seddon et al. 2020). For example, past research has shown a lack of awareness for the capacity of wetlands (Davenport et al. 2010) or sustainable urban drainage systems (SuDs) (Williams et al. 2019) to reduce flooding. Our findings suggest malleability in preferences and more information, evidence, and experience of NbS benefits potentially leading to greener preferences. Experiential and participatory learning would be ideal (Herringshaw et al. 2010), coupled with the provision of easily understandable evidence of effectiveness through NbS monitoring. In the case of Catterline, a willow tree at the toe of the slope withstood decades of high impact storm surge events, whereas a seawall made of concrete blocks was destroyed and remains scattered on the beach. Combining the transparent provision of technical evidence in an understandable format for lay-persons (Blastland et al. 2020) with this kind of visual evidence within a compelling story could counteract the common misperception in the focus groups regarding the potentially inadequate strength of green approaches and their longevity (Krakow et al. 2018).

However, if expectations are not met or the NbS are seen as inadequate, this could quickly result in supporting assumptions that these measures are softer, weaker, and ‘less engineered’. This dominant framing is further demonstrated by the descriptive language used by FGD participants. If we, as NbS researchers and practitioners, refer to grey measures as ‘hard’ and ‘engineered’ to contrast with NbS (IUCN 2020b; Jones et al. 2012a), the initial public position of grey=strong/effective and NbS=weak/ineffective should be expected. Although the ‘natural’ and ‘green’ framing may be initially appealing (Mell 2013; Osaka et al. 2021), presenting the technical aspect of NbS and its practitioners -e.g., environmental engineers, physical geographers, geologists, geophysicists, etc.- may act to legitimize its image in the eyes of an at-risk public. The emphasis on *natural* co-benefits must therefore be approached carefully, on a case-by-case basis, and depending on the values of the stakeholders.

4.4.2 NbS as ‘no-regret’ measures?

Past research has shown that co-benefits can shape preferences for risk reduction measures despite their perceived (lack of) effectiveness at risk reduction (Karrasch et al. 2014; Khew et al. 2015; Roca and Villares 2012). In the case of Catterline, wildlife habitat and aesthetics was highly valued by participants (supported by their high underlying *commitment to nature*), but this was framed as a secondary benefit and only acceptable if the measures first met a high threshold for slope stabilisation. This dominant perspective, in line with the OPERANDUM project's primary objective, led to remarkably little conflict among participants when discussing group preferences. Only one FGD participant was initially more interested in natural co-benefits, but quickly deferred preferences to other group members who were more concerned about landslide risk. When asked directly, residents wanted to maximise both *risk reduction* and *wildlife habitat and aesthetics* and stated that this was realistic to attempt. However, discussion regarding green-hybrid-grey preferences suggested some perceived non-complementarity between these two attributes, i.e., the attributes also acted as trade-offs. This expands on previous findings by raising the possibility that an overemphasis on co-benefits from project managers could detract from public acceptance and even the perceived ability of the measures to reduce risk.

Regret was not seen as a potential outcome since participants thought that any green-hybrid-grey choice should be based on all available technical criteria to ensure a minimum threshold of risk reduction. Any measure would then either meet expectations (success) or not (failure). This framing suggests that provision of co-benefits in Catterline will not maintain or increase public acceptance of NbS unless adequate risk reduction is also provided. This is crucial because it implies that the 'low- or no-regret' framing promoted by NbS practitioners is not always shared by those at risk. Therefore, marketing measures as 'no-regret' may lead to skeptical perceptions characteristic of 'green-washing' and an eventual degradation of trust in the NbS 'brand' (Goh and Balaji 2016; Leonidou and Skarmeas 2017; Seddon et al. 2021). NbS principles aim to address this to some degree, e.g., with co-creation for clear and transparent aims to avoid misaligned expectations (IUCN 2020b). However, the funding and general framing of projects mostly occurs prior to engaging and sufficiently understanding the values of all relevant stakeholders.

Two other 'no-regret' characteristics were recognised by FGD participants - cost and adaptability. Cost was frequently mentioned as an important factor and constraint behind the process of determining green-hybrid-grey preferences. Our findings suggest that if NbS effectiveness meets a public threshold for risk tolerance (Anderson and Renaud 2021; Sjöberg 1999; Winter and Bromhead 2012), the low-cost and/or cost-effectiveness aspect of the 'no-regret' framing

(IPCC 2012) may increase acceptance. Some participants also recognised the greater flexibility of green measures over time, although this was referenced in relation to “stabilisation over time” and lower maintenance (Table 4-3) rather than climate change. These other aspects of the ‘no-regret’ framing of NbS (IPCC 2012; Jones et al. 2012a) would likely prove more appealing than that of co-benefits to the residents of Catterline and other at-risk NbS host communities, since it is more directly linked to the effectiveness of the measures over time as well as reduced cost and effort. FGD participants did value wildlife habitat and aesthetics, but their provision as a ‘win-win’ scenario (IPCC 2012) aligned public preferences with hybrid measures rather than strictly green.

4.4.3 Hybrid measures as the “best of both worlds”?

Hybrid measures were favoured by FGD participants since they were seen as hedging against uncertainty, avoiding unacceptable trade-offs in green or grey measures, and because the current slope is green, natural and yet unstable (and intolerable). This latter factor was exacerbated by the perceived current ecosystem disservice of an out-of-control rabbit population, and supported the participants’ idea that something ‘more’ or ‘other’ than green was needed. Along with the need to carefully consider the ‘green’ and ‘natural’ framing, NbS implemented without noticeably altering the existing ecosystem (i.e., Type 1 or Type 2 as per Eggermont et al. (2015)) may be perceived as inadequate in contexts of intolerable risk. This is possibly more relevant for the rural OPERANDUM project sites rather than urban NbS, since rural changes and benefits are often less noticeable, making public acceptance of NbS more difficult (Anderson and Renaud 2021). One respondent also explained, “it's not like we're living in an area where there's nowhere else for the rabbits and the starlings to go” (G4P1), indicating the decreased relative value of the green framing in a rural natural area.

The residents’ general preferences for hybrid measures, although informed by some misperceptions, are supported by relevant academic and DRR practitioner literature (Browder et al. 2019; Cheong et al. 2013; Depietri and McPhearson 2017; Seddon et al. 2020). Hybrid approaches may more closely reflect the ‘low- or no-regret’ framing, given their synergies for climate change adaptation against a range of possible future scenarios and increasingly intense hazard events (Cheong et al. 2013; Depietri and McPhearson 2017). Similarly, Salgado and Martinez (2017) and Sutton-Grier et al. (2015) argue that hybrid measures for coastal resilience may capitalise on the strengths of grey and green while minimizing their weaknesses. Some of the most proven examples of this practice include restoring floodplains while moving existing grey structures back (i.e., managed realignment) (Esteves and Thomas 2014; Vriend et al. 2015), using permeable dams to protect restored mangrove forests (Winterwerp et al. 2016), or using vegetation to protect existing grey infrastructure (Slobbe et al. 2013). In the case of landslides, using geo-textiles and anchors combined with vegetation can create synergies (Singh 2010). This was favoured by several participants since a vegetated ecosystem covering grey infrastructure would not detract from the natural co-benefits while the grey elements would provide a greater sense of security.

Hybrid measures may instil more confidence in at-risk communities since often their grey elements are immediately effective and their green elements take time to establish and may require initial protection (Depietri and McPhearson 2017; Sutton-Grier et al. 2015). This synergy can better satisfy short- and long-term stakeholder aims (Browder et al. 2019). Seasonal variations in effectiveness are also a potential limitation of strictly green measures, given vegetative growth cycles (Browder et al. 2019; Shah et al. 2020). Considerations surrounding time were highly influential on preferences, and legitimate concerns were raised in the FGDs. Among these was the preference of some participants' to deploy different kinds of measures at different times and in different locations in the community.

A final compelling argument for hybrid measures is related to the path-dependency of grey infrastructure (Davies and Lafortezza 2019; Depietri and McPhearson 2017). Along with grey measures being less adaptable and more 'locked-in', the existing technical knowledge of engineers and architects must be integrated and adapted for NbS (Kabisch et al. 2016), along with creating the educational and institutional environments for dedicated technical NbS practitioners. Additionally, grey infrastructure already exists in many places, and integrating green with grey can reduce political, financial, and engineering constraints (Cheong et al. 2013; Onuma and Tsuge 2018). As supported by our study, integrating green with grey may also increase public acceptance of measures (Depietri and McPhearson 2017; Sutton-Grier et al. 2015). Ongoing climate change, biodiversity, and development crises warrant advocacy against the dominant grey paradigm and towards greener measures (JNCC 2021; Seddon et al. 2020). However, hybrid measures may act as a societal steppingstone from grey to green. In any case, the cost-effectiveness and potential synergies of NbS in relation to viable alternatives that use varying degrees of grey infrastructure should be systematically considered (IUCN 2020a).

4.4.4 Study limitations and way forward

Limitations of the surveys include the single item dependent variables (rather than more robust scales), the low reliability of the risk perception scale, non-random sampling, and sample sizes, as described in more detail in Anderson et al. (2021). To counteract low internal reliability scores of scales, we tested correlations against individual survey items without notable differences in results. Although residents of different areas of the Catterline community participated in the FGDs, the 10 participants were too few to ensure that all perspectives were captured and participants likely represented a more knowledgeable and engaged perspective. However, most findings were triangulated with the survey data and/or reflect perspectives that repeatedly emerged among FGDs.

Because NbS were already being planned within the OPERANDUM project, preferences were more hypothetical than actionable. It was made clear that preferences would not immediately influence OPERANDUM work but were important for future work and better collaboration with the community. We encourage similar studies at green-hybrid-grey sites within different social-ecological systems and at different project phases. Situations of actionable choices should also be studied, while scenario-based methods like serious games could better simulate the temporal element needed for exploring regret (Henly-Shepard et al. 2015; Riddell et al. 2018; Tompkins et al. 2008).

We elicit preferences based on the two attributes of *risk reduction* (efficacy) and *wildlife habitat and aesthetics*, but other attributes, particularly cost, were important to the participants. Cost considerations like fixed budgets can act on perceived complementarity or non-complementarity of attributes and the 'regret' or 'no-regret' characteristics of the measures. We view (non-)complementarity and (no-)regret findings as preliminary and call for further research using attribute-centric methods like choice experiments as well as exploring group preference shifts (based on our experience with one FGD participant; e.g., in what situations (and risk contexts) will NbS stakeholders who prioritise co-benefits defer their green-hybrid-grey preferences to others who prioritise risk reduction?) (Jagau and Offerman 2018; Olschewski et al. 2012). In addition to more temporally dynamic methods, a greater emphasis on methods from psychology and (risk) communication could inform further research needed to understand stakeholder connotations of NbS-relevant terminology (Osaka et al. 2021). For example, comparing perceptions of 'NbS' with 'green infrastructure' and 'ecological engineering' could help us understand connections between framings, connotations, and public expectations to improve stakeholder engagement and public acceptance.

Further research is needed to determine whether increased information and background knowledge would decrease uncertainty (Walker et al. 2013) in this context and shift preferences away from hybrid. In the meantime, increased two-way and transparent communication is needed in NbS projects. As an example, in Catterline some residents understood the NbS to be implemented as "trials" or "experiments" for risk reduction that could be unavoidably undermined by "freak storms" in the coming years. Others placed unrealistic certainty in the measures, based largely on trust in the project and its implementers. Here, transparency and better communication could help avoid the potential erosion of trust through unmet expectations. Further research should explore learning processes and how information is integrated into the pre-existing beliefs and resulting preferences for NbS (Herringshaw et al. 2010; Murti and Mathez-Stiefel 2019).

Continued research on the effectiveness of green and hybrid measures across social-ecological risk contexts is also needed. But can the NbS community also make green measures intuitively seen as (more) effective for reducing risk? How does the multi-attribute nature of NbS with co-benefits support or detract from this objective? What about the connotations of the terms 'NbS', 'green', and 'grey'? Answering these questions is important given the reliance of NbS on public support, while the need to reduce risk and address climate change further increase their urgency.

4.5 Conclusion

NbS in Europe generally enjoy widespread public support (European Commission 2015a). This is a testament to the ability of NbS to provide a range of societal benefits and generally positive perceptions of nature and 'naturalness'. However, we have shown that greyer measures, and particularly hybrid measures, can be more appealing to an at-risk public. Negative public perceptions of green measures can act in concert to discourage their use, including their characterization as being weaker and surrounded by uncertainty, requiring more effort, and not being immediately beneficial. These factors are exacerbated by a more limited technical evidence base than grey measures and a lack of associated public awareness, knowledge, and skills. For continued uptake of NbS, the ongoing surge in NbS projects must meet the high public expectations associated with risk reduction. Collecting and demonstrating evidence, along with managing these expectations, will help prevent reputational damage. If we fail, the current cautious optimism toward green measures in communities like Catterline may quickly lead to unwavering scepticism and support for greyer measures.

5 Conclusion

5.1 Summary of findings and implications

The research presented has aimed to *define, explore, and explain public acceptance of NbS, reflecting also on preferences for greyer measures, and to provide recommendations for increasing public acceptance within the OPERANDUM study sites and beyond*. The mixed-method and interdisciplinary approach used in this thesis represents an advancement of NbS for DRR research and enabled triangulation and in-depth exploration of findings. From a broad perspective, the work has shown that societal relations with NbS, and particularly public acceptance, are important for the success of NbS and differ from grey infrastructure approaches to DRR. NbS is an inclusive umbrella concept that allows for contextual specificity when implemented, defined by characteristics such as place, hazard, culture, and past experiences. Despite this, NbS for DRR measures have similarities that allow for the systematic consideration of public acceptance.

Taking the three papers together, and addressing the three corresponding overarching research questions outlined in the Introduction, this thesis has demonstrated that:

1. Public acceptance of NbS for DRR is important, and more important than for grey DRR measures. Crucially, public acceptance can lead to successful outcomes throughout NbS project phases, including for initial design and planning and longer-term sustainable use and upscaling.
2. Factors including perceptions of risk, nature, place, and DRR effectiveness, along with attitudes defined by trust, cost-benefit, and ‘good-satisfied’, are associated with differing degrees of acceptance and may be crucial for efforts to maintain or increase it.
3. Public acceptance of residents in planned NbS host communities is mostly high. However, certain underlying perceptions and attitudes, as well as preferences for greyer measures, make the future trajectory of acceptance uncertain.

Paper 1 (Review) showed that public acceptance of NbS is associated with positive outcomes, and that these outcomes are more relevant to NbS than grey measures. This addressed a gap in NbS research on societal relations with NbS and how these compare to grey DRR measures. This gap is in line with the first overarching research question of the thesis (Introduction): "Why, when, and how does public acceptance matter for NbS and how does this compare to grey DRR measures?" The protection of NbS against competing interests (e.g., conflicting land uses), the sustainable use and upscaling of NbS, along with the cooperation of land holders and co-implementation and co-monitoring were all significantly more important for NbS. Several of these outcomes re-emerged in the context of the surveys and focus groups. For example, in Paper 2 (Survey), perceptions regarding competing interests were important for defining attitudes towards NbS in Catterline and Puruvesi and were associated with cost-effectiveness and trust. In the FGDs (Paper 3), residents of Catterline expressed concerns regarding the effort required to maintain slope stability measures in the community. Crucially, results suggested that although the NbS were going to be implemented at the sites, concerns and negative or ambivalent attitudes surrounding the measures may lead to opposition for further NbS plans or an unwillingness to engage in long-term protection and maintenance.

Given the importance of public acceptance for positive outcomes of NbS, a greater emphasis within research and practice should be given to the recommendations and success criteria presented in the 'Public Acceptance of NbS Framework' (PA-NbS) from Paper 1 (Review). The PA-NbS synthesized four recommendations from relevant peer-reviewed literature: provide benefits, increase awareness of benefits, communicate effectively, and promote participation and collaboration. Neither the efficacy of these recommendations nor their ability to lead to successful NbS outcomes were tested in the OPERANDUM case study sites since all NbS were in the planning stage when the research was carried out. These recommendations mostly mirror NbS standards (IUCN 2020b) as well as established guidelines for stakeholder engagement within environmental issues and disaster risk research and practice (Aven and Renn 2010; Reed 2008). However, the compilation of their findings from relevant case studies in Paper 1 (Review) provides guidelines based on lessons learnt for future NbS projects. The analyses of data from local affected residents further supported their relevance. For example, the role of effective risk reduction emerged as an essential benefit to be provided for perceived success; awareness of this benefit was demanded and thus needs to be actively increased through providing evidence; effective and clear communication was called for in relation to linking risk reduction to local values and place; and collaboration was deemed necessary for improving residents' understanding of what is required (and not) for implementation and long-term maintenance of NbS.

The 'intermediary factors' in the PA-NbS derived from Paper 1 (Review) are also important for public acceptance and were explored in Papers 2 and Paper 3 (i.e., quantitatively across the three European NbS sites in Paper 2 and qualitatively in Catterline in Paper 3). This addressed the second overarching research question of the thesis (Introduction), "What is the strength of different factors behind public acceptance and do they show consistency or differ across European NbS contexts?" These factors capture different public perceptions, such as effectiveness, trust, sense of responsibility, and risk perception, and shape how the four general PA-NbS recommendations (benefits, awareness, communication, participation) are experienced at NbS sites. Generally, the literature review, correlations and regression models, and survey comments as well as FGDs showed that perceptions of risk, nature, and place, as well as attitudes defined by cost/benefit, trust, and good/satisfied with the measures are relevant for acceptance.

This work addressed knowledge gaps identified in the introduction (Table 1-2), e.g., a lack of NbS for DRR studies comprehensively identifying potentially influential factors and testing perceptions of risk, nature, place, and the NbS within the same study. Findings across the sites showed that factor associations with acceptance are context-dependent, but several similarities also emerged that may be generalisable to NbS for DRR in Europe and possibly beyond.

Cultural ecosystem services were highlighted throughout the papers as particularly influential. The review (Paper 1) was carried out at global scale, albeit primarily within developed countries, and showed that increases in aesthetic value, recreational space, and sense of place were most frequently related to greater public acceptance of NbS. Aesthetic concerns among residents of Catterline were consistently voiced during the FGDs (Paper 3), while *connectedness to place* (included to represent 'sense of place' as a cultural ecosystem service from the review) was a consistent correlate of attitudinal and behavioural acceptance, rivalled only in strength and consistency by *future impacts* and *commitment to nature*.

Past studies showing a positive relation between perceived future consequences (*future impacts*) and protective behaviour (Bubeck et al. 2012b; Sjöberg 1999) were supported in my research, while the risk perception and risk intolerance of residents were clearly relevant but inconsistently influential and possibly moderated by other variables (Paper 2). The relations among perceptions of risk and co-benefits were integrated into a theoretical framework describing their effect on public acceptance of NbS in Paper 1 (Review) - the 'Risk Perception – Measure Acceptance Model' or 'RP-MAM'. The model is a proposal for how some of the most frequently influential variables on public acceptance from the review are interconnected – risk perception, risk tolerance, effectiveness of the measure, and the provision of co-benefits as ecosystem services. The concept of risk intolerance emerged as a potentially separate consideration from risk perception in the reviewed literature, a position that found some support based on differences in correlations with measures of acceptance (Paper 2) and support for grey infrastructure (Paper 3). The theoretical relation of risk intolerance, its utility as a concept for research on public acceptance of DRR measures, and the efficacy of the RP-MAM is the subject of ongoing research I am carrying out.

Based on the evidence from Papers 2 and 3, and reflecting back on the general recommendations from the PA-NbS, recommendations can be summarised for the three NbS study sites in relation to these factors (Table 5-1). Such recommendations may form the basis of communication or behaviour change interventions. When NbS practitioners and researchers consult the PA-NbS, limited resources and contextuality will inevitably demand consideration of both the feasibility and importance of the different recommendations – i.e., what is absolutely necessary for success, what is desirable but less relevant in this case, or what should be attempted but may not be possible. As demonstrated by this research, surveys and focus groups can provide evidence regarding their relative site-specific importance.

Table 5-1 The PA-NbS framework related to study site recommendations. The recommendations from the Public Acceptance of NbS Framework (PA-NbS) most strongly supported as relevant by subsequent findings from Papers 2 and 3 are underlined (*left column)* and serve as guidance for recommendations for increasing public acceptance in the three European study sites (*right column)*.

Public Acceptance of NbS Framework recommendations (PA-NbS)	Study site recommendations
Provide benefits	
Multi-functional Equitable Tangible Non-competitive	• Ensure effective DRR • Enhance sense of place • Provide co-benefits, especially cultural ecosystem services, and protect existing natural elements • Foster trust through equitable benefits for improved attitudes • Consider unequal hazard impacts and ensure targeted but widespread benefits • Consider past impacts and future scenarios for prioritising risk reduction
Increase awareness of benefits	
Attributable Salient Evidence-based Culturally significant	• Demonstrate effective DRR • Foster participation in implementation and monitoring to increase salience • Feedback of monitoring data to the public as evidence of effectiveness • Elicit resident testimonials of benefits • Relate benefits to place-based cultural and historic contexts
Communicate effectively	
Clear and consistent Two-way and multi-path Value-framed Place-based	• Enable two-way communication (i.e., dialogue) of expectations to overcome the ‘wait and see’ mind-set • Provide evidence to support alignment of expectations for the NbS, also in relation to future scenarios (e.g., climate change, high intensity storms) • Frame communication in relation to place-based values and cultural and historic contexts • Ensure a common understanding of the problem/risk, also in relation to potential future impacts, linking the NbS as a solution
Promote participation and collaboration	
Early and sustained Broad and inclusive Meaningful and active Educational and capacity-building	• Promote sustained participation to ameliorate scepticism, build trust, and prevent erosion of current positive attitudes • Provide opportunities for learning about the NbS • Provide a range of possibilities for both passive and active engagement, with minimum entry barriers, to foster further subsequent engagement • Offer training for active collaboration and future autonomous community initiatives

Papers 2 and 3 both demonstrate relatively high *average* levels of public acceptance of NbS. This reflects the European-wide results detailed in the European Commission’s Eurobarometer 444 report *Citizen’s view on nature-*

based solutions (European Commission 2015a). At European level, 83% of respondents were in favour of the EU promoting NbS and 56% of respondents stated that they would like to participate with NbS in their area. Despite relatively high acceptance, my research also uncovered perceptions and attitudes at an individual level that act to either strengthen opposition to NbS and/or shift support towards greyer measures. For example, in addition to concerns regarding DRR effectiveness, participants around Lake Puruvesi expressed doubts regarding the seriousness of the risks and therefore whether the cost-benefit supports implementation of the measures. The *process* of implementation was highlighted, rather than just the idea of NbS. For example, many residents suggested alternative ways to reduce risk and measured 'satisfaction with implementation' was lower than general sentiments. Additionally, different degrees of trust in implementers were central to attitudes towards NbS, which were consistently correlated with items related to perceived risk and *commitment to nature* across the sites (Paper 2).

The 'wait and see' mind-set towards NbS expressed by the residents, also described as 'cautious optimism', was a trend across the papers. This reflects the uncertain future trajectory of public acceptance of NbS, both within the study sites and more broadly. It implies that acceptance can be increased but expectations must also be fulfilled in the coming months and years. The early project phases in OPERANDUM, during which this research was conducted, mirrors the still evolving NbS concept. The sense of cautious optimism expressed by study participants may reflect broader societal attitudes towards NbS, including among the non-affected public and other stakeholder groups. Although research is needed that also focuses on these groups, if true, it would suggest that we are at a decisive moment for the continued global uptake of NbS.

A parallel can be drawn between research focusing on public acceptance of wind energy, as described in the introduction. A common early assumption suggested that its benefits, combined with average public acceptance at broad spatial scales, would translate into community-level support (Wolsink 2007; Wüstenhagen et al. 2007). This turned out to be unreliable, since actual site-level implementation required difficult decisions regarding land use, the opportunity cost of using other energy sources, as well as concerns regarding aesthetics and equitable societal benefits from host communities (Wüstenhagen et al. 2007). Further research at the NbS study sites is needed to follow changing attitudes and behaviours throughout project phases. However, the factors identified as relevant to public acceptance and issues raised by residents should serve as a warning to NbS researchers and practitioners. Investments in efforts to ensure public acceptance at local levels must be made within NbS projects, rather than following the path of wind energy implementation and reactively managing obstacles fostered by assumptions. Early and sustained action can address emergent issues, while ensuring broad continued acceptance and shifting perspectives from cautious optimism to informed confidence, and even pride. Successful case studies with supporting evidence combined with stakeholder endorsement will be needed for upscaling NbS.

