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Published in:
Journal of Environmental Management

DOI:
10.1016/j.jenvman.2022.114727

Publication date:
2022

Document Version
Publisher's PDF, also known as Version of record

Journal of Environmental Management 310 (2022) 114727

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

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

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ARTICLE INFO

Keywords:
Nature-based solutions (NbS)
Public acceptance
Public perception
Stakeholder engagement
Hydro-meteorological hazards
Disaster risk reduction

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.

1. Introduction

Despite the increased use of nature-based solutions (NbS) to reduce risk from natural hazards, there remains barriers to its continued uptake (Seddon et al., 2020; Kabisch et al., 2016; 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 (Depietri and McPhearson, 2017; Sutton-Grier et al., 2015; Chausson et al., 2020; Sudmeier-Rieux et al., 2021). NbS must be designed with a greater consideration of surrounding (and embedded) social-ecological systems. The associated diversity and complexity makes a standardized approach to their design and implementation, along with evidence-basing, more difficult (Sudmeier-Rieux et al., 2021; Papathoma-Koehle and Glade, 2013). 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 (Sudmeier-Rieux et al., 2021; Dushkova and Haase, 2020; Faivre et al. 2017, 2018; Chausson et al., 2020). 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 (Giordano et al., 2020; Anderson et al., 2021; Wamsler et al., 2019; Triyanti et al., 2017; Seddon et al., 2021).

NbS is considered an umbrella concept for many approaches to

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https://doi.org/10.1016/j.jenvman.2022.114727
Received 16 October 2021; Received in revised form 20 December 2021; Accepted 13 February 2022
Available online 28 February 2022

addressing societal issues using nature (Cohen-Shacham et al., 2016). We focus on NbS with the primary intended function of disaster risk reduction (DRR), 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 (Poratelli et al., 2020; Onuma and Tsuge, 2018; Gray et al., 2017). 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; Turkelboom et al., 2021; Sutton-Grier et al., 2015). Here, we use 'green' as synonymous with 'NbS' and refer to a spectrum of green-hybrid-grey measures (that can be *greener* or *greyer*) (Raymond et al., 2017; Davies et al., 2006; Choi et al., 2021; Davies and Lafortezza, 2019).

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 (Kabisch et al., 2016; Depietri and McPhearson, 2017; 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; Stafford et al., 2021; Ruangpan et al., 2020), 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, 2020) 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, 2015), 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 (IPCC 2012; Kaufmann et al., 2021; Renaud et al., 2013; CBD, 2019). 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 (Ramírez-Agudelo et al., 2020; Waylen et al., 2018; Kabisch et al., 2016). Additionally, stakeholders must value the co-benefits for these to increase support for NbS (Hagedoorn et al., 2021; Giordano et al., 2020; Anderson 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; Evans et al., 2017; Esteves and Thomas, 2014; Howgate and Kenyon, 2009) and higher confidence in grey measures are common (Roca and Villares, 2012; Chou, 2016; Mallette et al., 2021). 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) (Buijs, 2009; Mallette et al., 2021; European Commission, 2015; Anderson and Renaud, 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 behaviors 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 (Osaka et al., 2021; Kaufmann 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; Schernewski et al., 2017; Holstead 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,[1] 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.

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 behavioral 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 (Fig. 1).

2.1. Study sites

We provide only a brief description of the surveyed NbS sites in Finland and Greece and describe the Catterline, Scotland site in more detail, since we rely heavily on FGD findings from Catterline to answer our research questions. We selected sites within the OPERANDUM project to 1) maximize differences in environmental and social systems 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 (Fig. 2).

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 A1) 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[2]) dedicated to slope protection and stabilization. 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 stabilization work in the community.

CBAG has supported the OPERANDUM NbS plans and research. Before OPERANDUM, CBAG led stabilization 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 (Fig. 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).

