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Beavers and flood alleviation: Human perspectives from downstream communities

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Abstract

Natural flood management (NFM) methods work with natural processes to reduce flood risk, while often providing additional benefits such as water quality improvement or habitat provision. Increasingly, the activity of an animal—beavers—is recognised to potentially provide flow attenuation, along with multiple benefits for the environment and society, but there can also be associated challenges. We use Q-Methodology to elicit and understand human perspectives of beavers and their potential role in flood management among communities living downstream of beavers at three sites in England (Cornwall, Yorkshire and the Forest of Dean). This is the first time a study has focused on downstream communities as the primary stakeholders. We identify diverse perspectives that exhibit a range of value judgements. We suggest a catchment-based approach to beaver management and public engagement may facilitate deeper recognition of contextual perspectives in decision-making and enable knowledge dissemination with communities. Further, we examine the relationship between beavers and other NFM methods through these perspectives. In doing so we identify features that relate to the unique element of relying on the natural behaviour of beavers for flood management, rather than human flood managers being the primary decision-makers.

KEYWORDS

Eurasian beaver, flood risk, human dimensions, natural flood management, perceptions, public engagement, Q-methodology, reintroduction

1 | INTRODUCTION

In recent decades, reports of flooding and ensuing economic losses have increased globally (Kundzewicz et al., 2014), and notably in countries such as the UK, where floods are projected to increase due to climate change (Dadson et al., 2017). Furthermore, catchments have been vastly altered by human activity, leading to increases in run-off and high-water flows (Brown et al., 2018; Hewett, Wilkinson, Jonczyk, & Quinn, 2020; Keesstra et al., 2018). Consequently, substantial funds have been directed at intervention and response. For example, the UK Government allocated £815.4million for flood and coastal erosion risk management in England in 2019/20 (DEFRA, 2019).

In Natural Flood Management (NFM), measures work with natural processes in the landscape as opposed to conventional engineered interventions (Ellis, Anderson, &

Brazier, 2021; Lane, 2017). For example, natural features can be restored to re-establish ecological functions, such as in-channel woody debris dams (or log jams) to slow water flows (Addy & Wilkinson, 2016; Black et al., 2021; Short, Clarke, Carnelli, Uttley, & Smith, 2019). A range of NFM techniques are available; for examples see Burgess-Gamble et al., 2017 and Dadson et al., 2017.

At the catchment scale NFM can alter flow regimes (Hewett et al., 2020), or locally NFM can be a cost-effective approach (Wilkinson, Quinn, Barber, & Jonczyk, 2014). NFM is often cited as a sustainable approach to flood management, with lower levels of maintenance required (Keesstra et al., 2018; Lane, 2017) and delivery of other multiple benefits such as water quality improvement and habitat restoration (Hewett et al., 2020; Keesstra et al., 2018; Thompson et al., 2018). For example, large woody debris (or engineered log-jams) can reduce sediment movement downstream and improve habitat quality, leading to an increase in macroinvertebrate diversity (Deane, Norrey, Coulthard, McKendry, & Dean, 2021; Short et al., 2019). Recognition of multiple benefits from NFM has been growing in recent years, including by government bodies in the UK (Burgess-Gamble et al., 2017; Ellis et al., 2021).

Public and stakeholder engagement and involvement is important in the delivery of conventional flood interventions and NFM (Maskrey, Mount, Thorne, & Dryden, 2016; Short et al., 2019; Waylen, Holstead, Colley, & Hopkins, 2018). Without it, there can be barriers to implementation (Eden & Tunstall, 2006; Waylen et al., 2018). Challenges include effectively communicating scientific knowledge or motivating publics to participate (Barr & Woodley, 2019; Buijs, 2009; Henderson, 2020; Waylen et al., 2018). When engagement is insufficient, controversy can arise, such as when publics disagree with scientists about the basis for decision-making (Barr & Woodley, 2019). However, successful engagement can lead to consensus solutions and local support (Wilkinson et al., 2014).