To achieve this, supported by perhaps the most consistent finding across the papers, risk must be effectively reduced from the respective natural hazards. This is unsurprising given its positioning as the primary objective of the OPERANDUM project within the sites. However, my research has shown that while co-benefits were important for acceptance (e.g., cultural ecosystem services were highlighted in all three papers), they were mostly perceived as supplementary. In other words, at least for an at-risk public, acceptance may only increase with co-benefits if a certain threshold of risk reduction is met. Additionally, preferences towards hybrid measures emerged from this perspective in Paper 3 (FGDs), since they were seen as the best way to balance potential trade-offs between green NbS and grey measures. This relates to the third overarching research question of the thesis (Introduction), "Do local residents at planned NbS sites prefer NbS over hybrid or grey measures and what factors and/or (mis)perceptions influence their preferences?" Paper 3 also advanced NbS for DRR research by determining local preferences along the full green-hybrid-grey spectrum, as well as challenging the associated potential for perceived 'win-win' and 'no-regret' measures. The FGDs conducted in Catterline elicited a range of perspectives regarding the cost, effort, maintenance, and short- and long-term effectiveness of NbS (Paper 3). Although most perceptions reflected some degree of accuracy regarding green NbS, contradictory and misinformed positions also emerged (e.g., in relation to the weakness, cost, and effort needed).

The shift towards increased stakeholder engagement within DRR and NbS projects implies a transfer of some decision-making power from experts to the affected public (Aven and Renn 2010; Kuhlicke et al. 2020; Puskás et al. 2021; Renn 2015). If preferences from at-risk host communities are truly integrated into the design and planning of measures, my research suggests that hybrid measures may become increasingly popular. Indeed, this trend may already be underway based on their increased promotion in academic and grey literature (Browder et al. 2019; Depietri and McPhearson 2017; Sutton-Grier et al. 2015). Of course, technical considerations are crucial in this context, but public (mis)perceptions regarding greener or greyer options must also be accounted for. Knowledge gaps should be targeted within projects, while at the same time transparently communicating any trade-offs associated with implementation of greener measures.

As mentioned in Paper 1 (review), the IUCN Global Standard for NbS (IUCN 2020b) share similarities with the criteria and recommendations provided in the PA-NbS. Papers 2 and 3 further reveal areas of convergence as well as potential gaps. The first criterion, “NbS effectively address societal challenges” has as its first indicator (1.1), “The most pressing societal challenge(s) for rights-holders and beneficiaries are prioritised” (IUCN 2020b, p. 6). Both the perceived importance of effective DRR and the implications of its positioning as the most pressing societal challenge by study participants support the prominence of this first criterion and indicator. Criterion 6 qualifies Criterion 1 in relation to co-benefits, “NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits” (IUCN 2020b, p. 16). Here, Paper 3 (FGDs) strongly supports this consideration for NbS practitioners, since Catterline residents’ descriptions of benefits from NbS suggested some non-complementarity between DRR and *wildlife habitat and aesthetics*. My research within the OPERANDUM project highlights the importance and underlying intricacies of Criterion 6. There is an intuitive but possibly counterproductive assumption on the part of NbS practitioners and researchers that emphasizing more co-benefits should lead to greater stakeholder acceptance. Research should not only identify the primary goal of stakeholders and the importance of a range of ecosystem services as co-benefits, but also the perceived and actual relations among these (i.e., the degree to which they represent synergies or trade-offs).

The role of Criterion 5 was also highlighted: “NbS are based on inclusive, transparent and empowering governance processes” (IUCN 2020b, p. 14). Transparency is closely related to trust in implementers, which was the most consistent variable that comprised attitudes toward NbS in the sites (Paper 2). It is also relevant to managing and aligning public expectations regarding the efficacy of NbS in relation to other options and in the context of future scenarios (Paper 3). As mentioned, the importance of *processes* was emphasised, with general positive perceptions of NbS, but several avenues for conflict in relation to how they are being planned and implemented. This is linked to the equity of benefits, their relation to competing societal interests, and the different expectations regarding green NbS described by residents of Catterline.

I argued in Paper 1 (Review) that the recommendation from the PA-NbS to ‘increase awareness of benefits’ is not addressed in the IUCN standards (IUCN 2020b) and should be taken up in the future. Evidence from Papers 2 and 3 further supports this stance, regarding the importance of effective DRR and scepticism of the strength of NbS. Similarly, a lack of relevant local awareness, knowledge, and skills was identified in Paper 3 (FGDs), with all corresponding public perspectives detracting from preferences for green measures and supporting preferences for grey measures. Most prominently, residents of Catterline described difficulties in understanding how NbS provide DRR benefits and in finding relevant case studies and information. Active and evidence-based stakeholder learning is needed that attributes benefits to NbS, increases the salience of benefits, and is culturally significant (corresponding to PA-NbS success criteria). NbS rely on inclusive governance approaches (Criterion 5) for the equitable provision of benefits (Criteria 1 and 6). Involving at-risk public stakeholders within NbS host communities while accounting for their perceptions and corresponding attitudes and interests is crucial for fulfilling these criteria and for the success and continued uptake of NbS.

5.2 Limitations and potential misinterpretations of the research

This research has focussed on acceptance by the affected public of planned NbS for DRR at three rural European sites. My research aligns with the broader field of public acceptance by demonstrating that societal uptake is crucial for success despite any proven instrumental merit of the object (NbS in this case). However, I have focussed on one issue for successful NbS among many, and my research should not detract or distract from other efforts. Additionally, drastically different circumstances surrounding NbS for DRR, and other NbS approaches, would likely alter results. Without discounting the exposure of the study participants to the hazards, it is nevertheless worth considering the relative safety and well-being of the affected public in my research. In contrast, there are other global NbS host communities with perspectives influenced by a high risk of loss of life and a reliance on ecosystem services for survival (e.g., in relation to mangrove restoration in Southeast Asia) (Barbier 2006; Nguyen et al. 2015). The importance of cultural ecosystem services like aesthetic value in this research are very likely secondary to issues of life and livelihood in another context. As mentioned in Paper 2 (Survey), my research is embedded within the OPERANDUM project and is therefore grounded within a project-based scenario with external managers who are the ultimate decision-makers but who seek to collaborate with local stakeholders. Local perceptions as well as the relevance of recommendations provided may differ for NbS in situations of community self-organization (Puskás et al. 2021).

My research has generated guidance for approaching the issue of public acceptance within NbS for DRR projects through case-study examples and identification of highly relevant factors. Triangulating findings based on the global literature review (Paper 1) and similarities across the sites suggests some generalisation to other contexts is possible, but further research is needed. Additionally, the strength and relevance of the factors as well as the feasibility and appropriateness of acting on corresponding findings must be tested within specific contexts. The PA-NbS can be used as a starting point for addressing this societal barrier to NbS, while the replication of the methods and consideration of the factors and their interconnections should lead to evidence-based strategies.

The influence of the factors and efficacy of the recommendations for actively increasing acceptance necessarily make some assumptions regarding causality and should therefore be seen rather as suggestions that require testing. Causal relations cannot be determined based on the single-point data collection methods used in this research. This distinction is important given that the recommendations based on the results mostly aim to *increase* public acceptance. In response, the mixed-methods approach used allows for triangulation across data sources, particularly in the case of Catterline. The relations among factors from the literature review provided an underlying argument for exploring their potential causal relevance towards public acceptance in the study sites. Subsequently, knowledge of the sites from national experts (i.e., OPERANDUM project managers) played a role in determining what should be assessed and why, along with plausible hypotheses regarding what *influences* public acceptance. Comments on the surveys provided a useful qualitative dimension to support understanding of variable relations, while the FGDs described in Paper 3 explored factors that were often explicitly described by residents as acting on acceptance.

As an example, *connectedness to place* showed a consistent positive association with willingness to engage with the NbS (behavioural acceptance). This means that those participants with higher *connectedness to place* are generally more willing to engage (and/or residents with low *connectedness to place* are generally less willing to engage). However, this does not imply that acting on *connectedness to place* will (causally) create a change in willingness to engage within an individual. The historical and cultural relevance of the village of Catterline to its residents (as well as the region and country) was understood prior to collecting data through desktop research, informal conversations with researchers, and documented past experiences with stakeholders in the sites. Also, data from the surveys and FGDs show that a) *connectedness to place* is high among residents, b) the perceived threat to history and culture presented by landslides is associated with behavioural acceptance, and c) aesthetic beauty and whether the NbS 'fits in' with its surrounding environment is one explicit driver of green-hybrid-grey preferences as described by residents (Paper 3). This evidence, taken together, suggests that the role of perceptions of place *in relation to the NbS* should at least be considered within the project. If possible, the provision of cultural benefits and framing of the objectives of the NbS should be subsequently tested for their efficacy at increasing public acceptance.

Such efforts should also consider other potential positive outcomes, trade-offs, and opportunity costs (i.e., how could resources otherwise be used and are other factors or framings more important). For example, there may be a risk of creating ambivalence in those few residents with low *connectedness to place* who have recently moved to the village and are only motivated by protection of personal property. As mentioned in Paper 2 (Survey), segmenting results so that recommendations are as targeted as possible and do not assume a homogenous public can be helpful in this regard. Section A.4 (Additional analyses) of the appendix is devoted to describing further analyses in relation to comparing statistics for low and high-risk respondents, the role of ecosystem services for acceptance based on survey responses, and how spatial NbS perceptions relate to acceptance in Catterline. Moreover, in the *connectedness to place* example above, it is unlikely that a closer consideration of place-based characteristics throughout the NbS project phases will lead to *worse* outcomes. Unreasonable cost or opportunity cost associated with this effort is the most serious issue. Similarly, following the site-specific and general PA-NbS framework recommendations can improve outcomes irrespective of public acceptance. Ensuring that NbS provide benefits obviously improves outcomes, but successfully integrating local knowledge, for example, can also increase the long-term efficacy of NbS (IUCN 2020a; Mukherjee and Shaw 2021; Pueyo-Ros et al. 2019).

In addition to the instrumental motive of increasing public acceptance (e.g., the ‘positive outcomes’ outlined in Paper 1), there is a strong ethical argument for incorporating stakeholder perceptions and values into projects (Aven and Renn 2010; Reed 2008; Renn 2015). The PA-NbS recommendations are aligned with an ethical approach, mirrored also in IUCN guidelines. For example, transparent communication and a fair and equitable distribution of benefits are highlighted (Cohen-Shacham et al. 2016; IUCN 2020a). Issues of fairness and equity are often most relevant to marginalized groups. However, my research has not taken this approach due to the relative homogeneity of the study sites, and particularly the small village of Catterline where most of the data were collected. Related also to the generalisability of the results to other global contexts, the relative homogeneity of the sites underlines the fact that most participants in this study were WEIRD (Western, educated, industrialized, rich and democratic) (Henrich et al. 2010). If relevant, similar studies should incorporate diverse world views and indigenous knowledge and also consider diverse human-nature and human-risk perspectives (Díaz et al. 2015). Further research on public acceptance of NbS should more prominently describe the perceptions and acceptance of the marginalized, integrating issues of social vulnerability and climate justice into research design where appropriate (Cousins 2021; Kabisch et al. 2016; Kaufmann et al. 2021).

My description of 'promoting' NbS and the implicit objective of behaviour change from a position of power (e.g., project managers framing communication based on the values of residents) should not be misconstrued as unethical manipulation. This criticism has been made at the behavioural insights approach and practice of policy designed at 'nudging' individuals' choices (Schubert 2017). Critiques outlined in Franks et al. (2017) include undermining autonomy and loss of experiential learning gained through making mistakes, the potential erosion of trust in the nudgers (e.g., government), and issues of fairness such as whether vulnerable or marginalized groups are disproportionately affected.

The World Bank describes 'nudging' as "a policy that achieves behaviour change without actually changing the set of choices. It does not forbid, penalize, or reward any particular choices. Instead, it points people toward a particular choice by changing the default option, the description, the anchor, or the reference point" (World Bank Group 2015, p. 36). This definition is in line with one broad response to the criticisms outlined above – i.e., no coercion is involved. Another response is that the practice, even if often unintended, is in fact ubiquitous. Franks et al. (2017) point out that "Especially with respect to complex entities or events, any definition, explanation or argument will be selective to some degree, and so 'framing' can simply be understood as referring to the partial and provisional nature of knowledge" (p. 108). Therefore, the notion of critical and deliberative self-autonomy in a world of partial and tailored information is itself questionable (Schubert 2017). In relation to NbS, as described in Paper 3 (FGDs) and supported by Osaka et al. (2021) and Woroniecki et al. (2020), research is urgently needed on how its 'natural' framing affects acceptance among different stakeholder groups.

Using coercion, manipulation, or inaccurate information in an attempt to increase public acceptance would also be counterproductive. My work aligns with past research showing that ethical practices themselves are conducive to public support, including building trust, transparent communication, and active collaboration and power-sharing, among other practices (Aven and Renn 2010; Reed 2008). As I discussed in Paper 3 (FGDs), the long-term reputation of NbS may be susceptible to claims of green-washing if best practice guidelines are not followed and we fail to sufficiently account for the importance of public perceptions. Just recently, the popular political/environmental activist George Monbiot published an opinion article in the UK-based news outlet *The Guardian* equating NbS projects for carbon sequestration as 'carbon colonialism'[19]. Although controversial, the article highlights the range of contexts in which the term NbS is used, including its uptake by international oil and gas companies, and the threat of unmanageable reputational damage to the concept.

Impacts and outcomes at a local scale may involve some of the same stakeholders and be relevant for broader societal attitudes (Upham et al. 2015). Determining how acceptance and uptake of NbS diffuses among different stakeholders, including the perspectives of the local at-risk public, warrants further research (Kronenberg et al. 2017). A process of 'problem-framing' in NbS for DRR projects should be carried out very early in the stakeholder engagement process to ensure that the overall goal is shared between the project managers and the public, among other stakeholders (Albert et al. 2020; IUCN 2020b). With this transparently and collectively defined, attempts to address any misperceptions and improve attitudes should align with shared stakeholder goals, reducing the potential for hidden motivations or manipulation.

Another pertinent critique of using behavioural insights in Franks et al. (2017) is the shifting of responsibility for deeply rooted collective issues onto individuals. This has been mentioned in the introduction and the papers in relation to the 'behavioural shift' in DRR, in which individuals are increasingly relied upon and governments therefore may not be held to the same level of accountability (Begg et al. 2018; Kuhlicke et al. 2020; Lisowski 2000). All powerful entities,

[19] https://www.theguardian.com/commentisfree/2022/jan/26/carbon-offsetting-environmental-collapse-carbon-land-grab

including governments, must be held societally accountable in proportion to their power. To the extent that any blame should be ascribed, individual misperceptions or low acceptance towards NbS by local public stakeholders represent a societal rather than a personal shortcoming. There is a history of manipulation and over-attribution of blame to the public for environmental issues worth remembering. For example, the responsibility placed on citizens to recycle plastics despite its longstanding economic unviability[20] or to make substantial personal sacrifices to reduce carbon emissions despite the trillions of USD in global government subsidies still given to oil companies (Parry et al. 2021). Regarding NbS for DRR, further research is needed to assess when and how responsibility is allocated, the role of power dynamics among stakeholders, and the implications for accountability (Puskás et al. 2021; Woroniecki et al. 2020).

5.3 Outlook and way forward

Learning from experience and subsequently following best practices is crucial for the success and sustainability of the ongoing rise in NbS funding and projects. The need for further social science research has been addressed throughout this thesis. Most importantly, determining causal relations among stakeholders, attitudes and behaviours, and NbS outcomes could greatly advance this body of research. NbS take a long-term perspective to addressing societal problems (Cohen-Shacham et al. 2019; IUCN 2020a), and therefore adequately collecting and evaluating relevant monitoring data takes time. Follow-up research should test the recommendations provided here using experimental and longitudinal designs (Kuhlicke et al. 2020). This is particularly relevant for public acceptance since past research has shown how local public attitudes can shift before, during, and after implementation. Typically for wind power, a U-shaped trend of high positive attitudes to the idea is followed by lower acceptance once the project must be sited, but eventually positive attitudes return some time after implementation (Devine-Wright 2005; Wolsink 2007). Shifts in the factors assessed can also occur. For example, Bubeck et al. (2012a) describe how risk

[20] https://www.npr.org/transcripts/912150085

perceptions and the strength of their relation to precautionary behaviour often decrease after a measure has been carried out.

Perceptions of risk, nature, place, and NbS effectiveness are influenced by surrounding environmental attributes, including cultural characteristics (Han and Kuhlicke 2021; Eiser et al. 2012). The analysis conducted could be expanded by comparing influential cultural factors regarding human-nature and human-risk relations (e.g., Sjöberg 2000c), as well as differences in institutional culture (e.g., regarding risk management) across case studies (Loft et al. 2015; Rufat et al. 2020). One possibility is that by reducing a risk using nature, that risk becomes increasingly perceived as being embedded within nature. This is in opposition to the technocratic paradigm of DRR in which nature and natural phenomena are viewed as an external threat to be subdued or managed (Harries and Penning-Rowsell 2011; Hewitt 1983; O'Keefe et al. 1976). Further research could determine links between public acceptance and cultural characteristics through a greater understanding of societal relations with nature and their effect on perceptions of the 'naturalness' of NbS and preferences for green-hybrid-grey measures.

Potential influential factors beyond these themes also deserve consideration, but were not addressed here due to the context of the research. For example, the role of knowledge and self-efficacy would help align relevant research more closely with established behavioural theories (Ajzen 1991; Rogers 1975). In addition, there is a need to further emphasize the role of past acceptance and cost, which were consistently associated with public acceptance in the three papers but could be explored in more detail within a different context or using a different research design. Linking perceived cost to feasibility and cost-effectiveness studies may provide insight, since my research has shown that the attitudes, behaviours, and green-hybrid-grey preferences of local public actors, not just decision makers, are influenced by relative cost.

Similarly, I have mostly focused on what influences behaviour in relation to cognitive appraisal (i.e., 'System 2', or 'slow' and deliberative thinking) (Kahneman 2012). However, relevant research from psychology has demonstrated the role of affect (i.e., feelings and emotions) for determining attitudes and behaviours (Breakwell 2007; Sjöberg 2007). Emotions have been shown to be important predictors of perceptions of risk and acceptance of new technologies (Gupta et al. 2012) and their relevance is reflected in prominent behavioural theories (Epstein 2014). Affect should also be considered for (risk) communication to stakeholders (Breakwell 2007; Koo et al. 2019), including for designing and implementing the strategies to increase acceptance described in this thesis. I focused on cognitive deliberative factors given that communication, information, and knowledge are more easily addressed from an NbS for DRR project management perspective (Bubeck et al. 2012a; Bubeck et al. 2012b; Sjöberg 2007). In addition, values expressed by respondents in relation to place and nature (Papers 2 and 3) have an affective component and were strongly related to acceptance. Such insights suggest that more closely embedding research design and methods within the tradition of psychology-oriented research is warranted, particularly regarding the feelings and emotions elicited by NbS, associated ES, and their relation to effective risk reduction. The more disciplinary approaches used to address barriers to successful NbS, including geography, psychology, economics, engineering, anthropology, sociology, and public health, the greater the potential for complementary insight, learning, and advancement.

The interrelations among the influential factors identified in my research as well as among actual and perceived benefits of NbS as ecosystem services demands further research. Past work has not sufficiently explored the effects of multiple benefits on each other, i.e., synergies and trade-offs, and how these interact to shape stakeholder perceptions (Sutton-Grier et al. 2015). Systems approaches are generally well-suited to explore interrelations among influential factors, which routinely describe complex sustainability issues and human-nature relations (Anderson et al. 2019; Mattijssen et al. 2020; West et al. 2020). Based on data from the literature review, I began exploring possible causal connections among factors using systems modelling (Figure 5-1). Such models could be further developed using more extensive evidence and tested with system dynamics approaches or structural equation modelling (i.e., going beyond moderation and mediation in Paper 2). With sufficient data, embedding the role of individual perceptions within systems of broader social and ecological variables relevant to NbS projects may also be possible. This would allow for scenario-based testing of the systemic effects of interventions on specific factors, and therefore where resources are best allocated for achieving positive outcomes.

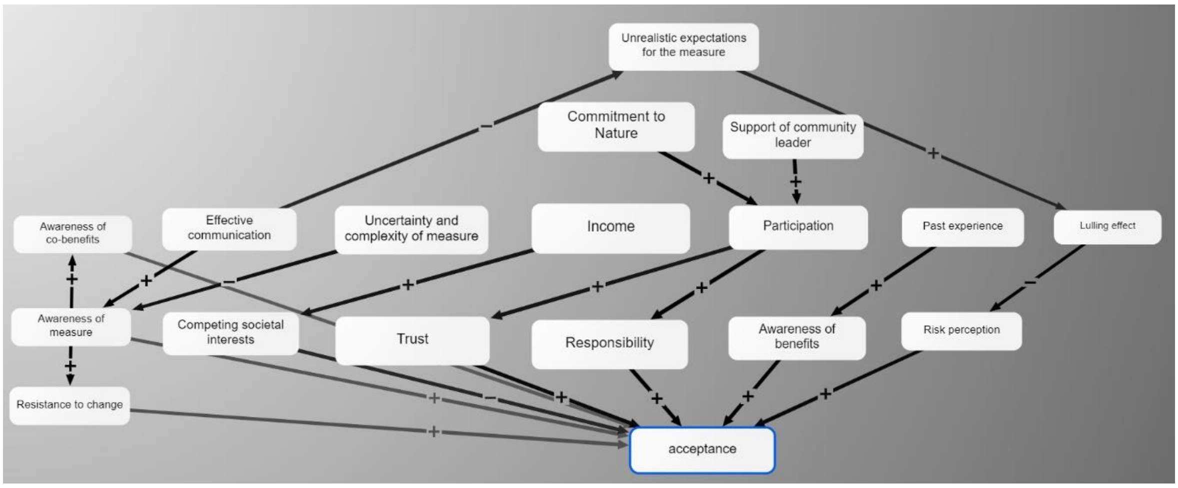


Figure 5-1 Interrelations among factors influencing acceptance. Based on descriptions from the literature review, potential causal connections among factors were mapped using the systems modelling tool iMODELER (https://www.imodeler.info/imodeler). Factors cause increases (+) or decreases (-) in subsequent factors, all ultimately acting on 'acceptance'.

Lastly, the PA-NbS needs further development and testing. In my research, I have used Paper 1 (Review) and the synthesized evidence in the PA-NbS as a backdrop to ensure that methods would be supported by literature and any recommendations would be grounded in past research. However, the PA-NbS itself could be applied to a project, for example, by creating a guidebook with case studies that assess project dimensions and refer directly to the criteria and recommendations within the framework. Assessing these against other measures of public acceptance, including the behavioural acceptance scale used in this research or actual pro-NbS behaviour, could further establish the relation between these guidelines and public acceptance.

5.4 Closing remarks

Despite its immense promise at addressing some of the world's most pressing issues, the future of NbS for DRR is uncertain. Overcoming economic and political barriers to its uptake are crucial, but public acceptance may determine sustained success regardless of concurrent achievements. A rapid growth in popularity, driven in part by current broad public support, makes the concept susceptible to overuse, misuse, or an association with inadequate or failed measures. There is also a risk that NbS researchers and practitioners will assume sustained acceptance and acceptance across scales, without sufficient consideration of public perceptions and resulting preferences, attitudes, and behaviours within NbS host communities. Public acceptance leads to positive outcomes during planning, implementation, and long-term monitoring and stewardship. A reliance on the public, and therefore their attitudes and behaviours, can lead to greater and more equitable impact, but also carries inherent risk. Broad stakeholder support is needed to ensure that NbS provide ecosystem services to successfully reduce risk from natural hazards, improve human well-being, and address concurrent interconnected global crises including climate change and biodiversity loss. Ensuring the success of NbS can create a positive feedback loop – satisfying local public actors, increasing public support, and thereby also improving the sustained success of measures and the concept more generally.

Appendix (A)

List of Tables

List of Figures

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A.1 Paper 1 (Review) additional material

Table. A-1 Terminology used to describe nature-based solutions (NbS) in the 65 reviewed NbS articles. Terms are grouped into classes based primarily on the authors' own description of the NbS and are listed in order from highest frequency to lowest frequency.