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

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

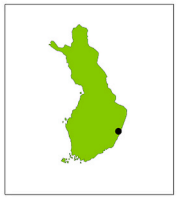
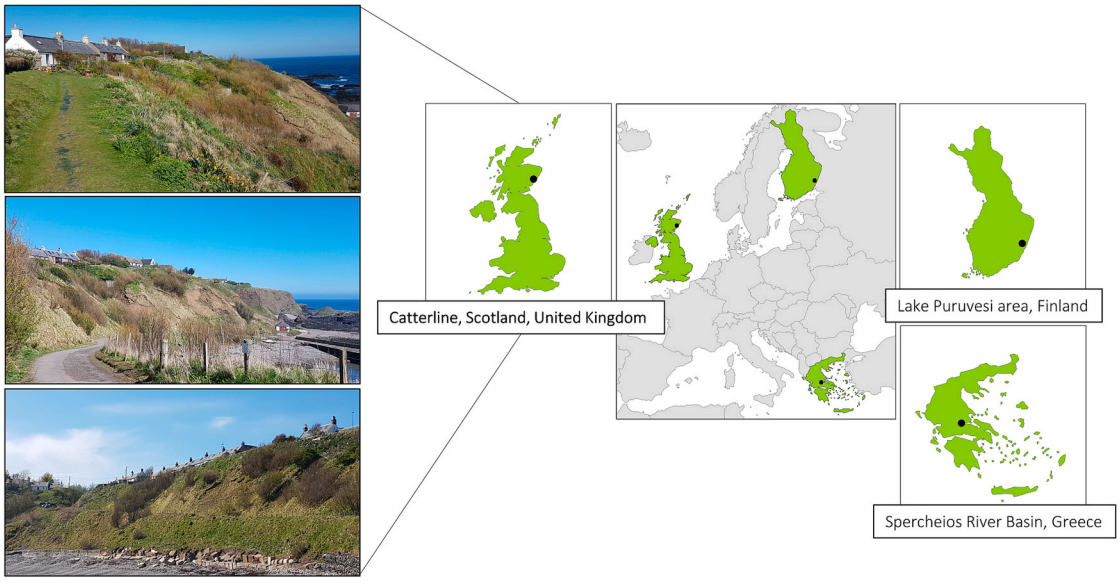
	RQ1. To what degree do residents in communities with planned NbS (green) prefer grey measures in addition to green measures (hybrid approach) or grey measures instead of green measures?	RQ2: Are perceptions of NbS effectiveness, risk, and nature associated with these preferences?	RQ3: What other factors, 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

Fig. 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 respective countries (Scotland, Finland, and Greece).

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

Fig. 2. (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.

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 maximize 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 institutional mailing lists were then used to reach additional residents (Table A1).

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 B1).

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 (Rundmo, 2002; Peters et al., 2006; Gifford and Comeau, 2011; Terpstra, 2011) (see Table C1 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; Maynard et al., 1976; Haynes et al., 2008). 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 behavior. 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 C1). We determine Spearman's rank correlations between preferences for grey or hybrid measures and all variables related to perceptions of effectiveness, risk, and nature.

2.3. Focus group discussion (FGD) design and analysis

The FGDs were held in April 2021 using the video/audio software, 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-h sessions, with two groups of two residents and two groups of three. Small groups were used to maximize 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 summarized results of the 2019 survey they had completed. We first assessed characteristics of FGD participants based on 2019 survey items using a five-item 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 D1). 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 specturm, first regarding direct slope stabilization, 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 stabilization 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 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 stabilization in Catterline.

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 D1). 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 D1) 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, manually transcribed by the lead author

Table 1
Three primary focus group discussion activities. Although most relevant data were collected during these activities, dialogue was also generated with participants during the presentation of 2019 community survey results (see Table D1 for full FGD schedule).

Discussion activity 1
As a group, please decide where (ideally) the measures for Catterline [1. slope stabilization 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"?

using f4transkript software,[3] and coded using NVivo Pro v.12. Codes were created to categorize 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.

3. Results

3.1. Survey respondents' preferences for greyer measures and associated variables

On average, survey results showed that respondents in Spercheios and Puruvesi were slightly in favor 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 (Fig. 3).

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 favor. However, most responses are at (or close to) the mid-point of the Likert ranges for the three sites (Table E1).

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 11 (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 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 (Fig. 3; Table 2, Part A). 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 2, Part B).

In Catterline, confidence in the effectiveness of NbS (i.e., "NbS will reduce risk") is negatively correlated with preferences for using *grey measures instead* ($\rho = -0.368$, $p < .01$), along with perceptions of nature and especially *commitment to nature* ($\rho = -0.468$, $p < .01$).

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 F1). 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 F2; 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).

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 maximize 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 focusing 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 G.1).

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.

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 (Fig. 4).