Recently, the activities of an animal have been suggested to play a role in NFM (Brazier et al., 2020; Puttock, Graham, Ashe, Luscombe, & Brazier, 2020; Puttock, Graham, Cunliffe, Elliott, & Brazier, 2017; Westbrook, Ronnquist, & Bedard-Haughn, 2020). North American beaver (*Castor canadensis*) and Eurasian beaver (*Castor fibre*) are similar species of semi-aquatic rodents. They modify landscapes through unique tree-felling, dam-building, and burrowing behaviours (Brazier, Puttock, et al., 2020; Larsen, Larsen, & Lane, 2021). Beaver dams push water sideways onto floodplains, thus storing water and reducing flow rates in high rainfall events, contributing towards reduced fluvial flooding downstream (Puttock et al., 2020; Westbrook et al., 2020). By storing water, dams also help maintain base flows during drought (Brazier, Puttock, et al., 2020; Hood & Bayley, 2008).

In Eurasia, Eurasian beaver populations (herein referred to as beaver) were diminished by human hunting and landscape change but have now recovered across much of their historical range from both natural spread and human-led reintroductions (Gaywood, 2018; Halley, Saveljev, & Rosell, 2020). In England, beavers were resident until approximately 500 years ago and are being reintroduced. Between 2015 and 2020, a free-living population was monitored on the River Otter in Devon (south-west England) in a project called the River Otter Beaver Trial (ROBT) (Brazier et al., 2020; River Otter Beaver Trial, 2019). There are also several fenced projects—three are described under 'Study Sites'. Beaver reintroduction is devolved to UK nation governments; beavers are now legally protected in Scotland following a reintroduction trial (Coz & Young, 2020; Gaywood, 2018; Tayside Beaver Study Group, 2015a), and in Wales a beaver family were released under licence to an enclosure at Cors Dyfi Nature Reserve in March 2021 (Wildlife Trusts Wales, 2012).

In August 2020, UK Government announced the River Otter beavers may remain permanently (UK Government, 2020), and a consultation on a national approach to reintroduction and management took place in 2021 (UK Government, 2021). Science contributing towards this decision includes evidence of flow attenuation impact of beavers, which is of particular interest due to projected increases in UK flood risk (Brazier, Elliott, et al., 2020; Dadson et al., 2017; Graham et al., 2020). Other factors include benefits for biodiversity (Law, Levanoni, Foster, Ecke, & Willby, 2019; Nummi & Holopainen, 2020; Stringer & Gaywood, 2016), water quality (Puttock et al., 2017; Puttock, Graham, Carless, & Brazier, 2018) and wildlife tourism (Auster, Barr, & Brazier, 2020c; Campbell, Dutton, & Hughes, 2007).

It is important to note that, where beavers are reintroduced, there can also be potential for conflict with agriculture, property or infrastructure. Examples could include beavers storing water behind dams on agricultural land (Brazier, Elliott, et al., 2020; Gaywood, 2018), grazing on crops (Mikulka, Homolka, Drimaj, & Kamler, 2020), or burrowing beneath human infrastructure (Campbell-Palmer et al., 2020; Kloskowski, 2011). The people who experience these conflicts may differ from those who garner the benefits so a management framework will be required to support those negatively affected (Auster, Barr, & Brazier, 2020b; Brazier, Puttock, et al., 2020; Campbell-Palmer et al., 2016; NatureScot, 2021a, 2021b; River Otter Beaver Trial, 2019; Schwab & Schmidbauer, 2003; Ulicsni, Babai, Juhász, Molnár, & Biró, 2020). This will require early consideration (Auster, Barr, & Brazier, 2020b; Auster, Puttock, & Brazier, 2020). A range of management techniques are available (Campbell-Palmer et al., 2016) and are applied in a range of strategies across Europe (see Campbell-Palmer,

Schwab, & Girling, 2015 and Pillai & Heptinstall, 2013 for details). Additionally, there are diverse opinions regarding beaver impacts upon fish (Auster, Barr, & Brazier, 2020a). Research here continues, although existing literature suggests varied but net beneficial effects (Bouwes et al., 2016; Brazier, Puttock, et al., 2020; Bylak & Kukuła, 2018; Kemp, Worthington, Langford, Tree, & Gaywood, 2012; Malison & Halley, 2020; Needham et al., 2021).