Term used	Reference
Ecological restoration (n=17)	
Mangrove restoration	(Badola and Hussain 2005)
Mangrove restoration	(Biswas et al. 2008)
Mangrove restoration	(Gilman and Ellison 2007)
Mangrove restoration	(Iftekhar and Takama 2008)
Mangrove replanting/restoration	(Barbier 2006)
Mangrove conservation	(Badola et al. 2011)
Wetland restoration	(Kim and Petrolia 2013)
Wetland restoration	(Scholte et al. 2016)
Wetland restoration	(Davenport et al. 2010)
Wetland restoration	(Pueyo-Ros et al. 2019)
Wetland restoration and conservation	(Wang et al. 2018)
Floodplain restoration	(Barthélémy and Armani 2015)
Floodplain restoration	(Schaich 2009)
River restoration	(Buijs 2009)
Coral reef restoration	(Trialfhianty and Suadi 2017)
Ecological restoration	(Herringshaw et al. 2010)
Coastal vegetation planting	(Tanaka et al. 2011)
Risk and ecosystem management (n=15)	
Flood risk management	(Buchecker et al. 2013)
Flood risk management	(Geaves and Penning-Rowsell 2015)
Natural flood management (NFM)	(Holstead et al. 2017)
Natural flood management (NFM)	(Howgate and Kenyon 2009)
Flood management strategies	(Vávra et al. 2017)
Integrated coastal zone management (ICZM)	(Koutrakis et al. 2011)
Integrated coastal zone management (ICZM)	(Brandolini and Disegna 2015)
Integrated flood risk management	(Buchecker et al. 2015)
Coastal zone management	(Jones and Clark 2014)
Urban storm-water management	(Kuo et al. 2016)
'Blue-Green' approaches to Flood Risk Management (BG-FRM)	(Everett and Lamond 2014)
Wetland management	(Rambonilaza et al. 2016)
Risk management initiatives - coastal resilience planning	(Bostick et al. 2017)
Community-based mangrove management (CBMM)	(Damastuti and Groot 2017)
Community-based natural resource management (CBNRM)	(On-prom 2014)
Green and blue-green infrastructure (n=13)	
Green infrastructure	(Beery 2018)
Green infrastructure	(Chou 2016)
Green infrastructure	(Dhakal and Chevalier 2017)
Green infrastructure	(Duan et al. 2018)
Green infrastructure	(Miller and Montalto 2019)
Conventional or green infrastructure	(Reynaud et al. 2017)
Blue-Green Infrastructure (BGI)	(Everett and Lamond 2018)
Blue-Green Infrastructure (BGI)	(Everett et al. 2018)
Engineered and natural infrastructure	(Gray et al. 2017)

Sponge city	(Ding et al. 2019)
Sponge city	(Wang et al. 2017)
Multi-functional coastal defence structures	(Evans et al. 2017)
Engineering solutions	(Saengsupavanich 2013)
Managed realignment (n=6)	
Managed realignment	(Esteves and Thomas 2014)
Managed realignment	(Myatt et al. 2003a)
Managed realignment	(Myatt et al. 2003b)
Managed realignment	(Myatt-Bell et al. 2002)
Managed realignment	(Roca and Villares 2012)
Depolderisation	(Goeldner-Gianella et al. 2015)
Risk reduction and mitigation measures (n=6)	
Flood risk reduction measures	(Otto et al. 2018)
Hazard reduction strategies	(Ryan and Wamsley 2008)
Mitigation measures	(McGee 2007)
Wildfire mitigation	(Christianson et al. 2013)
Engineering-based coastal flooding and erosion risk mitigation options	(Touili et al. 2014)
Risk reduction and adaption actions	(Brink and Wamsler 2019)
Ecosystem-based approaches (n=5)	
Eco-engineering	(Kienker et al. 2018)
Eco-engineering	(Nguyen et al. 2015)
Ecosystem-based adaptation	(Carro et al. 2018)
Ecosystem-based approaches	(Triyanti et al. 2017)
Building with Nature (BwN)	(van den Hoek et al. 2014)
Other (n=3)	
Defensible space actions	(Bihari and Ryan 2012)
Tree planting and filling in drainage ditches	(Drake et al. 2013)
Landscape engineering	(Chen et al. 2018)

Table. A-2 Manifestations and indicators of acceptance. These were identified in the reviewed literature, grouped into generally positive, neutral, or negative association with acceptance.

	Acceptance manifestations and indicators	Example references
Positive	*Acceptance*	(Buchecker et al. 2015; Dhakal and Chevalier 2017; Everett et al. 2018)
	Buy-in	(Esteves and Thomas 2014)
	Commitment	(Davenport et al. 2010)
	Cooperation	(Howgate and Kenyon 2009)
	Engagement	(Beery 2018; Everett and Lamond 2018)
	Intention	(Bubeck et al. 2012b)
	Interest	(Biswas et al. 2008; Herringshaw et al. 2010)
	Involvement	(Buchecker et al. 2013; Nguyen et al. 2015)
	Participation	(Fuchs et al. 2017; Godschalk et al. 2003)
	Satisfaction	(Jones and Clark 2014)
	Support	(Chou 2016; Geaves and Penning-Rowsell 2015; Kienker et al. 2018)
	Uptake	(Holcombe and Anderson 2010)
	Willing to collaborate	(Bihari and Ryan 2012)
	Willingness to pay	(Ghanbarpour et al. 2014; Goeldner-Gianella et al. 2015)
Neutral	*Attitude*	(Chen et al. 2018; Duan et al. 2018; Holstead et al. 2017)
	Behaviour	(Everett and Lamond 2014)
	Perception	(Duan et al. 2018; Gray et al. 2017)
	Preferences	(Boyer-Villemaire et al. 2014; Fordham et al. 1991; Lara et al. 2010)
	Valuation	(Rasid et al. 1996)
Negative	*Aversion*	(Gray et al. 2017)
	Conflict	(Geaves and Penning-Rowsell 2015; Myatt et al. 2003a; Roca and Villares 2012)
	Lack of participation	(Biswas et al. 2008)
	Opposition	(Groot and Groot 2009)
	Protest	(Buijs 2009; Schernewski et al. 2017)
	Rejection	(Goeldner-Gianella et al. 2015; Saengsupavanich 2013)
	Resistance	(Davis and Cole 2004)
	Tension	(Otto et al. 2018)

Table. A-3 Influential factors on public acceptance. Influencing factors for public acceptance grouped by relation to the measure, the individual, or the society. Within these groupings, the factors are listed from highest frequency to lowest frequency considering all the articles (n=99; including articles describing NbS [n=65], grey measures [n=28], and two or more measures [n=6]). The second column (green) shows the number and percentage of NbS articles (out of the 65 total) that reference each factor in relation to public acceptance. The third column (grey) replicates this for articles describing grey measures. A factor is highlighted in green if it a) occurs in n>=10 total articles and b) the percentage of NbS articles that reference it is at least double the percentage of grey articles that reference it. An example is provided in the footnote of the table.

Influencing factors for public acceptance	Frequency of articles describing NbS or grey measures that reference each factor		Example references	
NbS/Grey/Two or more (n=99)	NbS (n=65)	Grey (n=28)	NbS	Grey
Factors related to the measure (n=13)				
Benefits and trade-offs of measure[1] 62 (63%)	48 (74%)	10 (36%)	(Barthélémy and Armani 2015; Buijs 2009; Evans et al. 2017)	(Holcombe et al. 2018; McCarthy and Penning-Rowsell 2008; Reilly et al. 2018)
Effectiveness of measure for risk reduction 37 (37%)	31 (48%)	4 (14%)	(Badola and Hussain 2005; Carro et al. 2018; Howgate and Kenyon 2009)	(Abbas et al. 2016; Verbrugge et al. 2017; Wedawatta et al. 2016)
Costs and funding 13 (13%)	12 (18%)	1 (4%)	(Beery 2018; Brink and Wamsler 2019; Myatt et al. 2003a)	(Ghanbarpour et al. 2014)
Financial compensation or incentives 6 (6%)	5 (8%)	1 (4%)	(Buchecker et al. 2013; Damastuti and Groot 2017; Otto et al. 2018)	(Abbas et al. 2016)
Effectiveness of communication and collaboration 6 (6%)	4 (6%)	1 (4%)	(Ding et al. 2019; Howgate and Kenyon 2009; Otto et al. 2018)	(Calvello et al. 2016)
Uncertainty and complexity of measure 6 (6%)	3 (5%)	2 (7%)	(Brink and Wamsler 2019; Schernewski et al. 2017)	(Godschalk et al. 2003; Reilly et al. 2018)
Equity of costs and benefits 5 (5%)	5 (8%)	0	(Drake et al. 2013; Geaves and Penning-Rowsell 2015; Otto et al. 2018)	N/A

Influencing factors for public acceptance	Frequency of articles describing NbS or grey measures that reference each factor		Example references	
Health and safety concerns 3 (3%)	3 (5%)	0	(Everett et al. 2018; Ryan and Wamsley 2008; van den Hoek et al. 2014)	N/A
Implementation / construction externalities 3 (3%)	2 (3%)	1 (4%)	(Myatt et al. 2003a; Saengsupavanich 2013)	(Myatt et al. 2003a; Saengsupavanich 2012, 2013)
Past institutional outreach 3 (3%)	2 (3%)	1 (4%)	(Buchecker et al. 2015; On-prom 2014)	(Holcombe and Anderson 2010)
Past effectiveness of DRR measures 3 (3%)	2 (3%)	1 (4%)	(Badola et al. 2011; Buchecker et al. 2015)	(Verbrugge et al. 2017)
Media coverage 3 (3%)	3 (5%)	0	(Miller and Montalto 2019; Schernewski et al. 2017)	N/A
Duration of implementation 1 (1%)	1 (2%)	0	(Schernewski et al. 2017)	N/A
Factors related to the individual (n=15)				
Risk perception of natural hazards 33 (33%)	18 (28%)	12 (43%)	(Holstead et al. 2017; Kim and Petrolia 2013; McGee 2007)	(Fordham et al. 1991; Holcombe et al. 2018)
Awareness and understanding of measure 20 (20%)	15 (23%)	3 (11%)	(Kienker et al. 2018; Ryan and Wamsley 2008; Schernewski et al. 2017)	(Hoque and Siddique 1995; Neef et al. 2013)
Awareness of benefits 17 (17%)	13 (20%)	4 (14%)	(Everett et al. 2018; Nguyen et al. 2015; Scholte et al. 2016)	(Abbas et al. 2016; Holcombe et al. 2018; Saengsupavanich 2012)
Responsibility for measure 17 (17%)	14 (22%)	3 (11%)	(Everett and Lamond 2018; Rambonilaza et al. 2016; Touili et al. 2014)	(Fuchs et al. 2017; Neef et al. 2013)
Participation 11 (11%)	9 (14%)	2 (7%)	(Herringshaw et al. 2010; Howgate and Kenyon 2009; On-prom 2014)	(Davis and Cole 2004; Fordham et al. 1991)

Influencing factors for public acceptance	Frequency of articles describing NbS or grey measures that reference each factor		Example references	
Fatalist or agentic perspective 8 (8%)	5 (8%)	3 (11%)	(Bihari and Ryan 2012; Brink and Wamsler 2019; Everett and Lamond 2018)	(Abbas et al. 2016; Fuchs et al. 2017; Schmidt et al. 2014)
Past experience with hazard 8 (8%)	5 (8%)	3 (11%)	(Badola et al. 2011; Bihari and Ryan 2012; Brink and Wamsler 2019)	(Ghanbarpour et al. 2014; Godschalk et al. 2003; Lara et al. 2010)
Age of individual 7 (7%)	5 (8%)	2 (7%)	(Duan et al. 2018; Myatt et al. 2003a; Schernewski et al. 2017)	(Abbas et al. 2016; Schmidt et al. 2014)
Expectations of measure 6 (6%)	5 (8%)	1 (4%)	(Biswas et al. 2008; Chou 2016; Schernewski et al. 2017)	(Verbrugge et al. 2017)
Perceived inclusion or exclusion 5 (5%)	5 (8%)	0	(Everett et al. 2018; Miller and Montalto 2019; Triyanti et al. 2017)	N/A
Level of education of individual 4 (4%)	4 (6%)	0	(Badola et al. 2011; Brink and Wamsler 2019; McGee 2007)	N/A
Distance from measure 4 (4%)	3 (5%)	1 (4%)	(Myatt et al. 2003b; Schaich 2009; Trialfhianty and Suadi 2017)	(Abbas et al. 2016)
Number of visits to measure 3 (3%)	3 (5%)	0	(Duan et al. 2018; Reynaud et al. 2017; Schaich 2009)	N/A
Income level of individual **2 (2%)**	1 (2%)	1 (4%)	(Brink and Wamsler 2019)	(Ghanbarpour et al. 2014)
Mental associations with measure 2 (2%)	1 (2%)	1 (4%)	(Scholte et al. 2016)	(McCarthy and Penning-Rowsell 2008)
Factors related to the society (n=8)				
Place attachment 13 (13%)	8 (12%)	2 (7%)	(Bihari and Ryan 2012; Brink and Wamsler 2019; Buijs 2009)	(Chowdhury 2002; Schmidt et al. 2014)
Trust in responsible party 11 (11%)	7 (11%)	3 (11%)	(Buchecker et al. 2015; Ding et al. 2019; Myatt et al. 2003a)	(Schmidt et al. 2014; Verbrugge et al. 2017)
Competing societal interests 11 (11%)	9 (14%)	2 (7%)	(Barbier 2006; Everett and Lamond 2018; Iftekhar and Takama 2008)	(Abbas et al. 2016; Holcombe et al. 2018)

Influencing factors for public acceptance	Frequency of articles describing NbS or grey measures that reference each factor		Example references	
Resistance to change and new concepts **7 (7%)**	5 (8%)	1 (4%)	(Koutrakis et al. 2011; Schernewski et al. 2017)	(Davis and Cole 2004)
Civic culture and tradition 4 (4%)	3 (5%)	1 (4%)	(Barbier 2006; Gilman and Ellison 2007; Schernewski et al. 2017)	(Schmidt et al. 2014)
Human versus nature perspectives 4 (4%)	3 (5%)	0	(Barthélémy and Armani 2015; Myatt et al. 2003a)	N/A
Support of community leader(s) 2 (2%)	2 (3%)	0	(Damastuti and Groot 2017; Trialfhianty and Suadi 2017)	N/A
Social norms 2 (2%)	2 (3%)	0	(Brink and Wamsler 2019; Holstead et al. 2017)	N/A

[1] 'Benefits and trade-offs of measure' is referenced in 63% (n=62) of all 99 articles. It is referenced in 74% (n=48) of the 65 NbS articles and 36% (n=10) of the 28 grey articles. The remaining four articles of the 62 total in which it is referenced describe two or more measures. It is highlighted in green because a) the total mentions is greater than 10 (62 > 10) and b) the percentage of NbS articles is at least double the percentage of grey articles that reference this factor (74 >= 36*2).

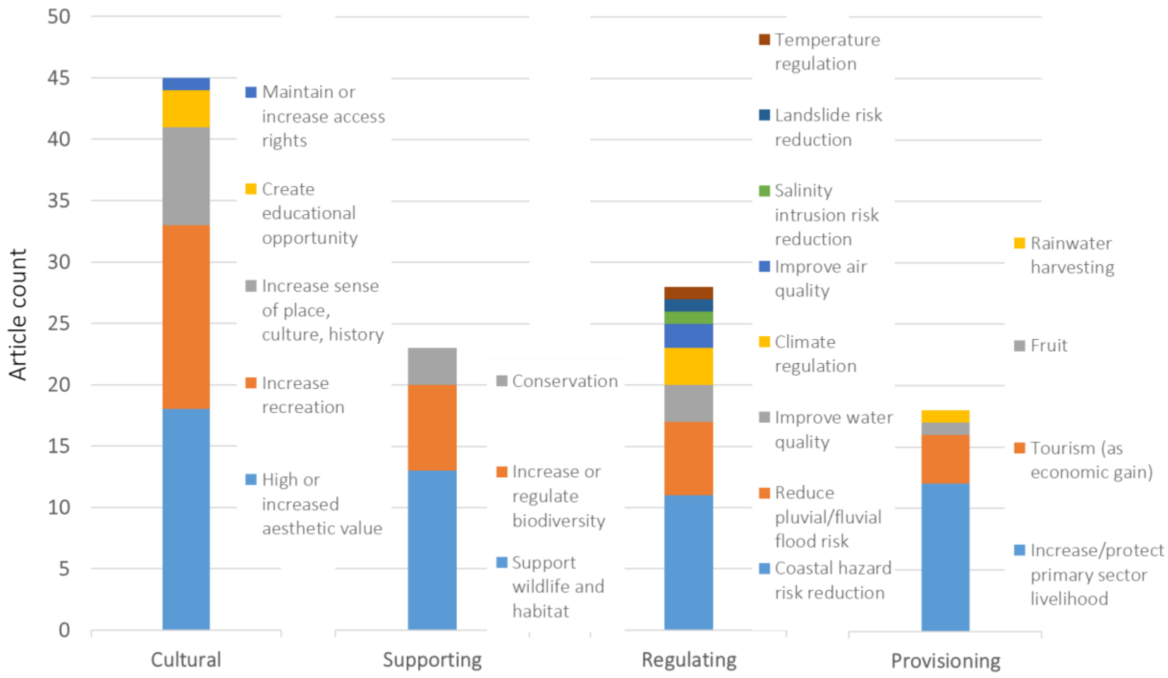

Figure. A-1 Ecosystem services and public acceptance. Number of articles in the review that associate public perception of each ecosystem service (cultural, supporting, regulating, and provisioning) with public acceptance of the measures.

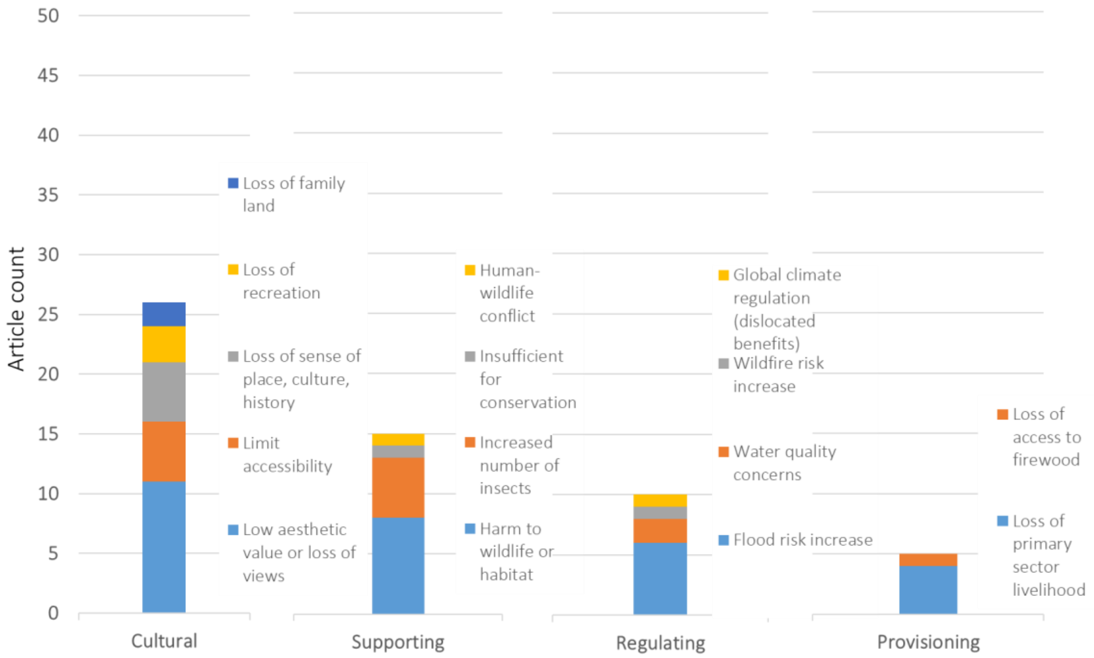

Figure. A-2 Ecosystem disservices and public acceptance. Number of articles in the review that associate public perception of each ecosystem disservice or lack of ecosystem service (cultural, supporting, regulating, and provisioning) with public acceptance of the measures.

Text. A-1 Search term sequence.Full search term sequence used in Scopus on May 15, 2019. The search (including automatic screening criteria) yielded 5,900 returns.

TITLE-ABS-KEY (((local w/2 accept*) OR (public w/2 accept*) OR (social w/2 accept*) OR (societ* w/2 accept*) OR(stakeholder w/2 accept*) OR (communit* w/2 accept*) OR (individual w/2 accept*) OR(household w/2 accept*) OR(resident w/2 accept*) OR(citizen w/2 accept*) OR (local w/2 reject*) OR (public w/2 reject*) OR (social w/2 reject*) OR(societ* w/2 reject*) OR(stakeholder w/2 reject*) OR(communit* w/2 reject*) OR(individual w/2 reject*) OR(household w/2 reject*) OR(resident w/2 reject*) OR(citizen w/2 reject*) OR (local w/2 apath*) OR (public w/2 apath*) OR(social w/2 apath*) OR(societ* w/2 apath*) OR(stakeholder w/2 apath*) OR(communit* w/2 apath*) OR(individual w/2 apath*) OR(household w/2 apath*) OR (resident w/2 apath*) OR (citizen w/2 apath*) OR (local w/2 fatigue) OR (public w/2 fatigue) OR(social w/2 fatigue*) OR (societ* w/2 fatigue) OR(stakeholder w/2 fatigue) OR(communit* w/2 fatigue) OR(individual w/2 fatigue) OR(household w/2 fatigue) OR(resident w/2 fatigue) OR(citizen w/2 fatigue) OR (local w/2 burnout) OR (public w/2 burnout) OR(social w/2 burnout) OR(societ* w/2 burnout) OR(stakeholder w/2 burnout) OR(communit* w/2 burnout) OR(individual w/2 burnout) OR(household w/2 burnout) OR(resident w/2 burnout) OR(citizen w/2 burnout) OR (local w/2 indifferen*) OR (public w/2 indifferen*) OR (social w/2 indifferen*) OR (societ* w/2 indifferen*) OR(stakeholder w/2 indifferen*) OR (communit* w/2 indifferen*) OR (individual w/2 indifferen*) OR(household w/2 indifferen*) OR (resident w/2 indifferen*) OR (citizen w/2 indifferen*) OR (local w/2 perception) OR (public w/2 perception) OR(social w/2 perception) OR (societ* w/2 perception) OR(stakeholder w/2 perception) OR(communit* w/2 perception) OR(individual w/2 perception) OR(household w/2 perception) OR(resident w/2 perception) OR(citizen w/2 perception) OR (local w/2 participat) OR (public w/2 participat*) OR(social w/2 participat*) OR(societ* w/2 participat*) OR(stakeholder w/2 participat*) OR(communit* w/2 participat*) OR(individual w/2 participat*) OR(household w/2 participat*) OR(resident w/2 participat*) OR(citizen w/2 participat*) OR (local w/2 preference*) OR (public w/2 preference) OR(social w/2 preference) OR(societ* w/2 preference) OR(stakeholder w/2 preference) OR(communit* w/2 preference) OR(individual w/2 preference) OR(household w/2 preference) OR(resident w/2 preference) OR(citizen w/2 preference) OR (local w/2 buy-in) OR (public w/2 buy-in) OR(social w/2 buy-in) OR(societ* w/2 buy-in) OR(stakeholder w/2 buy-in) OR(communit* w/2 buy-in) OR(individual w/2 buy-in) OR(household w/2 buy-in) OR(resident w/2 buy-in) OR(citizen w/2 buy-in) OR (local w/2 involv*) OR (public w/2 involv*) OR(social w/2 involv*) OR(societ* w/2 involv*) OR(stakeholder w/2 involv*) OR(communit* w/2 involv*) OR(individual w/2 involv*) OR(household w/2 involv*) OR(resident w/2 involv*) OR(citizen w/2 involv*) OR (local w/2 engag*) OR (public w/2 engag*) OR(social w/2 engag*) OR(societ* w/2 engag*) OR(stakeholder w/2 engag*) OR(communit* w/2 engag*) OR(individual w/2 engag*) OR(household w/2 engag*) OR(resident w/2 engag*) OR(citizen w/2 engag*) OR (local w/2 "collective action") OR(public w/2 "collective action") OR(social w/2 "collective action") OR (societ* w/2 "collective action") OR (stakeholder w/2 "collective action") OR(communit* w/2 "collective action") OR (individual w/2 "collective action") OR(household w/2 "collective action") OR (resident w/2 "collective action") OR (citizen w/2 "collective action") OR (local w/2 sentiment) OR (public w/2 sentiment) OR(social w/2 sentiment) OR(societ* w/2 sentiment) OR(stakeholder w/2 sentiment) OR(communit* w/2 sentiment) OR(individual w/2 sentiment) OR(household w/2 sentiment) OR(resident w/2 sentiment) OR(citizen w/2 sentiment) OR (local w/2 attitude) OR (public w/2 attitude) OR (social w/2 attitude) OR(societ* w/2 attitude) OR(stakeholder w/2 attitude) OR(communit* w/2 attitude) OR(individual w/2 attitude) OR(household w/2 attitude) OR(resident w/2 attitude) OR (citizen w/2 attitude) OR (local w/2 belief) OR (public w/2 belief) OR (social w/2 belief) OR (societ* w/2 belief) OR(stakeholder w/2 belief) OR(communit* w/2 belief) OR (individual w/2 belief) OR (household w/2 belief) OR(resident w/2 belief) OR(citizen w/2 belief) OR (local w/2 behavio) OR (public w/2 behavio*) OR(social w/2 behavio*) OR(societ* w/2 behavio*) OR(stakeholder w/2 behavio*) OR(communit* w/2 behavio*) OR(individual w/2 behavio*) OR(household w/2 behavio*) OR(resident w/2 behavio*) OR(citizen w/2 behavio*)) **AND**
(resilien* OR drr OR nbs OR "hazard mitigation" OR "hazard adjustment" OR disaster OR "risk mitigation" OR "risk reduction" OR "risk management" OR "risk communication" OR "nature-based solution" OR "eco-engineering" OR "ecological restoration" OR "ecological engineering" OR "forest landscape restoration" OR "ecosystem-based adaptation" OR "ecosystem-based mitigation" OR "climate adaptation services" OR "ecosystem-based disaster risk reduction" OR "natural infrastructure" OR "green infrastructure" OR "integrated coastal zone management " OR "integrated water resources management" OR "protected area management" OR "ecosystem-based management" OR "wetland restoration" OR "floodplain restoration" OR "building with nature" OR "natural infrastructure" OR "river management" OR "ecosystem services" OR "landscape restoration" OR "coastal management" OR "coastal protection")) **AND**