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 summarizes 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

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

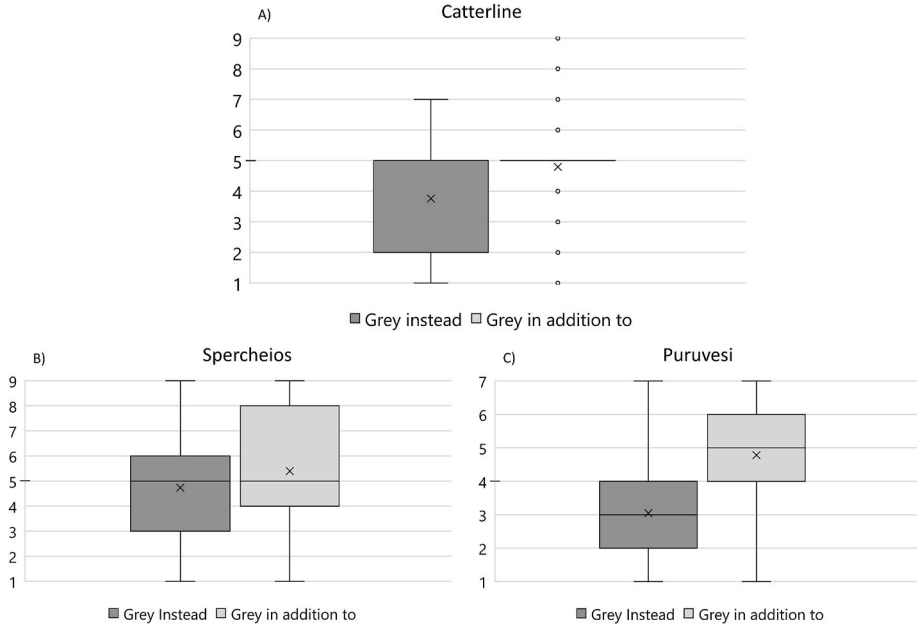


Fig. 3. Box plots of two Likert survey items: 1) degree of preference for *grey measures instead of NbS* (grey) and 2) degree of preference for *grey measures in addition to NbS* (hybrid) in the three study sites: A) Catterline, B) Spercheios, and C) Puruvesi). The strongest preference for grey/hybrid 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).

Table 2
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 $p < .10$, $p < .05$, and $p < .01$ are shown in bold.

A)

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

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****

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

and effort model on the greyer side that could have been used …" (G2P1).

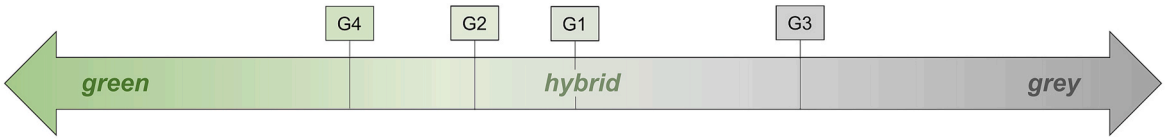
3.2.3. Influential factors for green, hybrid, or grey preferences

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 3).

Although some perspectives among participants were contradictory (e.g., under *time* and *effort*; Table 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 (Fig. 5).

3.2.3.1. Factors contributing to support for green measures. Considerations in relation to the factors *cost*, *aesthetics*, *effort*, and *habitat* tended

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 stabilization, 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.*

Fig. 4. Group preferences for the approximate position of the "ideal measure for Catterline" on a spectrum of green-hybrid-grey (A) and corresponding dominant rationale synthesized from the group discussions (B). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

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 Catterline 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 favor 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 favorably 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 F1) 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 stabilize 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 3).

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 stabilization. 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 stabilize to bring the habitat back … there's probably a mixture of solutions …" (G3P1).

The more immediate effectiveness of hybrid and grey measures is recognized 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 stabilization work done in the community using mesh stabilization 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).

Table 3
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 stabilize slopes ✓ May be more effective long-term if self-reinforcing × Cannot stop energy from the sea × Skepticism 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 alwaysrequired
Time	✓ Stabilizes over time for less maintenance × Willow drains clog over time × May not last as long × Ecosystems take a very long time to stabilize × Takes time for effectiveness, situation could get worse × Takes time for aesthetics	✓ Stabilizes 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 stabilize 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
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	✓ Stabilizes 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		✓ Stabilizes 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 stabilizes over time ✓ Least amount of work × Natural system may revert to prior ineffective state × Manually intensive × Requires some maintenance × Requires active community support		× Difficult to implement × 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, storms, 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	✓ Effectiveness and aesthetic benefits	✓ Failure to maintain past measures means

(*continued on next page*)

Table 3 (*continued*)