Considerations on impacts for society and engagement with publics are key in reintroductions, as recommended by the International Union for the Conservation of Nature (IUCN & SSC, 2013). Accordingly, such evidence was gathered for both the ROBT and the preceding Scottish Beaver Trial (Brazier, Elliott, et al., 2020; Devon Wildlife Trust, 2017; Gaywood, 2018; Jones & Campbell-Palmer, 2014). Research efforts have engaged with various publics, including the general public nationwide (Auster, Puttock, & Brazier, 2020; Scott Porter Research and Marketing Ltd, 1998) and stakeholder groups such as: anglers (Auster, Barr, & Brazier, 2020a; Beaver Salmonid Working Group, 2015); local land/property-owners including those who reported conflicts with beavers (Auster, Barr, & Brazier, 2020b; Scottish Beaver Trial, 2007; Tayside Beaver Study Group, 2015b); and businesses and community residents that experienced beaver tourism (Auster, Barr, & Brazier, 2020c; Moran & Lewis, 2014). Perspectives of beavers and their role in flooding have been considered within these works; however, these studies had primary focuses elsewhere. As the potential role of beavers in NFM is influential, and as NFM requires public engagement, knowledge of community perspectives towards beavers as flood managers is required.

This study seeks to understand perspectives towards beavers and their role in NFM among some of the first communities to live downstream of beaver sites in modern-day England (where flow attenuation has been observed, Puttock et al., 2020). This is the first time a study has taken such a focus with the downstream community as focal stakeholders. As beaver presence in modern-day Britain is a new concept for many people, we employ an exploratory method designed to elicit an understanding of perspectives that exist within this context: Q-Methodology. We will first describe this technique and provide insight into the study sites. We then detail the perspectives we identified and discuss the implications of our findings for beavers and NFM.

2 | METHODS

Q-Methodology seeks to understand participant views within a context, using a systematic approach and semi-qualitative analytical procedure (Eden, Donaldson, & Walker, 2005; Zabala & Pascual, 2016). Q originated in the psychological sciences and is increasingly used to explore discourses in environmental issues (Crowley, Cecchetti, & McDonald, 2020; Ockwell, 2008; Zabala & Pascual, 2016; Zabala, Sandbrook, & Mukherjee, 2018). It does not seek to understand prevalence of perspectives across society, but instead aims to develop deep understandings of subjectivities or shared viewpoints that exist (Auster, Barr, & Brazier, 2020a; Eden et al., 2005; Watts & Stenner, 2012). It can therefore be used with a small number of participants (Auster, Barr, & Brazier, 2020a; Watts & Stenner, 2012; Zabala et al., 2018). For respondents, the process involves sorting several statements (the 'Q-Set') and ranking them in relation to one another (producing a 'Q-Sort'). In analysis, Q-sorts are compared with one another holistically and reduced to a few 'factors' for interpretation. A factor is a representative response shared by multiple participants (Watts & Stenner, 2012; Zabala et al., 2018).

2.1 | Q-Set development

Statements were developed using a combination of researcher experience and literature review. The research team comprised of individuals experienced in the field of beaver reintroduction regarding human dimensions and hydrology. Two members recently worked on a literature review of beaver impacts on hydrology, geomorphology, and human-beaver interactions (Brazier, Puttock, et al., 2020). The statements were developed with this knowledge.

The Q-set was limited to 34 statements to provide adequate topic coverage, whilst minimising the number of statements for participants to sort; we intended sorting to be interesting rather than onerous. Statements were written to elicit participant responses of agreement or disagreement to aid sorting procedure. Statements primarily focused upon beavers and flooding, but included other matters related to beaver reintroduction (such as impacts upon agriculture, fish, and tourism). Three internal colleagues—also with experience in beaver reintroduction and hydrology—reviewed the Q-Set for clarity and subject coverage prior to distribution. The final Q-set is represented in Table 1.

2.2 | Participants

We recruited participants from communities living downstream of three beaver sites. These were fenced projects undertaken at least in part to attenuate flooding (Puttock et al., 2020).

TABLE 1 Statements in the Q-set and the identified factor arrays (representative Q-sorts)