(PUBYEAR > 1990) AND NOT TITLE-ABS-KEY ("alternative medicine" OR "childhood development" OR "cleft lip" OR "e. coli" OR "food safety" OR "machine learning" OR "mental illness" OR "renewable power" OR "search and rescue" OR "stress management" OR "technological disaster" OR "carbon credit" OR abusive OR ageing OR aging OR alcohol OR Alzheimer OR anaerobic OR antibiotic OR antidepressant OR anxiety OR arts OR autoreceptor OR biology OR cancer OR cardiovascular OR caribou OR circumcision OR coal OR compost OR consumer OR contaminat* OR customer OR dairy OR dance OR dementia OR depression OR diabetes OR diamorphine OR diet OR dietary OR digestates OR disease OR drug OR electricity OR electromagnetic OR emergency OR energy OR entrepreneurship OR evacuation OR e-waste OR exercise OR fracking OR fukushima OR garbage OR hernia OR hiv OR hunting OR infant OR influenza OR injury OR invertebrate OR macaque OR medical OR medication OR metabolic OR mice OR microbial OR milk OR mine OR myopia OR newborn OR nuclear OR nurse OR oil OR oxytocin OR pain OR particulate OR patient OR pediatric OR pension OR pesticide OR petrochemical OR phenotype OR phosphorus OR physician OR physiological OR poaching OR prenatal OR prophylaxis OR psychiatric OR psychosis OR "public housing" OR radiation OR radon OR railway OR resuscitat* OR robot OR rodent OR sarcoma OR sexual OR sleep OR stutter OR suicide OR surgeon OR surgical OR symptom OR terrorism OR terrorist OR thermoplastic OR ticks OR trpm2 OR UAV OR vaccine) **AND**
(LIMIT-TO (SUBJAREA,"ENVI") OR LIMIT-TO (SUBJAREA,"SOCI") OR LIMIT-TO (SUBJAREA,"AGRI") OR LIMIT-TO (SUBJAREA,"ENGI") OR LIMIT-TO (SUBJAREA,"EART") OR LIMIT-TO (SUBJAREA,"PSYC") OR LIMIT-TO (SUBJAREA,"ECON") OR LIMIT-TO (SUBJAREA,"ARTS") OR LIMIT-TO (SUBJAREA,"ENER") OR LIMIT-TO (SUBJAREA,"DECI") OR LIMIT-TO (SUBJAREA,"MULT"))
AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"ch")) **AND**
(LIMIT-TO (LANGUAGE,"English") OR LIMIT-TO (LANGUAGE,"Spanish") OR LIMIT-TO (LANGUAGE,"French") OR LIMIT-TO (LANGUAGE,"German") OR LIMIT-TO (LANGUAGE,"Portuguese"))

Text. A-2 The 97 articles and 2 book chapters included in the review.

1. Abbas, A., T. Amjath-Babu, H. Kächele, and K. Müller. 2016. Participatory adaptation to climate extremes: an assessment of households' willingness to contribute labor for flood risk mitigation in Pakistan. *Journal of Water and Climate Change,* 7, 621–636.

2. Badola, R., and S. A. Hussain. 2005. Valuing ecosystem functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India. *Environmental Conservation* 32. Cambridge University Press: 85–92.

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A.2 Paper 2 (Survey) additional material

All three versions of the surveys can be found in the published supplementary material of Paper 2 (external link). Here, I provide only the Catterline survey as an example since most of the survey items were identical across the three sites and due to space limitations.

Text. A-3 Questionnaire conducted in Catterline.

Natural Hazard Risk Reduction in Catterline: Resident Survey		
University of Glasgow College of Social Sciences	September 2019 Carl Anderson - University of Glasgow c.anderson.4@research.gla.ac.uk	OPERANDUM OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks

Participant Information
Project title: OPERANDUM - OPEn-air laboRAtories for Nature baseD solUtions to Manage environmental risk
You are being invited to take part in a research study. Before you decide if you would like to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Ask us if there is anything that is not clear or for which you would like more information. Thank you for reading this. This research is one part of the OPERANDUM project in which nature-based solutions to disaster risk reduction are being developed by project partners in Scotland, Finland, Germany, Austria, Italy, Greece, and Ireland. OPERANDUM is funded by the European Commission under its H2020 programme. With your consent, this survey will form an important part of post-graduate research being conducted at the University of Glasgow. The aim of the research is to understand how local citizens interact with the community's natural areas, the risks perceived by community members from natural hazards, and how best to support the sustained success of the nature-based solution through community engagement. We are interested in your experience and knowledge in relation to these issues. The survey time varies but it is designed to last on average 20 minutes. Your participation is voluntary. Some questions will relate to the effects of past hazard events that have the potential to cause distress. You may skip any question you do not want to answer or withdraw from the survey at any point and will not be asked to give a reason. Your participation in the questionnaire will be completely voluntary. No data collected will be attributed to you as an individual. In other words, the questionnaire will be anonymous. You will, however, be given the opportunity to provide contact information in case you are interested in participating in future research. Contact information will be kept confidential and responses only reported in anonymous or aggregated form. Confidentiality will be respected subject to legal constraints and professional guidelines.

The resulting data will be kept in a locked drawer and also stored electronically in a password protected location on a secure server. Data will be used by the research team for writing journal articles and for conferences and will only be shared as anonymous data with other trusted research institutions on request. Data will be kept for 10 years after publication and then securely disposed of.

Results from the research, in the form of written summaries or final manuscripts, will be provided by request to the post-graduate researcher (see below). Survey results and broader research results will also be shared with the community in an open meeting to take place in Summer 2021.

If you have questions about this project, you may contact the post-graduate researcher Carl Anderson (c.anderson.4@research.gla.ac.uk), the research supervisor Fabrice Renaud (Fabrice.Renaud@glasgow.ac.uk), or the College Ethics Officer [*removed*]. If you wish to pursue a complaint this should also be sent to College of Social Sciences Ethics Officer, [*removed*].

Natural Hazard Risk Reduction in Catterline: Resident Survey

University of Glasgow
College of Social Sciences

September 2019

Carl Anderson - University of Glasgow
c.anderson.4@research.gla.ac.uk

OPERANDUM
OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks

Consent Form

Research title: Natural Hazard Risk Reduction in Catterline: Resident Input Survey (as part of the OPERANDUM Project - OPEn-air laboRAtories for Nature baseD solUtions to Manage environmental risk)

Consent statement:

I confirm that I have read and understood the Participant Information Sheet (previous page) for the above study and have had the opportunity to ask questions.

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

- I understand that responses to this questionnaire will be used as research data for the above project.
- All surveys are anonymous.
- You will be given the option of providing contact information in case you are interested in participating in future research. Contact information will be kept confidential and responses only reported in anonymous or aggregated form.
- The data will be treated as confidential and kept in secure storage at all times.

- The data will be destroyed 10 years after the project is complete and only shared as anonymous material upon request with trusted research institutions.
- The data may be used in future publications, both print and online, and in conference proceedings.
- I agree to waive my copyright to any data collected as part of this project.

I agree to take part in this research study ☐

I do not agree to take part in this research study ☐

Natural Hazard Risk Reduction in Catterline: Resident Survey

University of Glasgow
College of Social Sciences

September 2019

Carl Anderson - University of Glasgow
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OPERANDU
OPEn-air laboRAtories for Nature b
solUtions to Manage hydro-meteo r

Section 1: Catterline

The items in this first section relate to your experience living in Catterline in relation to its unique natural area. Please list below a maximum of 6 ways the natural area **benefits you** and 6 ways it has a **negative effect** on you, in order of importance **(1 = most important; 6 = least important)**. Please list as many as you can, up to 6. If you feel there are no benefits or negative effects or do not know of any, you may leave this blank.

Benefits	Negative effects
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
6.	6.

The following questions are about time you spend in Catterline on average.

1. I normally spend ___ months per year in Catterline	1-3 ☐	4-6 ☐	7-9 ☐	10-12 ☐

2. I normally spend ___ days per week in Catterline	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐

3. When I am in Catterline, I visit the bay area once every... (please choose the closest answer)

day ☐	3-5 days ☐	week ☐	month ☐	2-3 months ☐	year ☐	Less than once a year ☐

Please rate your level of **disagreement** or **agreement** by circling the appropriate number in each row.
(1 = Strongly disagree; 9 = Strongly agree).

Nature	Strongly disagree 1	2	3	4	Neither agree nor disagree 5	6	7	8	Strongly Agree 9
1. I believe that the well-being of the natural environment can affect my own well-being.	1	2	3	4	5	6	7	8	9
2. I do **not** feel very attached to the natural environment.	1	2	3	4	5	6	7	8	9
3. It makes me feel good when something happens that benefits the environment.	1	2	3	4	5	6	7	8	9
4. I feel committed to keeping the best interests of the environment in mind.	1	2	3	4	5	6	7	8	9
Catterline									
1. My sense of who I am is tied to Catterline.	1	2	3	4	5	6	7	8	9
2. I do **not** miss being in Catterline when I'm away.	1	2	3	4	5	6	7	8	9
3. I enjoy spending my free time in Catterline.	1	2	3	4	5	6	7	8	9
4. It is a privilege to live in Catterline.	1	2	3	4	5	6	7	8	9
5. I am **not** proud of our community's natural area.	1	2	3	4	5	6	7	8	9
6. As a resident of Catterline, I believe I have a responsibility to protect its natural environment.	1	2	3	4	5	6	7	8	9

↓

6.1. Please guess even if you do not know. What percentage of Catterline residents believe that they have a responsibility to protect its natural environment?

0-20% ☐ 21-40% ☐ 41-60% ☐ 61-80% ☐ 81-100% ☐

Section 2: Risk Reduction in Catterline
Landslides are caused by many factors, but often are triggered by storms that bring heavy rains. They can have impacts on many aspects of our lives - roads, property, scenery, and recreation, among others. The following questions refer to the risk posed by these landslides and your experience with them in Catterline.

Please mark Yes, No or I do not know for the following statements.

In the past, landslides have...	Yes	No	I do not know
...affected roads that I use in Catterline.	Y	N	?
...affected my recreation in the natural area.	Y	N	?
...affected my enjoyment of the natural scenery.	Y	N	?
...damaged my property.	Y	N	?
Please list any other impacts from landslides that you have experienced.			

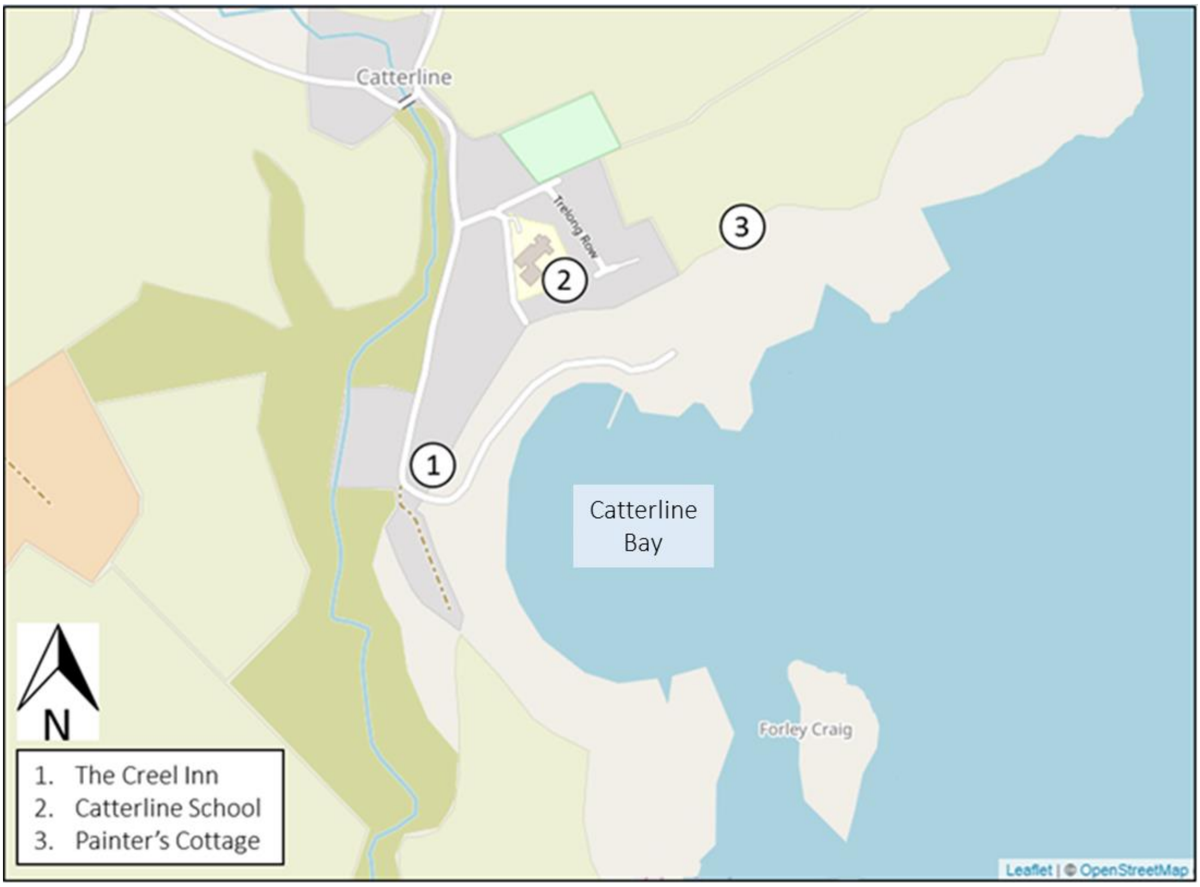
In the future, I believe landslides could...	Yes	No	I do not know
...affect roads that I use in Catterline.	Y	N	?
...affect my recreation in the natural area.	Y	N	?
...affect my enjoyment of the natural scenery.	Y	N	?
...damage my property.	Y	N	?
Please list any other impacts from landslides that you think could happen in the future.			

The following three items refer to the map below.

a) Please indicate **approximately** where, in relation to Catterline Bay, your residence is by marking an X on the below map of Catterline. If your residence is not on the map, mark an X anywhere next to the map.

b) Please draw one letter L on the map **approximately** where Landslides can impact you most (for example, this could be on a road you use, at your residence, or where a landslide that affects your views of the natural area could occur).

c) Please draw one letter N on the map **approximately** where you believe Natural measures to reduce landslide risk are most important (This could be where measures already exist or not).



Please rate your level of <u>**disagreement**</u> or <u>**agreement**</u> with the following statements about landslide risk <u>**to you**</u> by circling the appropriate number in each row <u>**(1 = Strongly disagree; 9 = Strongly agree)**</u>. Please first try to answer as best you can, then If you do not know mark “I do not know”.

	Strongly disagree 1	2	3	4	Neither agree nor disagree 5	6	7	8	Strongly Agree 9	I do not know ?
1. It is okay if the roads I use are affected by landslide <u>once every 5 years</u>.	1	2	3	4	5	6	7	8	9	?
2. It is okay if my recreation in the natural area is affected by landslide <u>once every 5 years</u>.	1	2	3	4	5	6	7	8	9	?
3. It is okay if my enjoyment of the natural scenery is affected by landslide <u>once every 5 years</u>.	1	2	3	4	5	6	7	8	9	?
4. It is okay if my personal property is damaged by landslide <u>once every 20 years</u>.	1	2	3	4	5	6	7	8	9	?
5. If a major landslide occurs, I will easily be able to deal with any negative impacts on my daily life.	1	2	3	4	5	6	7	8	9	?
6. If a landslide occurs, I will be <u>more</u> negatively affected than other residents who live in <u>equally risky areas</u>.	1	2	3	4	5	6	7	8	9	?
7. Landslides with negative impacts occur frequently in Catterline.	1	2	3	4	5	6	7	8	9	?
8. Landslides in Catterline will be stronger and more frequent in the future.	1	2	3	4	5	6	7	8	9	?
9. I am concerned about negative impacts from landslides.	1	2	3	4	5	6	7	8	9	?
10. Landslides are a threat to the health of the land and its species	1	2	3	4	5	6	7	8	9	?
11. Landslides are a threat to our residents.	1	2	3	4	5	6	7	8	9	?
12. Landslides are a threat to our history and culture.	1	2	3	4	5	6	7	8	9	?

13. The current risk of negative impacts from landslides must be reduced.	1	2	3	4	5	6	7	8	9	?

↓

13.1. Please guess even if you do not know. What percentage of Catterline residents believe that the current risk of negative impacts from landslides must be reduced?

0-20% ☐ 21-40% ☐ 41-60% ☐ 61-80% ☐ 81-100% ☐

Optionally, if you would like to add any comments regarding content from this section, please write them here.

Section 3: Natural slope stabilisation measures

Natural slope stabilisation measures are intended to reduce risk of landslide but can also provide other benefits. Natural measures used on the slopes in Catterline include planting trees, creating natural drains, and laying erosion blankets that promote vegetation growth, sometimes also with ground anchors driven into the soil. These measures have been implemented by local community groups as well as external volunteers. The following questions are about <u>such measures implemented in Catterline</u>. In this survey, we do <u>not</u> refer to burning of vegetation or the extension of roof gutters, since these are not considered "natural".

How did you <u>first</u> find out about these natural measures in Catterline?

With this survey or the survey notification letter	Through a community organization	Word of mouth	Saw and recognised them	On the internet	Other
☐	☐	☐	☐	☐	☐

Please circle <u>Yes</u> or <u>No</u> for the following statements.

	Yes	No
1. Have you ever been an active and participating member of a community group to support such measures?	Y	N
2. Are you currently an active and participating member of a community group to support such measures?	Y	N
In the past, have you...	**Yes**	**No**
1. ...<u>sought out information</u> about such measures?	Y	N
2. ...volunteered by <u>attending meetings</u> about such measures?	Y	N
3. ...volunteered to physically help <u>implement or maintain</u> such measures?	Y	N
	Y	N

4. ...volunteered to help **monitor** such measures?		
5. ...volunteered to help **fundraise** or **source supplies** for such measures?	Y	N
6. ...volunteered by supporting such measures in **other ways**?	Y	N
7. ...undertaken **other measures**, besides the natural ones described, to reduce landslide risk?	Y	N

Please rate your level of **disagreement** or **agreement** with the following statements about natural slope stabilisation measures in Catterline by circling the appropriate number in each row. **(1 = Strongly disagree; 9 = Strongly agree)**. Please first try to answer as best you can, then if you do not know mark "I do not know".

	Strongly disagree 1	2	3	4	Neither agree nor disagree 5	6	7	8	Strongly Agree 9	I do not know ?
1. It is good that these measures are being implemented.	1	2	3	4	5	6	7	8	9	?
2. I am satisfied with how these measures are being implemented.	1	2	3	4	5	6	7	8	9	?
3. I would prefer that other **non-natural** measures be used **instead** of these.	1	2	3	4	5	6	7	8	9	?
4. I would prefer that other **non-natural** measures be used **in addition to** these.	1	2	3	4	5	6	7	8	9	?

In the future, I would like to...	Strongly disagree 1	2	3	4	Neither agree nor disagree 5	6	7	8	Strongly Agree 9	I do not know ?
1. ...(continue to) **learn more** about these measures.	1	2	3	4	5	6	7	8	9	?
2. ...**attend meetings** about such measures.	1	2	3	4	5	6	7	8	9	?
3. ...help **implement or maintain** such measures.	1	2	3	4	5	6	7	8	9	?
4. ...help **monitor** such measures.	1	2	3	4	5	6	7	8	9	?
5. ...help **fundraise or source materials** for such measures.	1	2	3	4	5	6	7	8	9	?
6. ...support such measures in **other ways**.	1	2	3	4	5	6	7	8	9	?

If you can think of any other ways you would like to support these measures, please write them here.

	Yes	No	I do not know
Is there anything that you think might motivate you to become more involved in these natural slope stabilisation efforts?	Y	N	?
If **<u>Yes</u>**, what might motivate you?			I do not know ?

In your opinion, do the natural measures described have any benefits or negative effects **<u>beyond reducing the risk of landslides?</u>** Please list below a maximum of 6 benefits and 6 negative effects, in order of importance **<u>(1 = most important; 6 = least important)</u>**. If you believe the measures have no additional benefits or negative effects or you do not know of any, you may leave this blank.

Benefits	Negative Effects
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
6.	6.

Please rate your level of **disagreement** or **agreement** with the following statements about natural slope stabilisation measures in Catterline by circling the appropriate number in each row. **(1 = Strongly disagree; 9 = Strongly agree)**. Please first try to answer as best you can, then if you do not know mark "I do not know".

	Strongly disagree 1	2	3	4	Neither agree nor disagree 5	6	7	8	Strongly Agree 9	I do not know ?
1. I believe the people implementing the natural slope stabilisation measures know what they are doing.	1	2	3	4	5	6	7	8	9	?
2. I believe the people implementing the measures are doing so in the best interest of the community.	1	2	3	4	5	6	7	8	9	?
3. I feel that the measures are being imposed on me.	1	2	3	4	5	6	7	8	9	?
4. I believe resources would be better used for other community concerns.	1	2	3	4	5	6	7	8	9	?
5. I would prefer to engage with more important community issues than slope stabilisation.	1	2	3	4	5	6	7	8	9	?
6. I feel responsible for protecting Catterline from natural hazards.	1	2	3	4	5	6	7	8	9	?
7. Too much responsibility has been placed on me to support the measures.	1	2	3	4	5	6	7	8	9	?
8. I need more evidence that natural slope stabilisation measures will reduce landslide risk in Catterline.	1	2	3	4	5	6	7	8	9	?
9. I believe that when storms come in the future, these measures will reduce the chance of landslides.	1	2	3	4	5	6	7	8	9	?
10. I believe there is nothing we can do to **reduce** risks from landslide in Catterline.	1	2	3	4	5	6	7	8	9	?
11. I believe the financial cost of these measures is too great.	1	2	3	4	5	6	7	8	9	?

Optionally, if you would like to add any comments regarding content from this section, please write them here.

Section 4: Background information

The following questions relate to background information. This will help us compare the composition of survey respondents with statistics from the Scottish Census. Please skip those that you do not wish to answer.

Age	19-24 ☐	25-34 ☐	35-44 ☐	45-54 ☐	55-64 ☐	65-74 ☐	75+ ☐
Gender? _________________________________							

The identities listed below are based on data for Catterline from the Scottish Census. Please mark only one box.

National Identity	Scottish Identity only	British Identity only	Scottish and British Identities only	English identity only	Any other combination of UK identities (UK only)	Other identity
	☐	☐	☐	☐	☐	☐

Section 5: Further contact (optional)

If you would like the option to take part in future research and make your opinion heard regarding the ongoing risk reduction measures in Catterline, please provide your email address and/or postal address. **This is entirely optional**. Email addresses and postal addresses will be processed separately from the rest of the responses to this questionnaire and will not be reported or shared in any way. This consent can be withdrawn at any time through request that your information be removed by contacting the post-graduate researcher Carl Anderson at c.anderson.4@research.gla.ac.uk and copying (cc) the research supervisor Fabrice Renaud at Fabrice.Renaud@glasgow.ac.uk.

Email address:

Postal Address:

Thank you for taking the time to complete this survey. We truly value the information you have provided.

Table. A-4 Survey items retained in each study site for each of the primary survey variables. Y=yes, retained; N=no, removed; N/A=not applicable (item not included in survey for site).