	Green	Hybrid	Grey
	benefits witnessed elsewhere	witnessed elsewhere	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	✓ Land not too rocky, rather clay with topsoil × Requires certain conditions to be feasible and practical	✓ Land not too rocky, rather clay with topsoil	
Visibility of benefits	× Water can accumulate with clogged willow drains		
Unintended consequences			× Inevitable with man-made structures

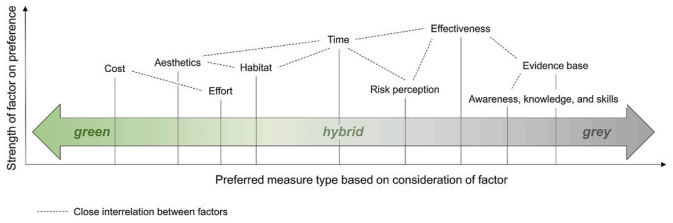


Fig. 5. The nine most frequently mentioned factors that influence preferences towards green, hybrid, or grey measures in Catterline. The estimated strength of each factor is displayed by its position on the y-axis, based on its total number of mentions, the number of groups and participants that mention 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 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. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

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 stabilize 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).

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 favor 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, 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 stabilize 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. Discussion

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 (Kim and Petrolia, 2013; Anderson and Renaud, 2021). 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 (Wood and Rünger, 2016; World Bank, 2015; Gifford, 2011).

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, 2020; Jones et al., 2012), 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 (Osaka et al., 2021; Mell, 2013), 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.

4.2. 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 (Roca and Villares, 2012; Karrasch et al., 2014; Khew et al., 2015). 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 stabilization. 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 maximize 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 greenwashing 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, 2020). 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 recognized 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 (Winter and Bromhead, 2012; Sjoberg, 1999; Anderson and Renaud, 2021), the low-cost and/or cost-effectiveness aspect of the 'no-regret' framing (IPCC 2012) may increase acceptance. Some participants also recognized the greater flexibility of green measures over time, although this was referenced in relation to "stabilization over time" and lower maintenance (Table 3) rather than climate change. These other aspects of the 'no-regret' framing of NbS (IPCC 2012; Jones et al., 2012) 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.

4.3. Hybrid measures as the "best of both worlds"?

Hybrid measures were favored 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 preference towards hybrid measures, although informed by some misperceptions, are supported by relevant academic and DRR practitioner literature (Depietri and McPhearson, 2017; Cheong et al., 2013; Seddon et al., 2020; Browder et al., 2019). 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 capitalize 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) (Vriend et al., 2015; Esteves and Thomas, 2014), 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 favored 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 (Shah et al., 2020; Browder et al., 2019). 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 (Depietri and McPhearson, 2017; Davies and Lafortezza, 2019). 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), as well as 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 (Seddon et al., 2020; JNCC, 2021). 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, 2020).

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 (Riddell et al., 2018; Tompkins et al., 2008; Henly-Shepard et al., 2015).

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 prioritize co-benefits defer their green-hybrid-grey preferences to others who prioritize risk reduction?) (Olschewski et al., 2012; Jagau and Offerman, 2018). 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 (Murti and Mathez-Stiefel, 2019; Herringshaw et al., 2010).

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 combined with the urgent need to reduce risk and address climate change.

5. Conclusion

NbS in Europe generally enjoy widespread public support (European Commission, 2015). 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 skepticism and support for greyer measures.

Author contributions statement

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

Data availability statement

The original contributions presented in the study are included in the article/appendix, further inquiries can be directed to the corresponding author.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The contribution of Carl C. Anderson was supported by a University of Glasgow College of Social Sciences PhD Scholarship. This work was supported by the European Union's (EU) Horizon 2020 research and innovation program. It was funded by and carried out within the framework of the OPERANDUM (OPEn-air laboRAtories for Nature baseD solUtions to Manage hydro-meteo risks) project (Grant No. 776848).

Appendix

Fig. A.1. 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.1
Characteristics of the data collection process and outcomes for each of the three study sites. Taken from Anderson et al. (2021) (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.	47.2%[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 organized 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 B.1
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 Anderson et al. (2021) 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 stabilization 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 C.1
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
Aggregationmethod	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 maximized; 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 maximized; 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.

Table D.1
Focus group schedule. We presented summarized 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 stabilization 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 behavioral 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 E.1
Number of mid-point responses on the Likert range 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 F.1
Descriptive statistics of responses to poll conducted via Zoom 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 F.2
Participant responses to poll conducted via Zoom 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 very important to me.	8	9	9	7	7	8	8	8	9	7

Table G.1
Allocation of 20 imaginary "Catterline pounds" 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

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