Statement		Factor						Z-score variance
		1	2	3	4	5	6	
1	I think beavers would be beneficial for wildlife.	3	0	1	−1	1	0	0.583
2	I think flood management measures should work with nature.	3	−1	0	0	2	2	0.518
3	I think water stored behind beaver dams will be useful in times of drought.	0	0	2	0	-1	−3	0.727
4	I do not know much about beavers.	−1	−2	0	1	1	2	0.369
5	I think the benefits of flood management must outweigh any management costs.	0	0	0	−3	−3	1	0.652
6	I think beavers would cause problems for agriculture.	−2	1	−2	1	−1	−2	0.585
7	I am pleased that there are beavers upstream of my property.	1	−2	2	−2	3	2	1.131
8	I think flood management measures must also be beneficial for wildlife.	2	0	−1	1	−1	1	0.435
9	I think beavers should be in England.	2	−2	2	−3	2	1	1.401
10	I think flood management measures should help to restore natural environments.	3	0	0	−2	2	2	0.844
11	I think wild beavers will not build dams where we need to manage flooding.	−2	3	−1	0	0	−1	0.773
12	I think the benefits of beavers outweigh the costs of management.	1	−3	1	−2	3	−1	1.565
13	I think local communities should be involved in beaver management.	0	1	1	2	0	1	0.179
14	I would find it enjoyable to visit a beaver wetland.	2	−1	2	1	1	3	0.688
15	I am worried that beavers live near me.	−3	2	−1	1	−3	−3	1.455
16	I am worried beaver dams may fail.	−1	−1	0	0	−2	−2	0.147
17	I think human-built flood measures are more reliable than beaver dams.	−1	3	−3	−1	−3	−1	1.081
18	I think beavers would benefit local businesses.	0	−1	1	−1	0	1	0.249
19	I think beavers would have a negative impact on fish.	−2	−1	−3	2	−1	−2	0.785
20	I think that a wild beaver population would need to be managed.	0	1	−1	3	−1	0	1.001
21	I worry that beavers would carry disease.	−2	0	−2	−1	0	−3	0.374
22	I would enjoy seeing beavers.	1	−1	3	2	1	3	0.548
23	I am worried that beavers would damage human infrastructure (e.g. roads, bridges, etc.).	−3	1	−1	1	−2	−2	0.806
24	I think humans could build woody dams as well as beavers can.	−1	−2	−3	0	1	0	0.449
25	I prefer human engineered flood management techniques to natural methods.	−3	2	−2	−3	−2	0	1.115
26	I think beavers should only be in enclosed areas rather than wild.	−1	2	−1	2	−2	−1	0.964
27	I think beavers will need to be regularly monitored.	0	2	−2	3	0	0	0.907
28	I think beaver activity will improve water quality.	1	1	1	−1	1	0	0.393
29	I think there is a potential for beaver tourism.	0	1	3	0	0	1	0.221
30	I think humans have altered the landscape too much for beavers.	−1	0	0	−1	0	0	0.165
31	I think there should be support for people who may experience negative beaver impacts.	0	3	0	3	3	−1	0.844
32	I think beavers will help to reduce erosion.	2	0	0	−2	−1	−1	0.404
33	Overall, I think beavers are good for people.	1	−3	1	0	2	0	0.887
34	Overall, I think beavers are good for the environment.	1	−3	3	0	0	3	1.066

2.2.1 | Ladock

Ladock is a village in mid-Cornwall, south-west England. At the last census, there were 1513 residents (673 households) in the parish, with an average age of 40.4 years (Office for National Statistics, 2011a). Ladock has experienced multiple flood events, including three which flooded 13–20 properties in 1979, 1993 and 2012 (Cornwall Council, 2011, 2012).

In June 2017, a pair of beavers was released in an enclosure upstream in the Cornwall Beaver Project, led by Cornwall Wildlife Trust. By 2020, the beavers had created '7+ dams in addition to damming and raising the water level in a pre-existing pond' (Puttock et al., 2020). For more information see Cornwall Wildlife Trust, 2021.

2.2.2 | Sinnington

Sinnington is a village in Yorkshire, northern England. At the last census, there were 287 residents (164 households) in the parish, with an average age of 53.2 years (Office for National Statistics, 2011c). Sinnington has experienced historical flooding, including events in 1999, 2000 and 2007 (Environment Agency, 2007; North York Moors National Park Authority, 2017).

In April 2019, a beaver pair were released into an enclosure upstream in a project led by Forestry England. Prior to release, several timber bunds were placed across the channel for NFM. By 2020, there was no recorded interaction between beavers and the bunds, and the beavers had built three dams (Puttock et al., 2020). For more information see Forestry England, 2021b.

2.2.3 | Lydbrook

Lydbrook is a village in the Forest of Dean in Gloucestershire, western England. At the last census, there were 2192 residents (1008 households) in the parish, with an average age of 42.4 years (Office for National Statistics, 2011b). Lydbrook has experienced multiple flood events, including in 2000, 2007 and 2012 (Environment Agency & Natural Resources Wales, 2015; Gloucestershire County Council, 2014).