Group ID	Scales/items	Retained in scale		
		Catterline	**Puruvesi**	**Spercheios**
	Attitudinal Acceptance			
Trust	I believe the people implementing the measures know what they are doing.	Y	Y	Y
Trust	I believe the people implementing the measures are doing so in the best interest of the community.	Y	Y	Y
Trust	I feel that the measures are being imposed on me.	N	Y	N
Competing interests	I believe resources would be better used for other community concerns.	Y	Y	N
Competing interests	I would prefer to engage with more important community issues than *(hazard)* risk reduction in *(place)*.	Y	N	N
Responsibility	I feel responsible for *(hazard)* risk reduction in *(place)*.	N	N	N
Responsibility	Too much responsibility has been placed on me to support the measures.	N	N	N/A
Effectiveness	I need more evidence that the natural measures will reduce risk of *(hazard)*.	Y	N	N
Effectiveness	I believe that when (storms) come in the future, these measures will reduce the chance of *(hazard)*.	Y	N	N
Effectiveness	I believe there is nothing we can do to **reduce** risks posed by *(hazard)* in *(place)*.	N	N	N
Cost	I believe the financial cost of these measures is too great.	Y	Y	N
Good	It is good that these measures are being implemented.	Y	N	Y
Satisfied	I am satisfied with how these measures are being implemented.	Y	N	Y
	Behavioural Acceptance			
	In the future, I would like to...			
learn more	...(continue to) **learn more** about such measures.	Y	Y	Y
attend meetings	...**attend meetings** about such measures	Y	Y	Y
implement or maintain	...help **implement or maintain** such measures	Y	Y	Y
monitor	...help **monitor** the effects of such measures on water quality	Y	Y	Y
fund or source supplies	...help **fundraise or source materials** for such measures	Y	Y	Y
support in other ways	...support such measures in **other ways**	Y	Y	Y

	Past Impacts[21]			
	In the past, (hazard) have...			
Past impact	...affected my *(exposed element)* in *(place)*.	*all items included as sum*		
	Future Impacts			
	In the future, I believe (hazard) could...			
Future impact	...affect my *(exposed element)* in *(place)*.	*all items included as sum*		
	Risk Perception			
Coping capacity	If *(hazard)* occurs, I will easily be able to deal with any negative impacts on my daily life.	N	N	N
Susceptibility	If *(hazard)* occurs, I will be **more** negatively affected than other residents who live in **equally risky areas**.	Y	Y	Y
Hazard frequency	*(hazards)* with negative impacts occur frequently in *(place)*.	Y	Y	Y
Hazard magnitude	*(hazards)* in *(place)* will be stronger and more frequent in the future.	Y	Y	Y
Concern	I am concerned about negative impacts from *(hazard)*.	Y	Y	Y
	Risk Intolerance[22]			
Risk intolerance	It is okay if *(exposed element)* is/are affected by *(hazard)* **once every *(time span)*.**	*one item removed from each site*		
	Commitment to Nature			
Well-being	I believe that the well-being of the natural environment can affect my own well-being.	Y	Y	Y
Attachment	I do not feel very attached to the natural environment.	Y	N	N
Feel good	It makes me feel good when something happens that benefits the environment.	Y	Y	Y
Best interests	I feel committed to keeping the best interests of the environment in mind.	Y	Y	Y
	Connectedness to Place			
Identity	My sense of who I am is tied to *(place)*.	Y	Y	Y
Attachment	I do **not** miss being in *(place)* when I'm away.	N	Y	N
Dependence	I enjoy spending my free time in *(place)*.	Y	Y	Y
Pride	It is a privilege to live in *(place)*.	Y	N	Y

[21] The number of past impact and future impact items varies by study site depending on the number of primary impacts from each hazard type (Catterline n=4; Puruvesi n=4; Spercheios n=6). An additional open response item for both past and future impacts is also included on each survey – "please list any other impacts..." Please see Text. A-3 for the complete Catterline survey.

[22] The number of risk intolerance items varies by study site depending on the number of primary impacts from each hazard type (Catterline n=4; Puruvesi n=4; Spercheios n=6).

Table. A-5 Data imputation per item per study site. These include "I don't know" responses (A) and for instances of missing data (B).

(A) Number of single "I don't know" responses imputed with Likert mid-points per item per study site. Only items with >5% imputed data are shown. Items for past and future impacts have their own imputation criteria for "I don't know" responses: if all given items (>=1) are *Yes*, input *No*; if all given items (>=1) are *No*, input *No*; if mixed (at least one *Yes* and one *No* given) these become *No*; if all missing, leave as missing data.

Theme	Item	Catterline	Puruvesi	Spercheios
	Attitudinal acceptance	N=66	N=205	N=84
Good	It is good that these measures are being implemented.			
Satisfied	I am satisfied with how these measures are being implemented.	7 (9.4%)		8 (9.5%)
Trust	I believe the people implementing the measures know what they are doing.	5 (7.6%)		
Trust	I believe the people implementing the measures are doing so in the best interest of the community.			
Trust	I feel that the measures are being imposed on me.			
Competing interests	I believe resources would be better used for other community concerns.	5 (7.6%)		
Competing interests	I would prefer to engage with more important community issues than *(hazard)* risk reduction in *(place)*.			
Responsibility	I feel responsible for *(hazard)* risk reduction in *(place)*.			
Responsibility	Too much responsibility has been placed on me to support the measures.			
Effectiveness	I need more evidence that the natural measures will reduce risk of *(hazard)*.			
Effectiveness	I believe that when (storms) come in the future, these measures will reduce the chance of *(hazard)*.	8 (12.1%)	15 (7.3%)	6 (7.1%)
Effectiveness	I believe there is nothing we can do to reduce risks posed by *(hazard)* in *(place)*.			
Cost	I believe the financial cost of these measures is too great.	10 (15.2%)		16 (19.0%)
Theme	**Item**	**Catterline**	**Puruvesi**	**Spercheios**
Coping capacity	If (hazard) occurs, I will easily be able to deal with any negative impacts on my daily life.	7 (9.4%)		
Hazard magnitude	(hazards) in (place) will be stronger and more frequent in the future.	12 (18.2%)		
Past impact	recreation			9 (10.7%)
Risk intolerance	Other residents believe risk must be reduced			9 (10.7%)
Future impact	enjoyment of natural scenery	4 (6.1%)		
Future impact	damaged property	10 (15.2%)		
Future impact	recreation			11 (13.1%)
Future impact	livelihood			6 (7.1%)
Future impact	Residential property damage			6 (8.3%)
Future impact	other property damage			8 (9.5%)
Future impact	Personal safety			16 (19.0%)

(B) Number of single missing data responses imputed with median responses for that respondent per item per study site. Only items with >5% imputed data are shown. Items for past and future impacts have their own imputation criteria for missing data: if all given items (>=1) are *Yes*, input *No*; if all given items (>=1) are *No*, input *No*; if mixed (at least one *Yes* and one *No* given) these become *No*; if all missing, leave as missing data.

Theme	**Item**	**Catterline**	**Puruvesi**	**Spercheios**
		N=66	N=205	N=84
Connectedness to Place	It is a privilege to live near Lake Puruvesi		16 (7.8%)	
Past impact	recreational use of the lake		11 (5.4%)	
Past impact	aquatic-based livelihood		12 (5.9%)	
Past impact	physical and mental well-being		12 (5.9%)	
Future impact	enjoyment of landscape		12 (5.9%)	
Future impact	recreational use of the lake		11 (5.4%)	
Future impact	recreational fishing		13 (6.3%)	
Future impact	agriculture and/or forestry activities		12 (5.9%)	
Future impact	aquatic-based livelihood		14 (6.8%)	
Future impact	tourism-based livelihood		13 (6.3%)	
Future impact	physical and mental well-being		12 (5.9%)	
Future impact	affected roads			9 (10.7%)

Table. A-6 Exploratory factor analysis (EFA) attitudinal acceptance outputs. First initial outputs and scale reliability metrics are provided (original scales prior to iterative item removal) (A) and then final outputs and scale reliability metrics (scales used to calculate weighted sum factor scores after iterative item removal) (B).

(A) Initial (prior to iterative item removal) *attitudinal acceptance* exploratory factor analysis (EFA) overview of output and scale reliability metrics for each study site.

Scale reliability	Catterline	Puruvesi	Spercheios
Alpha	.837	.759	.693
Alpha if item deleted increase or highest	.848 - I feel responsible for (hazard) risk reduction in (place). .838 - Too much responsibility has [not] been placed on me to support the measures	.792 - I believe that when (storms) come in the future, these measures will reduce the chance of *(hazard)*.	.720 - I [do not] need more evidence that the natural measures will reduce risk of (hazard). .710 - I feel responsible for (hazard) risk reduction in (place). .693 - I believe there is [not] nothing we can do to reduce risks posed by *(hazard)* in *(place)*.
CITC below .3 or lowest	.194 - I feel responsible for (hazard) risk reduction in (place).	.088 - I believe that when (storms) come in the future, these measures will reduce the chance of *(hazard)*. .288 - Too much responsibility has [not] been placed on me to support the measures .193 - I feel responsible for (hazard) risk reduction in (place).	.051 - I [do not] need more evidence that the natural measures will reduce risk of (hazard). .132 - I feel responsible for (hazard) risk reduction in (place). .197 - I believe there is [not] nothing we can do to reduce risks posed by *(hazard)* in *(place)*.
EFA Output	**Catterline**	**Puruvesi**	**Spercheios**
# of factors extracted	3	4	N/A – does not extract factors
% variance explained	61.77	58.41	N/A
Communality <.3 or lowest	.323 - I feel responsible for (hazard) risk reduction in (place).	.039 - I believe that when (storms) come in the future, these measures will reduce the chance of *(hazard)*. .169- Too much responsibility has [not] been placed on me to support the measures .089 - I feel responsible for (hazard) risk reduction in (place).	N/A

		Catterline	Puruvesi
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.798	.777
Bartlett's Test of Sphericity	Approx. Chi-Square	325.631	594.795
	df	78	78
	Sig.	.000	.000

	Communalities	Catterline		Puruvesi	
Theme	Item	Initial	Extraction	Initial	Extraction
Good	It is good that these measures are being implemented.	.587	.726	.345	.426
Satisfied	I am satisfied with how these measures are being implemented.	.618	.660	.354	.707
Trust	I believe the people implementing the measures know what they are doing.	.595	.531	.558	.561
Trust	I believe the people implementing the measures are doing so in the best interest of the community.	.479	.378	.498	.993
Trust	I [do not] feel that the measures are being imposed on me.	.431	.518	.493	.915
Competing interests	I believe resources would [not] be better used for other community concerns.	.587	.651	.519	.563
Competing interests	I would [not] prefer to engage with more important community issues than *(hazard)* risk reduction in *(place)*.	.448	.408	.284	.323
Responsibility	I feel responsible for *(hazard)* risk reduction in *(place)*.	.358	.323	.090	.089
Responsibility	Too much responsibility has [not] been placed on me to support the measures.	.378	.612	.182	.169
Effectiveness	I [do not] need more evidence that the natural measures will reduce risk of *(hazard)*.	.425	.437	.332	.337
Effectiveness	I believe that when (storms) come in the future, these measures will reduce the chance of *(hazard)*.	.487	.512	.070	.039
Effectiveness	I believe there is [not] nothing we can do to reduce risks posed by *(hazard)* in *(place)*.	.459	.350	.214	.192
Cost	I believe the financial cost of these measures is [not] too great.	.433	.524	.391	.504

	Structure Matrices (principal axis, promax rotation with Kaiser Normalization)	Catterline			Puruvesi			
Theme	Items Factors	F1	F2	F3	F1	F2	F3	F4
Good	It is good that these measures are being implemented.	.830	.284	.280	.442	.286	.611	.350
Satisfied	I am satisfied with how these measures are being implemented.	.699	.701	.163	.202	.368	.831	.273
Trust	I believe the people implementing the measures know what they are doing.	.557	.680	.151	.352	.701	.496	.458
Trust	I believe the people implementing the measures are doing so in the best interest of the community.	.566	.496	.276	.292	.994	.395	.316
Trust	I [do not] feel that the measures are being imposed on me.	.375	.314	.699	.608	.331	.281	.952

Competing interests	I believe resources would [not] be better used for other community concerns.	.528	.743	.520	.733	.272	.334	.585
Competing interests	I would [not] prefer to engage with more important community issues than *(hazard)* risk reduction in *(place)*.	.525	.567	.111	.541	.163	.348	.320
Responsibility	I feel responsible for *(hazard)* risk reduction in *(place)*.	.474	-.016	.119	.223	.113	.244	.095
Responsibility	Too much responsibility has [not] been placed on me to support the measures.	.170	.221	.779	.397	.111	.118	.319
Effectiveness	I [do not] need more evidence that the natural measures will reduce risk of *(hazard)*.	.117	.613	.210	.430	.238	.335	.560
Effectiveness	I believe that when (storms) come in the future, these measures will reduce the chance of *(hazard)*.	.709	.452	.222	.033	.145	.172	.042
Effectiveness	I believe there is [not] nothing we can do to reduce risks posed by *(hazard)* in *(place)*.	.486	.449	.426	.423	.222	.165	.329
Cost	I believe the financial cost of these measures is [not] too great.	.155	.683	.211	.702	.220	.180	.404

Factor correlation matrices	**Catterline**			**Puruvesi**			
	F1	F2	F3	F1	F2	F3	F4
F1	1.000	.526	.305	1.000	.318	.379	.630
F2	.526	1.000	.327	.318	1.000	.432	.383
F3	.305	.327	1.000	.379	.432	1.000	.382
F4				.630	.383	.382	1.000

(B) Final (after iterative item removal) *attitudinal acceptance* exploratory factor analysis (EFA) overview of output and scale reliability metrics for each study site.

Scale Reliability	**Catterline**	**Puruvesi**	**Spercheios**
Alpha	.840	.747	.704
Alpha if item deleted increase or highest	.846 - I [do not] need more evidence that the natural measures will reduce risk of *(hazard)*. .827 - I believe the people implementing the measures are doing so in the best interest of the community.	.731 - I believe the financial cost of these measures is [not] too great.	.680 – I believe the people implementing the measures know what they are doing. .665 - It is good that these measures are being implemented.
CITC below .3 or lowest	.406 - I [do not] need more evidence that the natural measures will reduce risk of *(hazard)*. .527 - I believe the people implementing the measures are doing so in the best interest of the community.	.442 - I believe the financial cost of these measures is [not] too great.	.427 – I believe the people implementing the measures know what they are doing. .447 - It is good that these measures are being implemented.
EFA Output	**Catterline**	**Puruvesi**	**Spercheios**
# of factors extracted	2	2	2

% variance explained	62.21	73.85	79.18
Communality <.3 or lowest	.404 - I believe the people implementing the measures are doing so in the best interest of the community.	.350 - I believe the financial cost of these measures is [not] too great.	.501 - It is good that these measures are being implemented.

		Catterline	Puruvesi	Spercheios
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.828	.667	.613
Bartlett's Test of Sphericity	Approx. Chi-Square	222.753	275.299	78.372
	df	36	10	6
	Sig.	.000	.000	.000

	Communalities		Catterline		Puruvesi		Spercheios	
Theme	**Items**	**Factors**	Initial	Extraction	Initial	Extraction	Initial	Extraction
Good	It is good that these measures are being implemented.		.492	.605			.309	.501
Satisfied	I am satisfied with how these measures are being implemented.		.584	.624			.338	.581
Trust	I believe the people implementing the measures know what they are doing.		.523	.546	.514	.848	.357	.561
Trust	I believe the people implementing the measures are doing so in the best interest of the community.		.414	.404	.471	.549	.438	.684
Trust	I [do not] feel that the measures are being imposed on me.				.363	.414		
Competing interests	I believe resources would [not] be better used for other community concerns.		.484	.551	.456	.829		
Competing interests	I would [not] prefer to engage with more important community issues than *(hazard)* risk reduction in *(place)*.		.414	.411				
Responsibility	I feel responsible for *(hazard)* risk reduction in *(place)*.							
Responsibility	Too much responsibility has [not] been placed on me to support the measures.							
Effectiveness	I [do not] need more evidence that the natural measures will reduce risk of *(hazard)*.		.417	.561				
Effectiveness	I believe that when (storms) come in the future, these measures will reduce the chance of *(hazard)*.		.478	.510				
Effectiveness	I believe there is [not] nothing we can do to reduce risks posed by *(hazard)* in *(place)*.							
Cost	I believe the financial cost of these measures is [not] too great.		.378	.447	.303	.350		

	Structure Matrices (principal axis, promax rotation with Kaiser Normalization)		Catterline		Puruvesi		Spercheios	
	Items	**Factors**	F1	F2	F1	F2	F1	F2
Good	It is good that these measures are being implemented.		.724	.142			.317	.707

Satisfied	I am satisfied with how these measures are being implemented.					.370	.762
Trust	I believe the people implementing the measures know what they are doing.	.657	.636	.411	.921	.742	.272
Trust	I believe the people implementing the measures are doing so in the best interest of the community.	.635	.362	.313	.741	.819	.496
Trust	I [do not] feel that the measures are being imposed on me.			.629	.394		
Competing interests	I believe resources would [not] be better used for other community concerns.	.605	.686	.909	.340		
Competing interests	I would [not] prefer to engage with more important community issues than *(hazard)* risk reduction in *(place)*.	.608	.497				
Responsibility	I feel responsible for *(hazard)* risk reduction in *(place)*.						
Responsibility	Too much responsibility has [not] been placed on me to support the measures.						
Effectiveness	I [do not] need more evidence that the natural measures will reduce risk of *(hazard)*.	.227	.725				
Effectiveness	I believe that when (storms) come in the future, these measures will reduce the chance of *(hazard)*.	.712	.330				
Effectiveness	I believe there is [not] nothing we can do to reduce risks posed by *(hazard)* in *(place)*.						
Cost	I believe the financial cost of these measures is [not] too great.	.317	.667	.591	.241		

Factor correlation matrices	**Catterline**		**Puruvesi**		**Spercheios**	
	F1	F2	F1	F2	F1	F2
F1	1.000	.531	1.000	.431	1.000	.501
F2	.531	1.000	.431	1.000	.338	1.000

Table. A-7 Exploratory factor analysis (EFA) behavioural acceptance outputs and scale reliability metrics. All items were retained from the original scales.

Scale reliability	Catterline	Puruvesi	Spercheios
Alpha	.933	.898	.856
Alpha if item deleted increase or highest	.943 - [1]...(continue to) learn more about such measures.	.893 - ...support such measures in other ways	.860 - ...support such measures in other ways
CITC below .3 or lowest	.611 - ...(continue to) learn more about such measures.	.634 - ...support such measures in other ways	.537 - ...support such measures in other ways
EFA Output	**Catterline**	**Puruvesi**	**Spercheios**
# of factors extracted	1	1	1
% variance explained	75.82	66.29	63.81
Communality <.3 or lowest	.401 - ...(continue to) learn more about such measures.	.448 - ...support such measures in other ways	.332 - ...support such measures in other ways

[1]All behavioural acceptance items begin with the phrase "In the future, I would like to..."

		Catterline	Puruvesi	Spercheios
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.880	.880	.747
Bartlett's Test of Sphericity	Approx. Chi-Square	355.669	630.696	233.340
	df	15	15	10
	Sig.	.000	.000	.000

Communalities	Catterline		Puruvesi		Spercheios	
In the future, I would like to...	Initial	Extraction	Initial	Extraction	Initial	Extraction
...(continue to) learn more about such measures.	.474	.401	.481	.494	.579	.384
...attend meetings about such measures	.747	.770	.601	.638	.723	.765
...help implement or maintain such measures	.787	.814	.699	.799	.636	.588
...help monitor the effects of such measures on water quality	.847	.881	.585	.635	.683	.726
...help fundraise or source materials for such measures	.617	.558	.562	.581	N/A	N/A
...support such measures in other ways	.841	.881	.455	.448	.331	.332

Factor matrices (principal axis)	Catterline	Puruvesi	Spercheios
Factors	F1	F1	F1
In the future, I would like to...	.633	.703	.620
...(continue to) learn more about such measures.	.877	.799	.875
...attend meetings about such measures	.902	.894	.767

...help implement or maintain such measures	.939	.797	.852
...help monitor the effects of such measures on water quality	.747	.762	.576
...help fundraise or source materials for such measures	.939	.669	.620
...support such measures in other ways	.633	.703	.875

Table. A-8 Descriptive statistics of all survey items for attitudinal and behavioural acceptance. Descriptive statistics of standardised NbS attitudinal acceptance items (n=13) and behavioural acceptance items (n=6) for each study site.

Catterline								
Theme	**Item**	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**SD**	**Variance**
	Attitudinal acceptance							
Good	It is good that these measures are being implemented.	66	.889	.111	1.000	.918	.177	.031
Satisfied	I am satisfied with how these measures are being implemented.	66	.889	.111	1.000	.754	.217	.047
Trust	I believe the people implementing the measures know what they are doing.	66	.556	.444	1.000	.777	.181	.033
Trust	I believe the people implementing the measures are doing so in the best interest of the community.	66	.889	.111	1.000	.872	.182	.033
Trust	I feel that the measures are being imposed on me.	66	.667	.333	1.000	.786	.212	.045
Competing interests	I believe resources would be better used for other community concerns.	66	.556	.444	1.000	.798	.186	.035
Competing interests	I would prefer to engage with more important community issues than *(hazard)* risk reduction in *(place)*.	66	.889	.111	1.000	.781	.195	.038
Responsibility	I feel responsible for *(hazard)* risk reduction in *(place)*.	66	.889	.111	1.000	.722	.230	.053
Responsibility	Too much responsibility has been placed on me to support the measures.	66	.667	.333	1.000	.818	.210	.044
Effectiveness	I need more evidence that the natural measures will reduce risk of *(hazard)*.	66	.889	.111	1.000	.591	.256	.065
Effectiveness	I believe that when (storms) come in the future, these measures will reduce the chance of *(hazard)*.	66	.889	.111	1.000	.707	.193	.037
Effectiveness	I believe there is nothing we can do to reduce risks posed by *(hazard)* in *(place)*.	66	.889	.111	1.000	.827	.208	.043
Cost	I believe the financial cost of these measures is too great.	66	.889	.111	1.000	.687	.232	.054

Theme	**Item**	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**SD**	**Variance**
	Behavioural acceptance							
	In the future, I would like to...							
learn more	...(continue to) learn more about such measures.	66	.889	.111	1.000	.813	.187	.035
attend meetings	...attend meetings about such measures	66	.889	.111	1.000	.717	.274	.075
implement or maintain	...help implement or maintain such measures	66	.889	.111	1.000	.722	.255	.065

monitor	...help monitor the effects of such measures on water quality	66	.889	.111	1.000	.667	.257	.066
fund or source supplies	...help fundraise or source materials for such measures	66	.889	.111	1.000	.635	.284	.080
support in other ways	...support such measures in other ways	66	.889	.111	1.000	.684	.243	.059
Puruvesi								
Theme	**Item**	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**SD**	**Variance**
	Attitudinal acceptance							
Good	It is good that these measures are being implemented.	187	.857	.143	1.000	.930	.143	.020
Satisfied	I am satisfied with how these measures are being implemented.	187	.857	.143	1.000	.794	.199	.040
Trust	I believe the people implementing the measures know what they are doing.	182	.857	.143	1.000	.833	.186	.034
Trust	I believe the people implementing the measures are doing so in the best interest of the community.	182	.857	.143	1.000	.812	.213	.045
Trust	I feel that the measures are being imposed on me.	182	.857	.143	1.000	.792	.237	.056
Competing interests	I believe resources would be better used for other community concerns.	182	.857	.143	1.000	.834	.193	.037
Competing interests	I would prefer to engage with more important community issues than *(hazard)* risk reduction in *(place)*.	182	.857	.143	1.000	.873	.174	.030
Responsibility	I feel responsible for *(hazard)* risk reduction in *(place)*.	183	.857	.143	1.000	.733	.251	.063
Responsibility	Too much responsibility has been placed on me to support the measures.	183	.857	.143	1.000	.838	.195	.038
Effectiveness	I need more evidence that the natural measures will reduce risk of *(hazard)*.	182	.857	.143	1.000	.695	.283	.080
Effectiveness	I believe that when (storms) come in the future, these measures will reduce the chance of *(hazard)*.	182	.857	.143	1.000	.561	.323	.105
Effectiveness	I believe there is nothing we can do to reduce risks posed by *(hazard)* in *(place)*.	182	.857	.143	1.000	.912	.196	.038
Cost	I believe the financial cost of these measures is too great.	183	.857	.143	1.000	.795	.233	.054

Theme	**Item**	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**SD**	**Variance**
	Behavioural acceptance							
	In the future, I would like to...							
learn more	...(continue to) learn more about such measures.	186	.857	.143	1.000	.806	.199	.040
attend meetings	...attend meetings about such measures	186	.857	.143	1.000	.667	.234	.055

implement or maintain	...help implement or maintain such measures	186	.857	.143	1.000	.692	.233	.054
monitor	...help monitor the effects of such measures on water quality	186	.857	.143	1.000	.740	.236	.056
fund or source supplies	...help fundraise or source materials for such measures	186	.857	.143	1.000	.617	.232	.054
support in other ways	...support such measures in other ways	186	.857	.143	1.000	.715	.223	.050
Spercheios								
Theme	**Item**	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**SD**	**Variance**
	Attitudinal acceptance							
Good	It is good that these measures are being implemented.	84	.889	.111	1.000	.861	.215	.046
Satisfied	I am satisfied with how these measures are being implemented.	84	.889	.111	1.000	.661	.229	.052
Trust	I believe the people implementing the measures know what they are doing.	84	.889	.111	1.000	.718	.238	.057
Trust	I believe the people implementing the measures are doing so in the best interest of the community.	84	.889	.111	1.000	.713	.238	.057
Trust	I feel that the measures are being imposed on me.	84	.889	.111	1.000	.640	.256	.066
Competing interests	I believe resources would be better used for other community concerns.	84	.889	.111	1.000	.808	.232	.054
Competing interests	I would prefer to engage with more important community issues than *(hazard)* risk reduction in *(place)*.	84	.889	.111	1.000	.827	.221	.049
Responsibility	I feel responsible for *(hazard)* risk reduction in *(place)*.	83	.889	.111	1.000	.657	.288	.083
Responsibility	Too much responsibility has been placed on me to support the measures.	0						
Effectiveness	I need more evidence that the natural measures will reduce risk of *(hazard)*.	84	.889	.111	1.000	.447	.275	.076
Effectiveness	I believe that when (storms) come in the future, these measures will reduce the chance of *(hazard)*.	84	.889	.111	1.000	.722	.207	.043
Effectiveness	I believe there is nothing we can do to reduce risks posed by *(hazard)* in *(place)*.	84	.889	.111	1.000	.812	.230	.053
Cost	I believe the financial cost of these measures is too great.	83	.889	.111	1.000	.639	.235	.055

Theme	Item	N	Range	Minimum	Maximum	Mean	SD	Variance
	Behavioural acceptance							
	In the future, I would like to...							
learn more	...(continue to) learn more about such measures.	83	.889	.111	1.000	.861	.204	.042

attend meetings	...attend meetings about such measures	83	.889	.111	1.000	.767	.254	.064
implement or maintain	...help implement or maintain such measures	83	.889	.111	1.000	.778	.243	.059
monitor	...help monitor the effects of such measures on water quality	83	.889	.111	1.000	.772	.250	.062
fund or source supplies	...help fundraise or source materials for such measures	N/A	N/A	N/A	N/A	N/A	N/A	N/A
support in other ways	...support such measures in other ways	83	.889	.111	1.000	.779	.241	.058

Table. A-9 Descriptive statistics (non-standardised) of the primary survey variables for each study site.