In July 2018, a beaver pair was released into an enclosure upstream in a project led by Forestry England. The beavers were removed in May 2019 though their dams prevailed, and a new pair was released into the same enclosure in August 2019. By 2020, the beavers had created three dams (Puttock et al., 2020). For more information see Forestry England, 2021a.

2.2.4 | Recruitment

In response to Covid-19 pandemic circumstances, participants were recruited remotely through online methods (avoiding face-to-face contact). We used purposive recruitment methods: we contacted each Parish Council and community newsletters with requests to advertise the invitation; requested each beaver project share the invitation; and advertised through community Facebook pages. Data collection was open from 3 August 2020 until 4January 2021.

Thirty-nine community members participated, 13 from each location (Table 2). There were 22 female and 14 male participants (three preferred not to specify gender). Of those who indicated their birth year, the average age was 59 (range 33–75).

All participants had seen beavers or signs of their activity on the television, internet or similar, and 27 had seen them in person, whether locally or elsewhere. Thirty participants had personally experienced the effects of flooding, with five in Ladock, eight in Sinnington and nine in Lydbrook having experienced it within those respective communities.

2.3 | Q-Sort process

Q-Sorting was undertaken online only (due to Covid−19 circumstances) using HTMLQ, an open-source software package (aproxima Gesellschaft für Markt- und Sozialforschung Weimar, 2014). Three internal colleagues piloted the study.

Participation took 24 min on average (range 7–79 min; 82% took <30 min). Upon opening the webpage, the study information was presented (Data S1). Notably, this highlighted the voluntary and anonymous nature of participation. Participants were informed that clicking 'Continue' would signify they had read and agreed to this information.

In Step 1, participants were presented with each Q-Set statement in turn (in randomised order) and required to sort them into three piles: Agree, Disagree or Neutral. This aided Step 2, where participants sorted statements into the Q-Sort matrix. Here, participants ranked statements in relation to one another between a score of +3 (statements most agreed with) and −3 (statements least agreed with). The matrix was of fixed, quasi-normal distribution to facilitate sorting (Figure 1). To help interpretation, Step 3 gave opportunity for participants to comment on why they agreed or disagreed with statements to which they assigned scores of +3 or −3. We then asked questions regarding respondents' backgrounds (Table 2) and gave opportunity to provide additional comments.

TABLE 2 Summary of participant details

ID	Year of birth	Gender	'I have visited my local beaver project'	'I have visited another beaver project'	'I have seen beavers or signs of their activity in another country'	'I have seen beavers or signs of their activity on the television, internet or similar'	'I have never seen beavers or signs of their activity in any way'	Have they personally experienced the effects of flooding?
Lad1	1967	Female	×	×	×	✓		Here
Lad2	1961	Female	✓	✓	×	✓	×	Here and elsewhere
Lad3		Prefer not to say	✓	×	×	✓	×	×
Lad4	1979	Female	✓	×	✓	✓	×	×
Lad5		Male	✓	×	×	✓	×	Here
Lad6	1951	Male	×	×	×	✓	×	×
Lad7	1953	Male	✓	×	×	✓	×	Here
Lad8		Prefer not to say	✓	×	×	✓	×	×
Lad9		Male	×	✓	✓	✓	×	Elsewhere
Lad10		Female	×	×	✓	✓	×	Elsewhere
Lad11		Female	✓	×	✓	✓	×	Here
Lad12	1953	Female	✓	×	✓	✓	×	Elsewhere
Lad13	1977	Female			✓	✓		×
Sin1		Male	✓	×	×	✓	×	Elsewhere
Sin2	1952	Male	×	×	×	✓	×	Here
Sin3	1953	Female	×	×	×	✓	×	Here
Sin4	1960	Female	×	×	×	✓	×	Here
Sin5	1966	Female	×	×	×	✓	✓	Elsewhere
Sin6	1962	Female	×	×	×	✓	×	Here
Sin7	1953	Female	✓	×	✓	✓	×	Here
Sin8	1946	Female	×	×	✓	✓	×	Elsewhere
Sin9	1969	Male	×	×	✓	✓	×	Here
Sin10	1952	Female	×	×	✓	✓	×	×
Sin11	1963	Male	×	×	×	✓		×
Sin12	1960	Male	✓	×	✓	✓	×	Here
Sin13	1960	Female	×	×	×	✓	✓	Here
Lyd1	1960	Prefer not to say	✓	×	×	✓	×	Here
Lyd2	1988	Female	×	×	×	✓		Here and elsewhere
Lyd3	1967	Female	✓	×	×	✓	×	Here
Lyd4	1961	Female	×	×	✓	✓	×	Here
Lyd5	1954	Female	✓	×	×	✓	×	Elsewhere
Lyd6	1961	Male	×	×	×	✓	×	Here and elsewhere
Lyd7	1962	Female	✓	×		✓		Here