Theme	Item	N	Range	Minimum	Maximum	Mean	SD	Variance
Catterline								
Acceptance	*Good and satisfied*	66	6.76	2.24	9.00	7.207	1.287	1.657
Acceptance	*Benefits outweigh costs*	66	7.00	2.00	9.00	6.186	1.690	2.857
Acceptance	*Behavioural acceptance*	66	8.00	1.00	9.00	6.319	2.004	4.018
Risk	*Risk perception*	66	5.27	1.78	7.05	5.019	1.279	1.635
Risk	*Risk intolerance*	66	8.00	1.00	9.00	3.388	2.051	4.208
Risk	*Past impacts*	66	5	0	5	2.23	1.200	1.440
Risk	*Future impacts*	66	5	0	5	3.03	1.136	1.291
Nature	*Commitment to nature*	66	4.76	4.24	9.00	7.852	1.213	1.471
Nature	*Responsibility for nature*	64	8	1	9	7.92	1.646	2.708
Place	*Connectedness to place*	66	8.00	1.00	9.00	7.504	1.461	2.136
Puruvesi								
Theme	**Item**	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**SD**	**Variance**
Acceptance	*Benefits outweigh costs*	183	5.89	1.11	7.00	5.653	1.281	1.640
Acceptance	*Trust in implementers*	183	6.11	.89	7.00	5.735	1.319	1.740
Acceptance	*Behavioural acceptance*	186	6.00	1.00	7.00	4.930	1.301	1.693
Risk	*Risk perception*	188	6.00	1.00	7.00	4.943	1.132	1.282
Risk	*Risk intolerance*	188	6.00	1.00	7.00	1.963	1.218	1.484
Risk	*Past impacts*	195	6	0	6	2.04	1.568	2.457
Risk	*Future impacts*	194	6	0	6	3.02	1.383	1.912
Nature	*Commitment to nature*	198	3.88	3.12	7.00	6.462	.715	.511
Nature	*Responsibility for nature*	197	4	3	7	6.53	.848	.720
Place	*Connectedness to place*	198	4.94	2.06	7.00	5.770	1.086	1.179
Spercheios								
Theme	**Item**	**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**SD**	**Variance**
Acceptance	*Trust in implementers*	84	8.00	1.00	9.00	6.439	1.917	3.674
Acceptance	*Good and satisfied*	84	8.00	1.00	9.00	6.817	1.754	3.075
Acceptance	*Behavioural acceptance*	83	6.99	2.01	9.00	7.0930	1.755	3.081
Risk	*Risk perception*	84	7.61	1.39	9.00	5.898	1.758	3.092
Risk	*Risk intolerance*	84	8.00	1.00	9.00	2.960	2.185	4.773
Risk	*Past impacts*	84	6	0	6	2.42	1.499	2.246
Risk	*Future impacts*	84	7	0	7	3.27	1.779	3.165

Nature	*Commitment to nature*	84	8.00	1.00	9.00	7.757	1.697	2.879
Nature	*Responsibility for nature*	84	8	1	9	7.67	1.884	3.550
Place	*Connectedness to place*	84	8.00	1.00	9.00	5.951	1.977	3.910

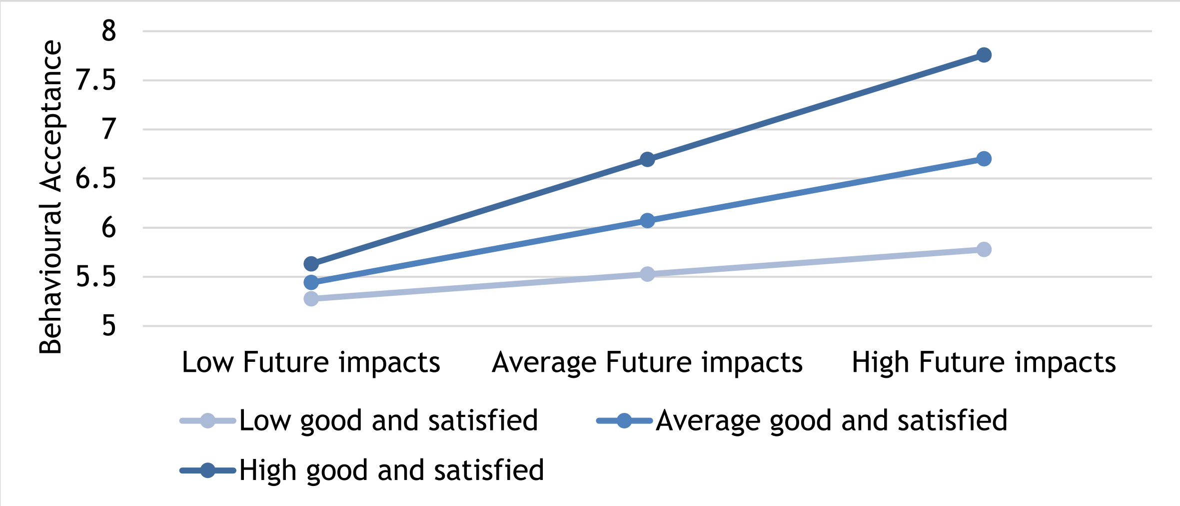
Table. A-10 Model statistics of attitudes as moderating variables. Simple regression moderation models of statistically significant (*p*<.05) moderating attitudinal acceptance factors in Catterline and Puruvesi and graphed relations. These factors moderate relations between primary predictor survey variables and *behavioural acceptance*. The PROCESS macro for SPSS is used to create the models ("Model 1" configuration) (Hayes 2017)[23]. Graphs are provided for each model using moderator values at one standard deviation below the mean ("low"), at the mean ("average"), and ("high").

Model	Predictor	*Moderating attitudinal factor*	R^2	*F*	P	df1	df2
Catterline_1	*Future Impacts*	*good and satisfied*	.294	8.610	.000	3	62
Catterline_2	*Commitment to nature*	*good and satisfied*	.343	10.80	.000	3	62
Catterline_3	*Responsibility for nature*	*good and satisfied*	.258	6.968	.000	3	60
Catterline_4	*Connectedness to place*	*good and satisfied*	.277	7.924	000	3	62
Puruvesi_1	*Risk perception*	*trust in implementers*	.126	8.584	.000	3	179

[23] Hayes, Andrew F. (2017): Introduction to mediation, moderation, and conditional process analysis: A regression-based approach. New York, NY: Guilford publications.

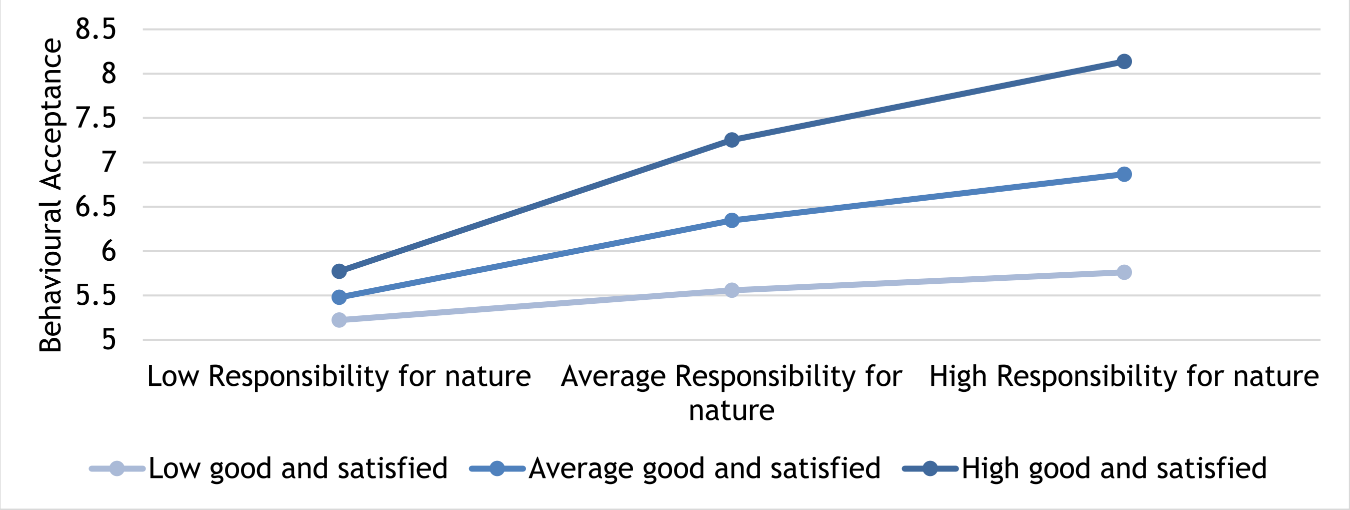
					95% CI	
Model	**Predictor**	***b***	***t***	***p***	**Lower**	**Upper**
Catterline_1	*Future Impacts*	-1.782	-1.828	.072	-3.731	.167
	good and satisfied	-.520	-1.309	.195	-1.315	.274
	Future Impacts* good and satisfied	**.333**	**2.476**	**.016**	**.064**	**.601**
Catterline_2	*Commitment to nature*	-1.788	-.2583	.012	-3.172	-.404
	good and satisfied	-2.013	-2.711	.009	-3.497	-.529
	Commitment to nature* good and satisfied	**.332**	**3.393**	**.001**	**.136**	**.527**
Catterline_3	*Responsibility for nature*	-.883	-2.204	.004	-1.685	-.082
	good and satisfied	-.918	-1.741	.087	-1.973	.137
	Responsibility for nature* good and satisfied	**.189**	**2.858**	**.006**	**.057**	**.321**
Catterline_4	*Connectedness to place*	-.814	-1.920	.059	-1.662	.033
	good and satisfied	-.932	-1.839	.071	-1.944	.081
	Connectedness to place* good and satisfied	**.193**	**2.891**	**.005**	**.060**	**.326**
Puruvesi_1	*Risk perception*	1.128	3.069	.002	.403	1.853
	trust in implementers	.832	2.866	.005	.259	1.405
	Risk perception* trust in implementers	**-.146**	**-2.393**	**.018**	**-.266**	**-.026**

Catterline_1

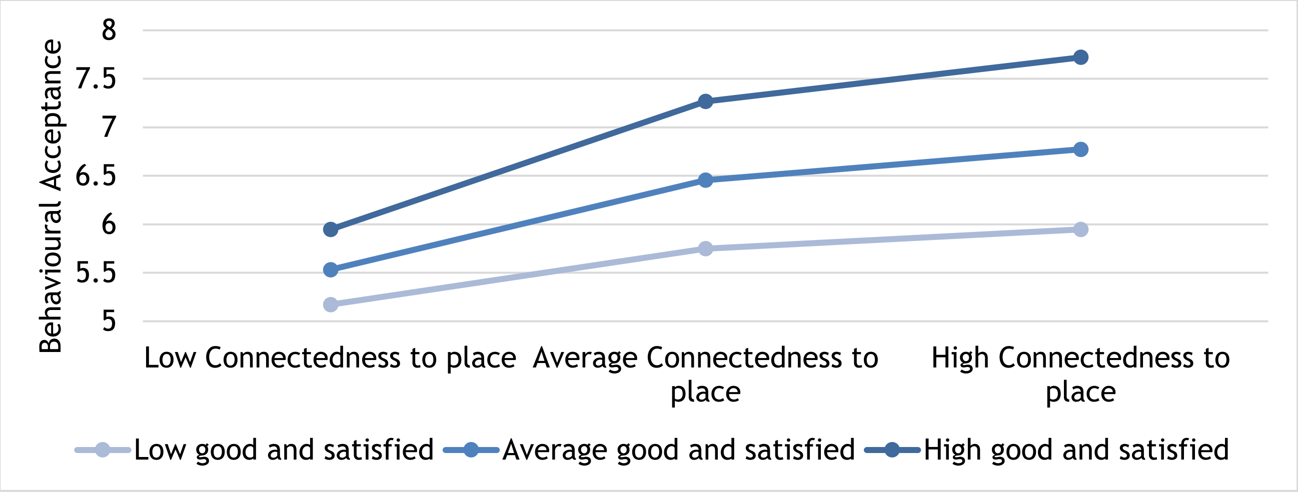


Catterline_2

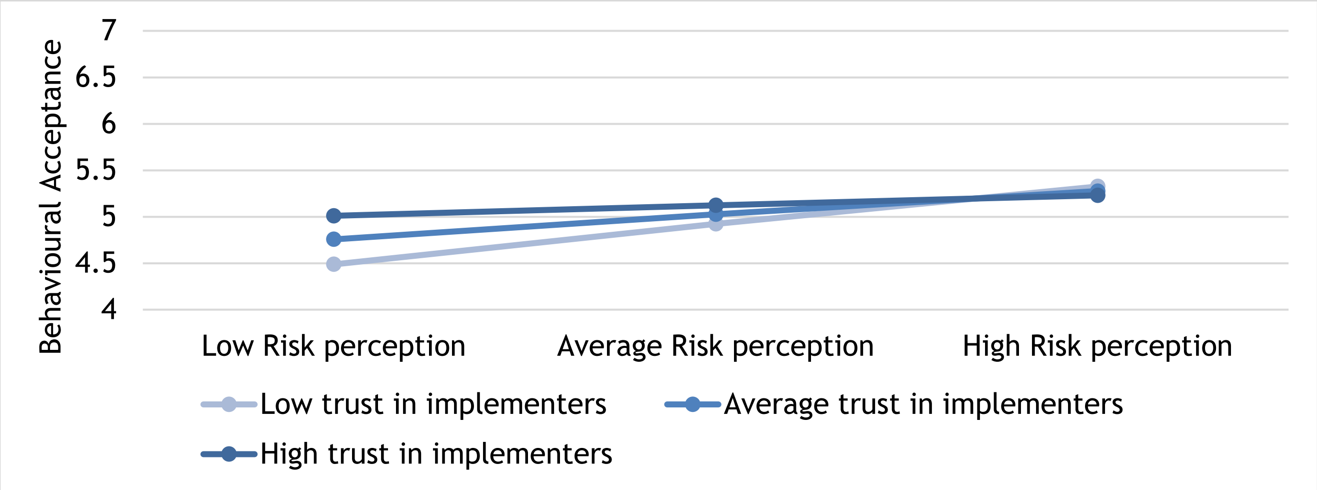
Catterline_3



Catterline_4



Puruvesi_1



Behavioural Acceptance
7
6.5
6
5.5
5
4.5
4
Low Risk perception
Average Risk perception
High Risk perception
Low trust in implementers
Average trust in implementers
High trust in implementers

Table. A-11 Comments provided by respondents on the surveys for each of the study sites. Comments are classified by theme (although some comments will have multiple themes, the main idea of the comment was used) and survey respondent number (R#). Survey comments for Puruvesi and Spercheios are translated by co-authors from Finnish and Greek, respectively.

R#	Catterline
	Risk
3	I suspect that coastal erosion is more of a threat to our community than landslides.
5	Landslides have always occurred but have become more frequent and extensive since (*unintelligible*) treatment of the braes has lapsed. This may or may not be a coincidence.
6	I am new to the area but am not aware of landslides being a problem.
46	I do not live on the coastal part of Catterline just inland, but know most of the residents in close proximity to the landslides and I do make a lot of use of the harbour.
57	Overdevelopment of caravan park is causing a change in water table causing more water run off to travel to Catterline. This affects roads causing potholes. Drainage is inadequate to support increased tourists to area having a negative impact.
	Issues regarding NbS
2	As a resident of [*removed*], by far the most worrying threat is that of erosion of the cliff caused by erosion from the sea. Since the gabions beneath the cliff in front of [*removed*] were destroyed several years ago this erosion has been unchecked. This is potentially very serious as it will cause landslides unless some form of sea defences are reinstated. This is not just about the inconveniences of roads being closed, but could put at risk our *[removed]* houses. I would be keen to ensure that the project does not exclude consideration of this severe threat [*removed*], which to date has received relatively little consideration.
3	I am not clear if all the community and external works are equally useful or worthwhile. I particularly do not like plastic matting on paths and see no purpose in this.
5	The cliffs will erode despite any measures. Some aspects will always be worth trying to save but all measures have restricted success.
32	Measures will reduce landslides caused by excessive rainfall, but will do nothing to protect base of cliff from sea rise/storm waves and erosion.
	Recommendations
12	The sea defences on the shore need urgent repair as they have moved and left exposed earth. If this is washed away by the sea it could cause a massive landslide as the earth is at the bottom.
24	Continued maintenance (drainage etc.) will mitigate this. [*Written in reference to item #8 in the risk perception section: "Landslides in Catterline will be stronger and more frequent in the future."*]
32	Focus of landslides has been on braes and where slips have occurred. If a slip occurred on main access road bridge the whole village would be affected badly.

	Other
9	I think if the measures are as natural as possible this is best for environment and residents if manmade prevention methods, I'd be less inclined to support them unless guaranteed benefits.
12	It's great that these efforts are being made and we as a community are indebted to those who have made such an effort to implement the measures.
18	Projects are never perfect, but I'm sure that the people implementing these measures are doing their best.
30	I don't know the financial cost.

R#	Puruvesi
	Negative Impacts
75	I am digging a cottage well as the use of lake water as wash water or for bathing is uncertain due to blue-green algae.
120	Blue-green algae severely limits lake water use and cottage life.
148	It is hardly nice for anyone to spend a summer day at the beach if you are not allowed to enjoy swimming or algae prevents you from carrying sauna water, for example.
166	The blue-green algae blooms are disgusting and smelly ... clean water is then not always available from the lake, wash water, sauna water when the inflorescences drift to the shore next to the pier.
196	Landing sites and swimming spots had to be sought as early as 2015 due to sliming of rocks. Reeding takes up space in open water, for example in the Jouhenjoki area.
	Recognition of risk
35	Our home is 15 meters from the shore of Puruvesi, and that is why I suffer more from cyanobacterial blooms than many others living further away. I received two evil eye inflammations after bathing.
36	Our apartment building is right on the shores of Puruvesi; 15 m away. Blue-green algae and other side effects appear and sometimes it is felt in the nose as well as with eye infections.
132	The number of cyanobacterial blooms in Suokonlahti has decreased in recent years. On the Myllylahti side they have increased. The change may be due to a change in flows when the "Value Bench" was removed a few years ago.
173	Blue-green algal blooms are a problem in shallow bay waters.
184	The bay of Ristlahti school is badly eutrophic, it could be mowed from vegetation somehow. It becomes eutrophic when water cannot circulate there.
195	Blue-green algae have a strong effect on everything related to the lake and water. Example. Due to the algae, it was not possible to swim at the turn of June-July 2015 in those rocky places as in 2010 (e.g., the beaches of Kanasaari. It felt amazing at first. In the summer of 2018, there were already swimming bans, e.g., Tavisalo).
158	As a Lake Puruvesi full-time resident, I've found the quality of the water to be a lot worse than in my youth

	Scepticism in the seriousness of the risk
96	When it comes to nutrient loads, has it been calculated what percentage of them come from so-called runoff waters? Have you taken into account, for example, beach wood, and the plant mass of reeds? Is there now a fuss about something that can be influenced, when in reality the effect is non-existent?
126	Blue-green algal blooms are a "trendy" thing. Sometimes the algae is mixed with, for example, pine pollen. - I do not underestimate the harmfulness of cyanobacteria. Blue-green algae are the oldest organisms in the world. They produced the first acids in the Earth's atmosphere, CO_2, from which life like today began. --Role in the future ??
142	Blue-green algae have been on the shores of Puruvesi for at least 25 years; the time when I have been enjoying their leisure time In Lake Puruvesi. Then it was not recognised in that way and it was not talked about as it is now. Especially in the autumn of the 1990s (October), blue-green algae drifted into the cottage beach.
193	Blue-green algal blooms occur in small and predictable areas.
205	There have hardly been any of them at my cottage beach.
	Scepticism in water protection measures
14	Ongoing and future water protection work is expected to reduce the occurrence of cyanobacteria, but the results are uncertain
158	the large variation of the water surface is a challenge in these solutions
	Lack of trust in implementers and responsible authorities
21	I know that the people who implement these solutions DO NOT implement water protection as they should. The practice does not correspond to theory / plan. Among other things, *[removed]* does not fully implement drainage water protection in the Puruvesi area.
193	The work also involves "performers", people who seek to benefit themselves in the advertising sense.
202	Regarding forest management, I would also like to say that the Forest Centre pushed open felling on my beach in [*removed*]. I refused. Instead, I would like to protect the nature of the area.
115	Why is the water level nowadays kept too high by regulation? The water washes away the soil from the beaches. Sandy beaches covered with water and mosquitoes brought by the water all summer.
	Cost / benefit of water protection measures
3	Climate change should also somehow be taken into account. I think strong winds have increased significantly in Puruvesi over the last 10 years. The water level varies quite a lot. There will probably be costs, but if we invest now, we will achieve more with less.
35	If and when our environment, where we live, improves with all its animal and plant species, then even this human animal may gradually "breed" to take better care of its immediate surroundings. Then no one needs to calculate costs, because QUALITY OF LIFE IS EVEN MORE VALUABLE CAPITAL. It is not taken by the taxpayer!
36	If and when Puruvesi improves, then at the same time animal and plant species will improve, as well as the human animal will slightly "breed" to take care of its immediate surroundings. Because it is a QUALITY that cannot be measured in money. The CAPITAL that the taxpayer does not take!
53	Even small actions have an effect. If done in a timely manner the cost will be reduced.

151	Whatever means should be used as long as the results in preventing eutrophication are good! And let's not be afraid of the cost either, this is really an important thing.
	Not knowledgeable / risk not relevant
27	I am not sufficiently familiar with the cyanobacterial phenomenon and its quantitative and qualitative, direct and indirect disadvantages to human life. I have no business in Puruvesi.
38	I have little experience with Puruvesi, as I live 14 km from Puruvesi and visit the lake and beaches very rarely. I have lived in Lake Puruvesi region from 2013 until now.
	Causes of the hazard
143	Agricultural run-off from fields is significant in the immediate area
	Recommendations for alternative / additional measures and actions
12	The water level should not change that much. Now variation is 1 m in a year. Lower variation may also help to decrease nutrient flows.
14	There is a need for reliable and popular research data and practical examples of water protection solutions in the Puruvesi area and their effectiveness and costs.
50	The Wastewater Regulation should be implemented and monitored.
53	Some repairs have already been made, more need to be done. Savonlahti, Kuonanjoki in need to get to good condition. Small nature reserve prevents building a sedimentation basin in the river and Nutrients flow into the lake. Exceptions should be made in these kinds of cases to not prevent water improvement. Management of fishing of Cyprinidae (to remove nutrients from the lake) needs to be implemented.
104	Intensive fishing for roach fish would be a good solution, for example in Sorvaslahti, which is a nearby area for many. You should do more mowing of reeds and plants. Local and cottage residents should be encouraged to do and participate in eutrophication prevention activities. Information should be actively communicated.
115	In recent years, the water level has been kept very high, the water washes nutrients into the lake and blue-green algae have occurred in abundance. The exception was summer 2019, when the water was shallow and no cyanobacteria were observed on our cottage beach.
118	Restoration of bogs /mires would be important. It would be even more important not to drain new bogs and rehabilitate former ditched mires. One could at least not give society support to open the ditches. Beavers and their dams could be conserved. Beavers are building water management solutions (dams and wetlands) with low cost.
132	The uniqueness of Puruvesi should be more prominent in the media, thus raising awareness.
187	Emissions from agriculture to the lake must be reduced. Ditches must be blocked and flows into the lake reduced. Air fertilizers should be banned on islands and near beaches.
195	MORE INFORMATION / TRAINING FOR LAND AND FOREST OWNERS! Related to catchment areas (rivers, ditches, streams), larger protection zones are needed. Lakeside forests and shoreline areas in the lakes need, I think, larger protection zones. On very lowlands, I would not accept arable farming as grassland cultivation.

196	As for the forest, the protection zones of beaches, rivers, streams and ditches should be larger. There is no cultivation at all in the lowlands of the fields. In arable farming, the protection zones of beaches, rivers, streams and ditches should be larger and focus on grassland cultivation.
	Support
153	Solidarity from Puruvesi
166	Great to have these active people !!!!
	Age as a limiting factor for engagement
10	For the sake of my age and health, I can no longer participate in anything.
116	I have already retired and do not have the forces to actively work and be involved in something larger. At the cottage, I try to protect what I can and do with my own, small actions.
	Other issues
102	There are large differences in the annual weather variations. phenomenon. The problem is not with Puruvesi alone and, in my view, cannot be treated only on a lake-by-lake basis. For example, air pollution knows no national, provincial or municipal boundaries.
198	The use of personal watercraft and similar equipment should also be prohibited. Noise is also a kind of pollution. Now sit there enjoying a summer evening as the high-speed Jet Ski spins in a circle. The difference with a motorboat is that it comes from somewhere and goes somewhere. The scooter spins in place.
	Other reflections
34	(It's a) question of values.
153	I hope the beach residents and cottage neighbours have the enthusiasm and responsibility to remove and destroy the reeds.

R#	Spercheios
12	I am glad that I helped to complete this study.
23	It is good to inform the local community about the causes and effects of flooding.
48	Despite the fact you did not provide us data about costs.
80	Climate change will bring severe effects in conjunction with the flooding of Spercheios.

A.3 Paper 3 (FGDs) additional material

Figure. A-3 Road blocked by landslide in Catterline.Landslide blocking the road down to the harbour from the residences of Catterline following heavy rains in February 2020. Photo credit: *Pieter voor de Poorte*.

Table. A-12 Characteristics of the data collection process and outcomes for each of the three study sites. Taken from Paper 2 (Survey) (CC-BY).

Study Site	Survey date	Format	Collection method	Detailed description	Response rate	Survey count	Survey count after pre-processing
Catterline	September 2019	Paper-based	Door-to-door	Seventy-two residences were included in the study area and contacted by the researcher, first with a survey notification letter one week prior to visiting the community. The lead author of this manuscript went door-to-door to every residence and all over 18-year-old residents were invited to complete the survey. Surveys were left with residents to be self-administered and collected within several days at the respondents' convenience. Surveys were completed at 60 residences.	51.6%[1]	67	66
Puruvesi	March-April 2020	Online (eHarava[2])	Postcard with online survey link	First, all 1662 households within the most affected postal code area (also where the NbS are planned) were contacted with a postcard describing the NbS work and inviting participation in the survey through a URL link. Next, 900 members of a local action group of lake users, ProPuruvesi, were also sent a survey notification email with invitation (an estimated 20% of whom were already contacted through the postcard). A short article in a free local newspaper was published in March 2020 that introduced the project and the NbS as well as informing/reminding readers of the ongoing survey.	10.3%	228	205
Spercheios	October 2019-January 2020	Paper-based	Focus group, convenience	First, surveys were distributed at the end of a public outreach focus group organised within the context of the OPERANDUM project in the town of Kompotades in October 2019. Thirty surveys were collected from the focus group, to which all surrounding residents were invited. In November 2019, 70 additional paper or electronic versions of the survey were distributed to residents by project partners representing the municipality of Lamia using existing institutional mailing lists and contacts.	79%	85	84

[1] Based on Scottish Census (2011) output area S00091368; https://www.scotlandscensus.gov.uk/ods-web/area.html
[2] www.eharava.fi

Table. A-13 Variables assessed in relation to preferences for greyer measures. Dependent variables of preferences for *grey measures instead of NbS* and *grey measures in addition to NbS* (i.e., hybrid) and independent variables related to perceptions of effectiveness of NbS, risk, and nature. Some variables were assessed as single items and others composite scales, including using exploratory factor analysis (EFA) to derive weighted factor scores. Items were translated from English for the sites in Finland and Greece. See Paper 2 (Survey) for more details on the survey.

Short version		Variable type	Number of items	Item type
Dependent variables				
Preference for grey measures				
"Grey instead of NbS"	I would prefer that other non-natural measures be used instead of these.	Item	1	1-9 Likert
"Grey in addition to NbS"	I would prefer that other non-natural measures be used in addition to these.	Item	1	1-9 Likert
Independent variables				
Effectiveness				
"Need more evidence for NbS"	I need more evidence that natural slope stabilisation measures will reduce landslide risk in Catterline.	Item	1	1-9 Likert
"NbS will reduce risk"	I believe that when storms come in the future, these measures will reduce the chance of landslides.	Item	1	1-9 Likert
"Nothing can reduce risk"	I believe there is nothing we can do to reduce risks from landslide in Catterline.	Item	1	1-9 Likert
Risk				
Risk perception	*Risk perception*	*Weighted EFA scale*	5	1-9 Likert
Risk intolerance	*Risk intolerance*	*Weighted EFA scale*	4-6	1-9 Likert
"Risk must be reduced"	The current risk of negative impacts from landslides must be reduced.	Item	1	1-9 Likert
"Concerned about impacts"	I am concerned about negative impacts from landslides.	Item	1	1-9 Likert
Past impacts	*Past impacts (sum)*	*Summed scale*	5-8	Binary yes/no
Future impacts	*Future impacts (sum)*	*Summed scale*	5-8	Binary yes/no
Nature				
Commitment to nature	*Commitment to nature*	*Weighted EFA scale*	4	1-9 Likert
"Responsible for nature"	As a resident of Catterline, I believe I have a responsibility to protect its natural environment.	Item	1	1-9 Likert
"Not proud of natural area"	I am not proud of our community's natural area.	Item	1	1-9 Likert

Table. A-14 Composition and computation of variable scales.For scales composed of 1-9 Likert items, processing and reliability testing was conducted by assessing Cronbach's alpha (α), corrected-item-total correlations (CITC), and exploratory factor analysis (EFA) using principal axis factoring. The 'original' Cronbach's α is a measure of the internal reliability of all scale items per site (C=Catterline, P=Puruvesi, and S=Spercheios), while the 'final' Cronbach's α results from removing items from the scales to increase their reliability, based on the processing steps described. Factor scores using weighted averages were calculated for further analysis. Taken from Anderson et al. (2021).

Scales[1]	*Risk perception*	*Risk intolerance*	*Past impacts*	*Future impacts*	*Commitment to nature*	*Responsibility for nature*	*Connectedness to place*
Item count	5	4-6	5-8	5-8	4	1	4
Agg. method	Factor score	Factor score	Sum	Sum	Factor score	N/A	Factor score
Themes / item structure	Coping capacity Susceptibility Hazard frequency Hazard magnitude Concern	*"It is okay if [exposed element] is/are affected by [hazard] once every [time span]."*	*"In the past, [hazard] has affected my [exposed element] in [place]."*	*"In the future, I believe [hazard] will affect my [exposed element] in [place]."*	Well-being Attachment Feel good Best interests	*"As a resident of [place], I feel responsible for protecting its natural environment."*	Identity Attachment Dependence Pride
Original Cronbach's α	C= .491 P= .630 S= .576	C= .864 P= .854 S= .851	N/A	N/A	C= .887 P= .587 S= .564	N/A	C= .734 P= .668 S= .724
Final Cronbach's α	C= .550 P= .653 S= .728	C= .864 P= .854 S= .839	N/A	N/A	C= .887 P= .759 S= .695	N/A	C= .771 P= .651 S= .776
Final % variance explained	C= 69.2 P= 51.1 S= 56.0	C= 72.6 P= 81.2 S= 62.3	N/A	N/A	C= 75.4 P= 68.0 S= 63.1	N/A	C= 72.8 P= 59.5 S= 69.9

Scale processing steps:

6. Compute Cronbach's alpha scores, alpha if item deleted and corrected-item-total correlations (CITC).
7. In parallel, run EFA using principal axis factoring (100 iterations max), eigenvalues 1, and promax rotation (100 iterations max).
8. Remove items from each EFA model until the following criteria are met, in this general order of importance: alpha maximised; no CITC <0.3; no communality <0.3; no cross-loading factors, low loadings on all factors, or stand-alone large negative loadings; percent variance maximised; adequate KMO and Bartlett's test.
9. Rerun this process iteratively, removing one variable at a time.
10. Calculate weighted averages (non-refined factor score method) to use for further analysis.

[1]*Responsibility for nature* is a single item.

Table. A-15 Focus group schedule in Catterline. We presented summarised results of the April 2019 Catterline resident surveys with intermittent structured discussion activities to collect more targeted data. Parts 1 and 2 were held in reverse order in two of the groups (G2 and G4) to not bias the aggregate data towards increased importance of risk reduction in subsequent discussion activities. Although most relevant data were collected during 'collect' phases of the FGDs, there were some intermittent questions posed to participants also during the 'present' phases (far right column).

Presentation content/discussion activity	**Primary purpose of activity**
Introduction	N/A
Introduction, participant information, verbal consent	
Part 1. Landslides and risk	Present
Past and future impacts of landslides	
Vulnerability, concern, and risk intolerance	
Poll – Risk and nature	Collect
I am very concerned about negative impacts from landslides in Catterline.	
In the future, I believe landslides could…	
The current risk of negative impacts from landslides must be greatly reduced.	
I feel very committed to keeping the best interests of the environment in mind.	
The natural benefits of the measures in Catterline (e.g., aesthetics, habitat for wildlife) are very important to me.	
Discussion activity 1	Collect
As a group, please decide where (ideally) the measures for Catterline (1. slope stabilisation and 2. drainage) would fall on this spectrum (green-hybrid-grey).	
Five years later, a series of major landslides has occurred, some of the worst Catterline has ever seen. How do you feel about your decision? Do you regret it? [follow-up] Does the continued issue of landslides make you consider moving to a new home? leaving Catterline?	
Discussion activity 2	Collect
Measures have different attributes like ***w**ildlife habitat and aesthetics* and ***r**isk reduction*. You can have minimum benefit of each of these (0%) and maximum possible benefit of each of these (100%). Where would you like each of these attributes to be? [follow-up] Do you think this is realistic?	
Discussion activity 3	Collect
You have 20 "Catterline pounds" to invest in a hypothetical measure for Catterline. The more you spend on an attribute of the measure (***w**ildlife habitat and aesthetics* and ***r**isk reduction*), the more of that benefit you get. As a group, how would you like to distribute your 20 "Catterline pounds"?	
Part 2. Catterline and nature	Present
Connectedness to place and commitment to nature	
Responsibility for nature, pride in nature	
Ecosystem services of natural area and NbS	
Part 3. The NbS	Present
Attitudinal and behavioural acceptance of NbS	
Correlations with acceptance of NbS, relation between concern and engagement	
CBAG membership	
Conclusion	N/A
Questions, feedback, information regarding upcoming NbS deployment	

Table. A-16 Number of mid-point responses on the Likert range. Mid-point responses for the two items related to preference for non-natural (grey) measures in each of the three study sites. Mid-point responses in Catterline and Spercheios are '5' responses (1-9 Likert range) and '4' responses for Puruvesi (1-7 Likert range).

	Catterline (n=66)	Puruvesi (n=204)	Spercheios (n=93)
Grey instead of NbS	27 (40.9%)	68 (33.3%)	28 (30.1%)
Grey in addition to NbS	32 (48.5%)	50 (24.5%)	20 (21.5%)

Table. A-17 Descriptive statistics of responses to Zoom poll. The poll was conducted before starting the presentation and discussion parts of the focus group discussions. All poll items were Likert items with a range of 1-9 except item 2, in which participants were asked to select all possible future impacts of landslides in Catterline out of a list of maximum 9.

	Item	Mean	Median	SD	Min	Max
1	*I am very concerned about negative impacts from landslides in Catterline.*	8.2	8	0.75	7	9
2	*In the future, I believe landslides could…*	5.9	5.5	1.22	5	9
3	*The current risk of negative impacts from landslides must be greatly reduced.*	7.8	8	0.98	6	9
4	*I feel very committed to keeping the best interests of the environment in mind.*	8.1	8	0.94	6	9
5	*The natural benefits of the measures in Catterline (e.g., aesthetics, habitat for wildlife) are very important to me.*	8	8	0.77	7	9

Table. A-18 Participant responses to Zoom poll. The poll was conducted before starting the presentation and discussion parts of the focus group discussions.

	Group 1		Group 2			Group 3		Group 4		
	G1P1	G1P2	G2P1	G2P2	G2P3	G3P1	G3P2	G4P1	G4P2	G4P3
I am very concerned about negative impacts from landslides in Catterline.	9	9	9	8	8	7	8	8	9	7
In the future, I believe landslides could…	5	7	5	6	5	6	5	5	9	6
The current risk of negative impacts from landslides must be greatly reduced.	9	8	9	7	7	6	8	8	9	7
I feel very committed to keeping the best interests of the environment in mind.	8	9	9	7	8	6	8	8	9	9
The natural benefits of the measures in Catterline (e.g., aesthetics, habitat for wildlife) are	8	9	9	7	7	8	8	8	9	7

very important to me.

Table. A-19 Participants' allocation of 20 imaginary "Catterline pounds". These were put towards the two primary benefits of NbS in Catterline: *wildlife habitat and aesthetics* and *risk reduction*.

	G1 (n=2)	G2 (n=3)	G3 (n=2)	G4 (n=3)
Wildlife habitat and aesthetics	5	8	2.5	5
Risk reduction	15	12	17.5	15

A.4 Additional analyses

A.4.1 Segmented results: Low versus high 'objective' risk

In the 'future outlook' of Paper 2 (Survey), I wrote that all efforts at increasing public acceptance "should first be piloted and segment the public as much as possible". Due to the number of variables tested across the three study sites, I was not able to present any segmented results in that paper. Using Spearman's rho (ρ) correlations, I found that there is an association between many of the survey variables tested and *behavioural acceptance* (Paper 2). However, it is possible that the strength of association may vary between different groups in the sample. Segmenting respondent groups as much as possible is important for transferring results into practical recommendations since sub-groups can have different characteristics. Divergent findings may point to the need for different strategies for increasing acceptance.

Although there are other ways to segment the survey data (e.g., by membership in a community group, demographic characteristics, distance to site), I present one line of inquiry here as an example – potential differences between respondents at *relatively* higher risk than those at *relatively* lower risk[24]. For example, there may be a weaker association between *risk perception* and *behavioural acceptance* among respondents who are at sufficiently low 'objective' risk. Similarly, these respondents' willingness to engage may be more

[24] For simplicity, I also refer to 'high' risk and 'low' risk groups rather than 'higher' risk and 'lower' risk groups. 'High' and 'low' should not be considered relative to any external or broader benchmark beyond Catterline and Puruvesi.

a function of perceptions of nature and place, and possibly attitudes, rather than variables related to risk and effectiveness.

I only segment data from Catterline and Puruvesi, since the data collection method in Spercheios did not allow for determining higher or lower ‘objective’ risk. After assigning respondents to groups, *behavioural acceptance, past acceptance* (the sum of yes/no responses for past behavioural acceptance actions), and all survey variables within the themes of attitudinal acceptance (n=2), effectiveness (3), risk (6), nature (3), place (1), as well as preferences for hybrid or grey (2) were tested for significant difference in means using Mann-Whitney *U* tests (Table. A-20). This answers, for example, whether there is a significant difference in *connectedness to place* between high and low-risk respondents. Next, all variables listed above were tested for correlations with *behavioural acceptance* within each of two segmented groups of respondents from Catterline and Puruvesi. Correlations were compared between groups to identify large differences and search for patterns within the themes.

Table. A-20 Variables tested for differences in means and for correlations with behavioural acceptance following segmentation. The attitudinal acceptance scales *benefits outweigh costs* is only applicable in Catterline, *good and effective* applicable in both Catterline and Puruvesi, and *Trust in implementers* only applicable in Puruvesi.

Acceptance
Benefits outweigh costs
Good and effective
Trust in implementers
Past acceptance (sum of past actions)
Effectiveness
"Need more evidence for NbS"
"NbS will reduce risk"
"Nothing can reduce risk"
Risk
Risk perception
Risk intolerance
"Risk must be reduced"
"Concerned about impacts"
Past impacts (sum)
Future impacts (sum)
Nature
Commitment to nature
"Responsible for nature"
"Not proud of natural area"
Place
Connectedness to place
Preference for hybrid or grey
"Prefer grey measures instead"
"Prefer grey measures in addition to"

Due to the number of variables being tested and objective of identifying differences between groups, I only present those correlations with at least one significant Spearman's rho (p<.05) and a difference of at least (ρ>.10) between the two segmented groups.

A.4.1.1 Catterline

Residents with houses directly facing the bay, and therefore close to the edge of the cliff, were assigned to the high-risk group. Although property damage has not occurred in the village, landslides have come within meters of some of these houses. While other impacts may affect all villagers, including road damage, property damage was taken very seriously by respondents of both the surveys (Paper 2) and focus groups (Paper 3). These residents are more exposed to coastal erosion and storm events that can trigger landslides. Results from Catterline must be approached cautiously due to the size of segmented groups, with many more in the low-risk group (n=43) than the high-risk group (n=23).

Behavioural acceptance shows the strongest difference in means, with those respondents at higher risk significantly more likely to be willing to engage with the NbS (Table. A-21).

Table. A-21 Mann-Whitney U tests of low-risk (n=43) and high-risk (n=23) groups in Catterline. The potential minimum and maximum response from the Likert survey items are provided in the 'Range' column, along with mean responses for each group and all significant *U* tests at (*p*<.05).

Variables with significant Mann-Whitney *U* test	Range	Low risk (mean)	High risk (mean)	Mann-Whitney *U* ($p<.05$)
*Good and satisfied***	1-9	6.97	7.62	.046
*Behavioural acceptance****	1-9	5.82	7.19	.007
Past acceptance (sum of past actions)	1-6	3.22	4.64	.022
*Connectedness to place***	1-9	7.29	7.88	.030
*Future impacts (sum)***	1-9	2.86	3.33	.017

**$p<.05$, ***$p<.01$

High-risk residents also significantly engaged more in the past, have more positive attitudes of *good and satisfied,* a higher *connectedness to place,* and believe that they are exposed to more possible *future impacts*. The perceived greater number of future impacts suggests that the segmentation method was valid, since this was based on a measure of exposure (i.e., to property damage). However, no significant differences in other risk items suggests that *risk perception* and *risk intolerance* are not strongly dependent on 'objectively' higher risk in Catterline.

The greatest difference between the groups is in relation to *past acceptance*, with a very strong correlation for those at high risk ($\rho=.613$, $p<.01$) and insignificant correlation for those at low risk (Table. A-22).

Table. A-22 Spearman's rho (ρ) correlations between behavioural acceptance and survey variables within high/low risk groups in Catterline. Only correlations at (*p*<.05) are shown (see Table. A-20 for all variables). The five variables with the greatest difference between groups are in bold.

	Behavioural acceptance	
	Low risk	High risk
Acceptance		
Good and satisfied	**.343****	**.634*****
Past acceptance (sum of past actions)	**.023**	**.613*****
Effectiveness		
"NbS will reduce risk"	.420***	.673***
Risk		
Risk perception	.365**	.450**
"Risk must be reduced"	.361**	.512**
"Concerned about impacts"	.402***	.540***
Future impacts (sum)	**.279***	**.689*****
Nature		
Commitment to nature	**0.204**	**.543*****
Responsibility for nature	**0.225**	**.655*****

$^{**}p<.05$, $^{***}p<.01$

The attitudinal acceptance variable *good and satisfied* is the most strongly correlated for the high-risk group (ρ=.634, *p*<.01). One of the items that composes the factor *good and satisfied* is the effectiveness item "NbS will reduce risk", also more strongly correlated for those at higher risk. This furthers evidence from the focus groups (Paper 3) in that effectiveness of the NbS was described as a priority for residents at risk. Results here show that perceived degree of effectiveness is also more associated with willingness to engage for residents at risk of property damage. However, nature items are also much more highly correlated for the high-risk group, supporting the hypothesis that *commitment to nature* and *responsibility for nature* are further motivators of acceptance even for those residents at risk of property damage. It is also noteworthy that all variables show stronger correlations with the high-risk group, suggesting that the surveys were better at capturing potential drivers behind *behavioural acceptance* for this group.

A.4.1.2 Puruvesi

In Puruvesi, respondents in the high-risk group a) have property near Lake Puruvesi (a residence or summer house) and b) visit the lake every day when at their residence or summer house. This latter difference in groups explains most of the variation, since only 13 of the 205 total respondents reported not having property near the lake. The segmented groups nearly evenly divide the sample (low-risk n=98; high-risk n=107). Contrary to the Catterline data, no significant difference was found between these groups in relation to past or future impacts (Table. A-23). It may be that the segmentation method captures something slightly different than merely ‘low’ or ‘high’ risk (e.g., those who visit the lake also have more disposable income and/or free time). However, past and future impacts were not phrased as time-dependent on the surveys - they could have occurred at any point in the past or be expected to occur at any point in the future. An item describing impacts in “the last 5 years”, for example, may have led to different results. The primary segmentation method, frequency of visits to the lake, thus means higher exposure to harmful algal blooms only when considering this temporal element.

Table. A-23 Mann-Whitney U tests of low risk (n=98) and high risk (n=107) groups in Puruvesi. The potential minimum and maximum response from the Likert survey items are provided under ‘Range’, along with mean responses for each group and all significant *U* tests at (*p*<.05).

Variables with significant Mann-Whitney *U* test	Range	Low risk (mean)	High risk (mean)	Mann-Whitney *U* (p<.05)
*Benefits outweigh costs***	1-7	5.45	5.84	.022
*Behavourial Acceptance****	1-7	4.59	5.25	.001
Past acceptance (sum of past actions) ***	0-10	2.27	3.34	.002
*Responsibility for nature****	1-7	6.33	6.71	.008
*Connectedness to place****	1-7	5.43	6.09	.000

**p<.05, ***p<.01

Like Catterline, respondents in the high-risk group have significantly greater positive attitudes, are more willing to engage, have engaged more in the past, and have a stronger *connectedness to place*. In Puruvesi, high-risk respondents also show significantly greater *responsibility for nature*. Considering correlations among these variables with significant differences in means, only the attitude *benefits outweigh costs* is more strongly correlated with behavioural *acceptance* for the high-risk group (Table. A-24).

Table. A-24 Spearman's rho (ρ) correlations between behavioural acceptance and survey variables within high/low risk groups in Puruvesi. Only variables with at least one correlation at (*p*<.05) are shown (see Table. A-20 for all variables). The five variables with the greatest difference between groups are in bold.

	Behavioural acceptance	
	Low risk	High risk
Acceptance		
Benefits outweigh costs	.190*	.387***
Past acceptance (sum of past actions)	**.496*** **	**.293*** **
Effectiveness		
"Need more evidence for NbS"	-.099	-.219**
"Nothing can reduce risk"	-.093	-.209**
Risk		
Risk perception	.201*	.335***
"Risk must be reduced"	**.096**	**.435*** **
"Concerned about impacts"	**.174* **	**.402*** **
Nature		
Commitment to nature	.320***	.428***
"Not proud of natural area"	**-.037**	**-.317*** **
Place		
Connectedness to place	.294***	.174*
Preference for hybrid or grey		
"Prefer grey measures instead"	.085	-.235**
"Prefer grey measures in addition to"	**.362*** **	**-.113**

*$p<.10$, **$p<.05$, ***$p<.01$

Past acceptance, risk items, and nature items were also stronger correlates for those at higher risk in Puruvesi. One difference in Puruvesi is that among low-risk respondents, behavioural acceptance increases with preferences for hybrid measures ("grey in addition to"). In Paper 3 (FGDs), results from the surveys showed that among the entire sample of Puruvesi residents, respondents were slightly in favour of using hybrid measures. Since low-risk respondents were defined by visiting the lake less frequently, it may be that there is less sacrifice in terms of other ecosystem services from green NbS and therefore the desire to reduce risk with a greyer option is related to acceptance. There is a moderate significant correlation between preference for hybrid measures and past impacts (ρ=.304, p<.01), indicating that active support for the measures among those in the low-risk group may also be related to variation in past impacts of eutrophication and algal blooms.