TABLE 2 (Continued)

ID	Year of birth	Gender	'I have visited my local beaver project'	'I have visited another beaver project'	'I have seen beavers or signs of their activity in another country'	'I have seen beavers or signs of their activity on the television, internet or similar'	'I have never seen beavers or signs of their activity in any way'	Have they personally experienced the effects of flooding?
Lyd8	1959	Male	✓	×	×	✓	×	Here and elsewhere
Lyd9	1962	Female	✓	×	×	✓	×	×
Lyd10	1978	Female	✓	×	✓		×	×
Lyd11	1958	Male	×	×	×	✓	×	Here
Lyd12	1969	Male	✓	✓	✓	✓	×	Here and elsewhere
Lyd13	1956	Male	×	×	✓	✓	×	Elsewhere

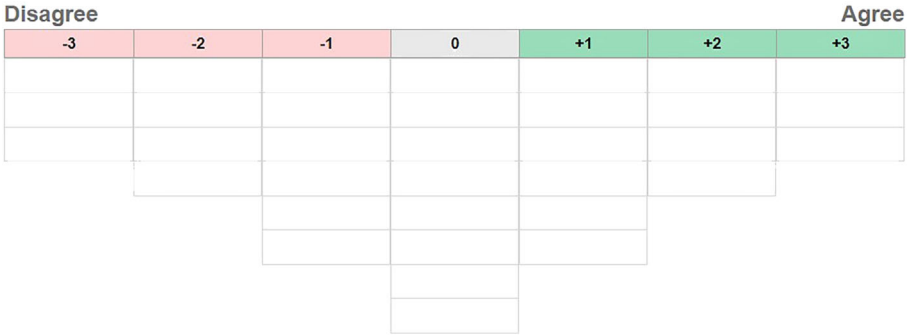

FIGURE 1 Example of the Q-Sort distribution matrix (as viewed by participants in HTMLQ)

2.3.1 | A note for future researchers

We here note a technological limitation to assist future online Q-Methodology researchers. No technological issues were identified in piloting; however, late in data collection some participants reported software issues when using alternative devices (e.g. Smartphones, tablets). These are more widely used now than when HTMLQ was developed. We recommend future HTMLQ studies highlight sorting should be completed on a desktop, or that there is investment in updating or developing open-access software packages, to be compatible with different devices.

2.4 | Statistical analysis

We used Ken-Q Analysis for statistical analysis (Banasick, 2019). Factors (shared perspectives) were extracted using centroid analysis and Varimax rotation. This standardised approach explains mathematically the maximum amount of variance in the data (Watts & Stenner, 2012, pp. 122–126). As is often the convention, factors were retained when Eigenvalues were >1 and at least two Q-Sorts significantly loaded onto (statistically correlated with) a factor (Watts & Stenner, 2012, pp. 105–107). Confounded Q-Sorts (which load onto multiple factors) were excluded (Watts & Stenner, 2012, p. 143; Armatas, Venn, & Watson, 2014).

Six factors were extracted, explaining 68% of variance in the data (Table 3). (Q-Method is a data reduction technique and remaining variance is explained by factors which did not meet the above criteria to be retained [Watts & Stenner, 2012, pp. 98–99]). 34 Q-Sorts loaded onto the extracted factors. Factor arrays (single representative Q-Sorts) were generated using weighted average Z-scores, presented in Table 1.

2.5 | Interpretation

We followed the systematic interpretation method suggested by Watts and Stenner (2012, Chap. 7). This evaluates: statements given highest or lowest scores; items sorted higher or lower than on other factors; a review of the remaining factor array for other important statements; comments of participants whose Q-Sorts

TABLE 3 Summary of factor loadings and the variance explained by each identified factor

Factor	No. sorts loaded	% variance explained
1	16	25
2	5	13
3	3	11
4	2	4
5	2	6
6	4	9

loaded onto each factor. This interpretation method means each statement is engaged with at least once and allows statements of importance to be identified in a data-driven manner.