In both Puruvesi and Catterline, the variables tested are more relevant for capturing willingness to engage with respondents who are at relatively higher risk. The only affective risk item, "concern" plays a larger role for those already at higher risk in both sites, as do the single risk intolerance item "risk must be reduced" and *commitment to nature*. In both sites the respondents at higher risk had a significantly higher *connectedness to place*, but there was no difference in correlation strength in Catterline and only a small difference in Puruvesi (i.e., *connectedness to place* is more associated with behavioural *acceptance* among those at lower risk). Results point to some consistent differences among groups across the sites, and thus efforts to increase acceptance should take into consideration differences in risk (including exposure, impacts, concern, and tolerance) if possible.

Additionally, the lack of significant differences in means for risk-themed items for both Catterline and Puruvesi is in line with the history of findings from risk perception research: a weak relation between 'actual' and perceived risk. For campaigns designed to increase public acceptance, this shows that assuming greater support based on interest in reducing risk for those at higher risk may be a faulty judgement. Instead, as suggested in Paper 2 (Survey), first establishing a communal understanding of the threat, potential impacts, and their severity, is important for achieving broad support for the NbS. Engaging with those at lower risk will require more effort and a deeper and broader exploration of potential motivators based on interests and values.

In Puruvesi, past engagement with similar measures or related efforts was strongly related to the willingness to engage in future efforts (ρ=.496, p<.01). Although further research is needed that can approach the identification of causality, it may be that some of the current behavioural acceptance is motivated by past engagement. If true, this would be in line with a body of relevant research showing that participation and engagement can increase acceptance and predict future engagement (Aven and Renn 2010; Herringshaw et al. 2010; Howgate and Kenyon 2009; Reed 2008). For example, residents may have been reluctant to engage, participated in an NbS event and enjoyed it, reframed their attitudes, and ended up with higher willingness to engage in the future. This process could be supported through participatory events. Even if the NbS engagement activity is simple, short, and perhaps without making an immediate or substantial difference to risk reduction, it may still improve acceptance if properly designed (Herringshaw et al. 2010). Other factors can be decisive, such as whether the event was enjoyable, there were few barriers to its success, and if other benefits were derived (e.g., social contacts and community cohesion, sense of pride, sense of responsibility, etc.). Designing inclusive, barrier-free, diverse, and achievable participatory activities that fit these descriptions is thus one strategy worth investigating.

A.4.2 The role of ecosystem services

The surveys conducted at the three NbS sites included several exercises to elicit residents' perceptions of the importance of different ecosystem services (ES) and ecosystem disservices (ED). I did not present analyses of ES and ED items in Paper 2 (Survey) due to space limitations and divergent data collection methods across the study sites. I rely on data from Catterline and Puruvesi to compare the same sites in more detail and describe two different data collection methods. In Catterline, open response items were provided for respondents to write in "a maximum of 6 ways the natural area benefits you and 6 ways it has a negative effect on you, in order of importance (1 = most important; 6 = least important)" (Text. A-3). Although this method allows for weighted analysis based on the respondents' ranking, I present only frequency of responses among respondents since results from this non-weighted analysis are more easily interpretable and results were consistent across both methods.

In a later section of the survey, respondents completed the same task but were asked to list any expected "benefits and negative effects of the measures [NbS] beyond reducing risk". Here, I focus on this latter section in relation to NbS benefits since these were hypothesised to be more directly related to public acceptance of the NbS. The term 'benefits' was used on the surveys rather than 'ecosystem services' to ensure broad understanding. Similarly, to elicit ED, the phrase "negative effect" was used for the items in Catterline. The ES and ED data collection in Catterline was exploratory, but generally it was hypothesised that more ES than ED would be listed and that natural co-benefits of aesthetics and wildlife would be important given the natural beauty of the village. Analysis in Catterline centred around describing the perceptions of the larger community rather than the individual. This is due to the qualitative nature of the items and lack of data, since many respondents skipped these items (described in the following section).

In Puruvesi, the online format of the surveys meant it was possible to include more items and reach more respondents. ES and ED items were therefore designed for quantitative analyses based on 1-5 Likert items. OPERANDUM colleagues familiar with the NbS site helped list the most relevant ES and ED of both the surrounding natural area and the NbS. Likert items were created for each, and respondents were asked to “rate their importance to you as follows: 1 = not important; 5 = very important; N/A = it does not apply to me/I can’t say”. ‘N/A’ responses were interpreted as zero values that equate to the lowest importance on the same scale (i.e., of no importance). Analyses focused on ranking the ES and ED and their association with forms of public acceptance.

A.4.2.1 Catterline

Among the nearly half of all respondents who wrote in at least one ES (n=31), the most frequently listed thematic benefit of the NbS was scenery/aesthetic value. This received both the highest number of instances and number of respondents (Table. A-25). Responses included “low visual impact” (P11), “positive impact on my view” (P4), “blend in better with surroundings” (P54), and “increase beauty” (P23). More benefits related to nature were listed than benefits related to society. Statements centred on the measures being “environmentally friendly” (P4) and their capacity to “increase habitat for wildlife” (P3) and “promote biodiversity” (P11). An unexpected finding was the importance of ‘community’ as a social co-benefit of the NbS. Eight different respondents listed 11 ES in relation to this sub-theme, including “community cohesion” (P2), “community awareness/education is raised” (P31), and “common goal for community” (P60). Another respondent listed “promoting community engagement” (P12), positioning *behavioural acceptance* itself as a co-benefit of NbS. The ‘Other’ category included “reassurance” (P20), “use of beach area/bay” (P45) and “less mud (…)” (P57).

Table. A-25 Summary table of perceived benefits of the NbS (ecosystem services; ES) in Catterline. ES are organised by themes (natural, social, other) and sub-themes listed in order of number of instances. A maximum of six responses per person was possible.

Themes and sub-themes	Number of instances	Number of respondents
Natural	*51*	*25*
Scenery (aesthetics)	17	15
Animal life	13	11
Nature	12	10
Plant life	8	8
Social	*26*	*16*
Community	11	8
Disaster risk reduction[1]	8	7
Education	3	2
Tourism	2	2
Other	*N/A*	*N/A*
Other	3	3

[1]Although the survey asked for *additional* and *co*-benefits, disaster risk reduction was mentioned by seven respondents. Based on other survey responses and data from Paper 3 (FGDs), DRR is generally perceived as more important than potential co-benefits.

Only 14 of 66 total respondents listed any potential ED of NbS and therefore only one thematic level was used to classify responses. Along with a lack of expected ED among residents, this low response rate is likely due to these items coming at the end of the survey. These items were phrased using ‘negative aspects’ of the NbS instead of ‘ecosystem disservices’. Beyond ensuring more widespread understanding, this allowed for the consideration of the NbS being ‘ineffective’, which was the most frequently listed negative aspect (listed five times by four different respondents) (Table. A-26). This was followed by the potential for the NbS to be ugly, non-natural, require maintenance, have inequitable benefits, change the landscape, or have higher costs to residents (i.e., than alternative options).

Table. A-26 Summary table of perceived negative aspects of the NbS (ecosystem disservices) in Catterline. ED are organised by themes listed in order of number of instances. A maximum of six responses per person was possible.

Theme	Number of instances	Number of respondents
Ineffective	5	4
Ugly	3	3
Non-natural	2	2
Maintenance	2	1
Inequitable	2	2
Landscape change	2	1
Higher cost	1	1

ES and ED results in Catterline reflect previous findings. Most relevant are the results from Paper 3 (FGDs), where it was found that despite the primary importance of effective DRR measures, the natural co-benefits of wildlife habitat and aesthetics were highly valued. This highlights the importance of wildlife and biodiversity monitoring following deployment of the NbS. After being collected, relevant evidence could be reported back to the community through social media and event messaging as well as provided through the local community organization CBAG. The ED listed are in line with findings from Paper 1 (Review), which described how public acceptance of NbS can be eroded by issues including poorly perceived aesthetics or inequitable benefits. NbS site managers within OPERANDUM should be proactive and address these concerns through open communication with residents, also coordinating with CBAG.

Regarding efforts to increase acceptance, these results suggest that investing more in efforts to use the NbS to create community links may increase acceptance. The benefits of having a common project/goal for the community of Catterline and results regarding the perceived risk to the history and culture of Catterline are important to address and may motivate residents. The community has come together with widespread engagement and coordinated DRR efforts in the past following major landslide events. A shift will need to occur with an effective NbS in place to maintain this level of commitment based on benefits and awareness/education of ongoing risk.

A.4.2.2 Puruvesi

Quantitative results from Likert items from the Puruvesi survey are organised by MEA ecosystem service classification (MEA 2005b). The ES ‘recreation’ received the highest average score (4.24/5.00), closely followed by 'aesthetic enjoyment' (4.23) (Table. A-27). All cultural ES listed received higher mean scores than the two provisioning ES items, likely due to the more communal versus private benefits involved, respectively. Generally, the ED from NbS were not very important to respondents, with only "challenges in forest technology" (2.55) crossing the mid-point of the scale (2.50). Additionally, each of the ED received around 25% of 'N/A' responses, indicating that respondents did not perceive them as relevant to their situation.

Table. A-27 Mean 1-5 Likert responses for ecosystem services (A) and disservices (B) in Puruvesi.

A)

	Ecosystem Services (ES)	Mean
CULTURAL	Recreation	4.24
	Aesthetic enjoyment	4.23
	Future generations' opportunity to enjoy the lake	4.16
	Forest plants and animals	4.15
	Education (learning in the environment and increasing knowledge)	3.66
	Cultural ES average	*4.09*
PROV.	Timber	3.08
	Game	2.75
	Provisioning ES average	2.91
	Total average	*3.75*

B)

	Ecosystem Disservices (ED)	Mean
SUPP	Forest damage	2.32
	Supporting ES average	*2.32*
REGUL.	Challenges in forest technology	2.55
	Decline in national income	2.43
	Reduced economic benefit	2.21
	Regulating ES average	*2.40*
	Total average	2.38

Exploratory factor analyses (EFA) were run and factor scores computed following the methodology described in Paper 2 (Survey) (see Table 3-3). This yielded a single factor for each ES of NbS and ED of NbS (Table. A-28). For ES of NbS, the provisioning service item "game from the forest environment" was removed due to a low communality score (0.214) and corrected item-total correlation (0.326). The emergent factor is most strongly composed of 'aesthetic enjoyment' and 'recreation', although other ES contribute nearly equally. The only exception is "timber harvested from the forest", which contributes relatively weakly with a factor loading of 0.559. All original items were included in the factor describing ED of NbS.

Table. A-28 Ecosystem service and disservice factor analysis results in Puruvesi.Principal axis factoring statistics and rotated structure matrix output (promax) used to determine latent variables from ES (A) and ED (B) of NbS items (with corresponding MEA class). All items were first included and iteratively removed one-by-one from the analysis to maximise reliability and percent variance explained within each site. One factor emerges for each ES and ED.

A)

	Analysis *n*	183
	Total percent variance explained	64.8
	Cronbach's alpha (α)	.928
	Lowest corrected item-total correlation (CITC)	.548
	Lowest communality	.313
MEA class	**Item**	
Cultural	Aesthetic enjoyment (enjoyment of the landscape)	.948
Cultural	Recreation (e.g., hiking, berry picking)	.928
Cultural	The value of forest plants and animals for me	.897
Cultural	Opportunities for future generations to enjoy the forest	.874
Cultural	Education (learning in the environment and increasing knowledge)	.775
Provisioning	Timber harvested from the forest	.559

B)

	Analysis *n*	205
	Total percent variance explained	63.4
	Cronbach's alpha (α)	.867
	Lowest corrected item-total correlation (CITC)	.600
	Lowest communality	.408
MEA class	**Item**	
Provisioning	Decline in national income	0.896
Provisioning	Reduced economic benefit for forest owners	0.852
Supporting	Forest damage	0.774
Provisioning	Challenges in forest technology	0.639

Spearman's rho correlations were run to determine the relation between ES of NbS and ED of NbS with attitudinal and behavioural acceptance. Results show that attitudinal acceptance factors are strongly associated with the emergent ES and ED factors (Table. A-29). In particular, the attitude *benefits outweigh costs* shows a strong correlation with both ES of NbS (ρ=.399, p<.01) and ED of NbS (ρ=-.476, p<.01). An association was expected given that the concepts of *benefits* and *costs* are closely related to ES and ED. However, as the importance of ES of NbS increased among respondents so too did positive attitudes regarding *trust in implementers* (ρ=.324, p<.01) as well as *behavioural acceptance* (ρ=.223, p<.01).

Table. A-29 Spearman's rho (ρ) correlation matrix among for ES and ED in Puruvesi. Relations among ES of NbS, ED of NbS, the attitudinal acceptance factors benefits outweigh costs and trust in implementers, and behavioural acceptance are shown. ES and ED results are highlighted with bold text.

Scales	Attitudinal acceptance		*Behavioural acceptance*	*ES of NbS*	*ED of NbS*
	Benefits outweigh costs	*Trust in implementers*			
Benefits outweigh costs	1.000				
Trust in implementers	.419***	1.000			
Behavioural acceptance	.327***	.223***	1.000		
ES of NbS	**.399*****	**.324*****	**.223*****	**1.000**	
ED of NbS	**-.476*****	**-0.156**	**-0.054**	**-.377*****	1.000

*$p<.10$, **$p<.05$, ***$p<.01$

ES and ED of NbS variables were tested for differences among high-risk and low-risk segmented groups in relation to *behavioural acceptance*. The behavioural acceptance of high-risk respondents shows no differences for ED of NbS, but a moderate to strong significant correlation with ES of NbS (ρ=.360, $p<.01$) and a weak insignificant correlation for low-risk respondents (ρ=.060, $p<.10$). This is in line with findings presented above for the segmented sample, in that most variables correlated more strongly with the high-risk group, composed of respondents who visit the lake more frequently and therefore also have more to gain from additional ES provided by the NbS.

Utilising cultural ES is highly important to the residents living near Lake Puruvesi and their perceived degree of importance is strongly associated with public acceptance of the NbS, particularly positive attitudes. Although the potential ED from the NbS are less important on average, their importance was even more strongly negatively associated with positive attitudes related to *benefits outweighing costs*. This, in turn, is associated with trust and *behavioural acceptance*. In general, results support the promotion of ES as benefits from the NbS towards the public, while reducing ED as much as possible is important for fostering positive attitudes. Along with limiting trade-offs from the project management perspective, residents should be trained to also contribute to minimizing negative impacts from the NbS. Additionally, addressing (mis)perceptions in relation to ED, particularly among forest owners, should be prioritised.

A.4.3 GIS analysis in Catterline

In Catterline, a low-resolution map of the village was provided in the surveys and respondents were asked to mark the approximate location of 1) their residence, 2) where landslides impact them the most, and 3) where they think it is most important that NbS are implemented (Figure. A-4). A GIS analysis aimed to determine whether the distance of residents to points 2) and 3) above, as well as the distance between the perceived best location and actual past NbS work carried out in the community by CBAG, would be correlated with acceptance of the proposed future NbS. The following hypotheses (H) guided this analysis:

1. Distance between residence and where most past NbS work has taken place

    H1. The farther the residents live from past NbS work, the less acceptance, particularly *behavioural acceptance*. I.e., as you live farther away from the risky coastal area, it is less likely you have been motivated to engage with past work and will be motivated for future NbS efforts.

2. Distance between the most important NbS location and actual past work

    H2. Significant correlation with both forms of acceptance. I.e., as you believe that past work has been properly situated, you are more likely to support future work.

3. Distance between residence and most important NbS location

    H3. Significant correlation with both forms of acceptance, particularly behavioural. I.e., as your home is closer to what you perceive as the most important location, risk perception increases along with acceptance.

Figure. A-4 Low resolution map of Catterline provided on the surveys for respondents to mark.

Distances between the points given on the survey and where most past NbS work has taken place were calculated using ArcMap 10.2.2 (Figure. A-5). A polygon was created on the sea-facing slope above the Harbour Road where most past NbS work has focused. This, combined with maps corresponding to the 3 items on the survey listed above, were used to calculate distances for the correlation analyses.

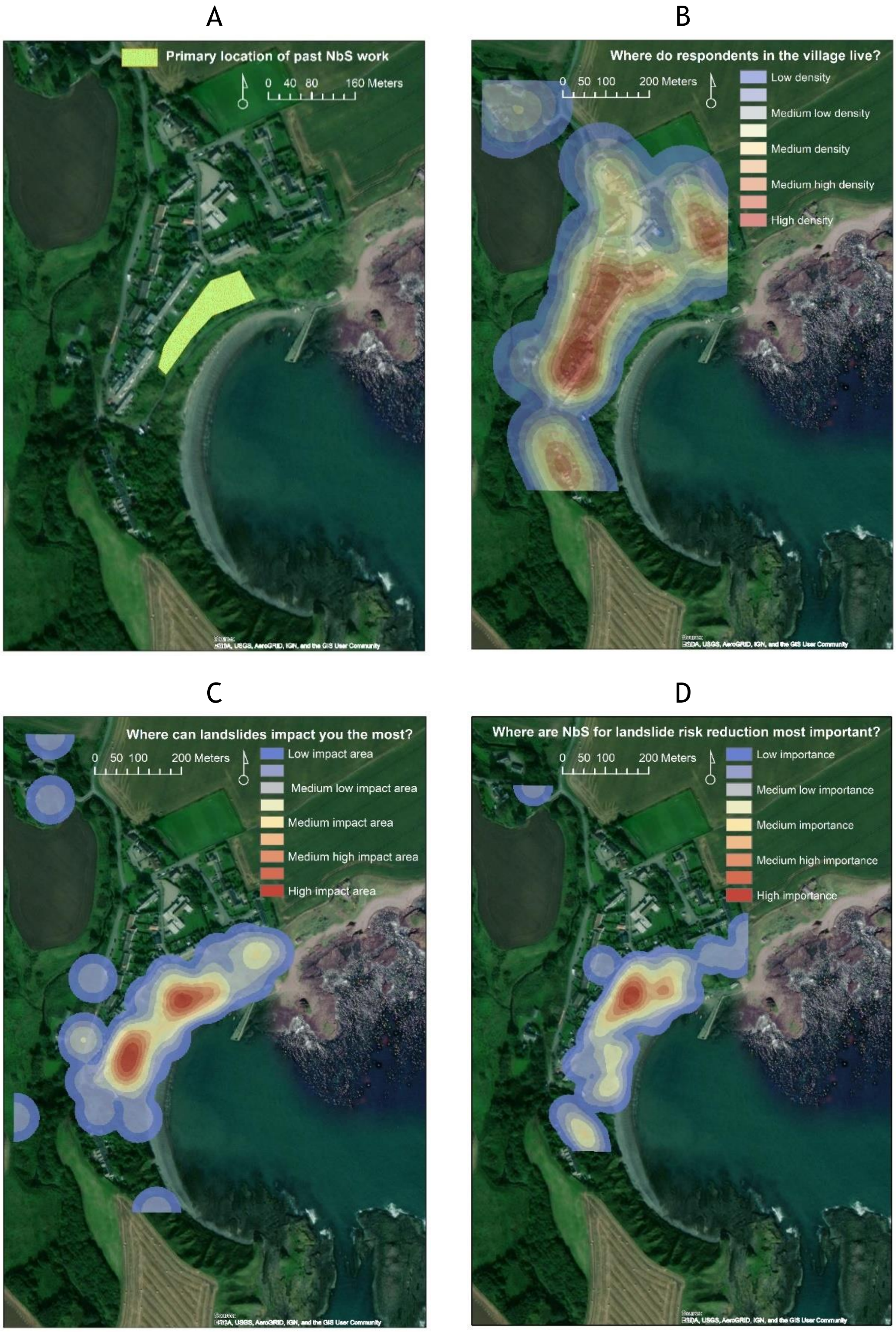


Figure. A-5 Maps showing the GIS analysis for acceptance in Catterline. These are overlaid with satellite imagery. Maps include a) the primary area where past NbS work has been carried out, and density maps of b) the residences of the respondents (n=64), c) where landslides impact them the most (n=58), and d) where they think it is most important that NbS are implemented (n=51). Map source: ESRI, USGS, AeroGRID, IGN, and the GIS User Community.

The distribution of respondents closely matches the actual population density of the village. There were slightly fewer responses in the norther part of the village which has houses farther from the cliff. The potential for landslide impacts centres around the area where most past NbS work has taken place. However, the high impact cluster farther south along the bay (Figure. A-5, Part C) has received less attention. The density of most important points for NbS deployment shows the highest concentration of points where most past NbS work has focused along the sea-facing brae. There were also points placed along the southern most vertically aligned row of houses as well as spreading along the bay. Notably, most points were placed on or just above Harbour Road that leads down to the dock in the bay, but there were also nine points below the road, possibly indicating a preference for measures to address wave erosion rather than slope stabilisation directly.

Testing the variables presented in prior sections (see Table. A-20), only few significant correlations were found, and none with *behavioural acceptance*. Only the distance between respondents' residences and past NbS work was related to more than one of the variables (Table. A-30). Both measures of risk intolerance showed significant correlations, indicating that as respondents' residences approach the sea-facing brae, they are less tolerant of risk. These residents also increasingly expect *future impacts* (ρ=-.298, p<.05), are increasingly *committed to nature* (ρ=-.247, p<.05), and have increasingly positive attitudes towards NbS in relation to *good and satisfied* (ρ=-.272, p<.05). These were all negative correlations (as distance decreases, acceptance and risk intolerance increases), except for preferences for "grey measures instead of NbS" (ρ=.337, p<.01). This means that as respondents' homes were located closer to past work and the bay (with its scenery), there was less preference for grey measures. This probably reflects satisfaction with prior NbS work carried out as well as the importance of nature and scenery among these respondents.

Table. A-30 Spearman's rho correlations among respondent-identified distances in Catterline and survey variables. Only variables for which a sig. correlation was found for one of the three distance measures are shown. Note that a negative correlation indicates that as distance decreases, the acceptance variable increases (and vice versa).

	Residence ⟷ Past NbS work	Residence ⟷ Most important NbS location	Most important NbS location ⟷ past NbS work
Good and satisfied	-.272**	-0.139	0.082
Commitment to nature	-.247**	0.188	-0.178
"Prefer grey measures instead"	.337***	-.346**	0.193
Future impacts (sum)	-.298**	-0.132	-0.208
Risk intolerance	-.247**	-0.023	0.153
"Risk must be reduced"	-.284**	-0.099	0.154

*p<.10, **p<.05, ***p<.01

Preferences for "grey measures instead of NbS" was the only variable significantly correlated with distance between respondents' residence and their perceived ideal location for NbS work (ρ=-.346, p<.01). In other words, as residents responded that they would like NbS increasingly close to their own homes (presumably to protect their own property), there was a significantly stronger preference for grey measures rather than NbS. In Paper 3 (FGDs), only several items related to risk were weakly correlated with preferences for grey measures, and none at a significance level of p<.05; i.e., *risk intolerance* (ρ=-.220, p<.10) and *future impacts* (ρ=-.230, p<.10). Therefore, risk perception alone likely accounts for very little of the correlation observed here. Another consideration is the more communal nature of NbS benefits such as improved aesthetics and wildlife as opposed to the potentially more inequitable benefits of risk reduction. The finding may also describe a relation between increasing demand for self-protection (or decreasing demand for communal co-benefits) and increasing preference for grey measures. Future research should more closely explore preferences for private versus communal benefits (e.g., Geaves and Penning-Rowsell 2015).

Applying the segmented high/low risk data, one additional relevant finding emerged. Among residents at higher risk of property damage, as the point where landslides can impact them the most approaches past NbS work, positive attitudes regarding *benefits outweigh costs* increases (ρ=-.513, p<.05; n=21). Generally, spatial distance does seem to play a role, but it may be that third variables (most notably the distance to the cliff), explain most of the correlations. Additionally, *behavioural acceptance* had no significant correlations. Because the village of Catterline is so small (one can walk across it in under five minutes), distance likely plays less of a role regarding engagement than in other NbS sites. Findings did suggest that potential issues regarding the inequitable distribution of DRR benefit from the NbS and preferences for siting may arise. Further research and communication with residents in Catterline should aim to determine the degree of this potential problem and how to best resolve it

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