3 | IDENTIFIED FACTORS

Here, we outline the extracted factors. Throughout, we reference key statements in parentheses with the formula: (statement number, corresponding score in the composite sort). Where appropriate, illustrative participant comments are provided.

3.1 | Factor 1 ('pro-beaver, eco-centric')

Sixteen sorts loaded onto this factor, including five respondents from Ladock (Lad2, Lad5, Lad7, Lad12 and Lad13), six from Sinnington (Sin1, Sin5, Sin7, Sin8, Sin10 and Sin13), and five from Lydbrook (Lyd6, Lyd8, Lyd10, Lyd11 and Lyd13). Thirteen participants had personal experience of flooding, and 12 had seen beavers or signs of their activity in person. The factor explained 25% of the variance.

This factor strongly agreed flood management measures should work with nature (2, +3) and help to restore natural environments (10, +3).

> '*I think it's imperative that flood management works with nature, particularly at this critical time of climate change*.'-Lyd6

> '*any measures which work against nature do tend to create more problems for the environment than they solve. Flood management which can work with nature is a win-win situation*.'-Lyd8

The factor agreed more than the others that flood management measures must also benefit wildlife (8, +2) and strongly agreed beavers would provide such a benefit (1, +3).

> '[Beaver] *habitats create a natural dam to slow the flow of water in heavy rains and floods, thereby retaining water and protecting other habitats. Their dams also clean the water and their wetland habitat is a beneficial addition to the environment as it attracts a variety of other wetland wildlife*.'-Lyd6

The factor disagreed more than others that beavers would not build dams where flood management is needed (11, −2), and strongly disagreed with a preference for human engineered flood management techniques to natural methods (25, −3).

> '*Human methods have been seen to repeatedly fail, unless we learn from nature and mimic the natural world*.'-Lyd6'*Human interventions should complement natural methods*.'-Lyd11

The factor felt beavers should be in England (9, +2).

> '*Historically, [beavers] were part of our natural environment*.'-Lad5

It believed beavers would help to reduce erosion (32, +2) and agreed more than other factors that beavers would improve water quality (28, +1). The factor was not worried beavers lived nearby (15, −3) and did not feel beavers would damage human infrastructure (23, −3).

> '*Simple land management steps could be taken to ensure successful co-habitation*.'-Lad5'*I'm happy, even proud, to have beavers living close by*.'-Lad7

It did not feel beavers would cause problems for agriculture (6, −2) and did not feel humans had altered the landscape too much for beavers (30, −1). The factor did not express strong feeling about the involvement of local communities in beaver management (13, 0) or potential for beaver tourism (29, 0), but these statements scored more negatively relative to their placement in other factors.

3.2 | Factor 2 ('anti-beaver, anthropocentric')

Five sorts loaded onto this factor, all of whom lived in Ladock (Lad3, Lad8, Lad9, Lad10 and Lad11). Three participants had personal experience of flooding, and all had

seen beavers or signs of their activity in person. The factor explained 13% of the variance.

This factor strongly felt human-built flood measures would be more reliable than beaver dams (17, +3) and that wild beavers would not build dams where flood management is required (11, +3).

> '*Man-made flood measures are predictable and work where they are required. Beavers are unpredictable. Beavers can flood river courses in the wrong areas, e.g. below/downstream from houses which can result in worse flooding*.'-Lad10

Compared with other factors, it agreed more that beavers would damage human infrastructure (23, +1) and cause problems for agriculture (6, +1).

> '*If beavers dam up water courses downstream of properties they can cause flooding*.'-Lad8

The factor felt it had knowledge of beavers (4, −2) but was worried beavers lived nearby (15, +2) and was not pleased there were beavers upstream of their property (7, −2).

> '*If they get out and find their way down [from] the village i am afraid [they] will build their dams there and the village will be flooded again*.'-Lad11

The factor indicated it would not enjoy seeing beavers (22, −1) or visiting a beaver wetland (14, −1). Although thinking beavers may improve water quality (28, +1), the factor strongly disagreed that beavers were beneficial for the environment (34, −3) or for people (33, −3) overall. It did not feel beavers would benefit local businesses (18, −1) and strongly felt management costs would outweigh benefits of beavers (12, −3).

> '*They only benefit some people, not everyone. They should be contained in enclosures, but if not they must be managed to prevent damage, irrespective of the cost*.'-Lad8

The factor thought beavers should not be allowed to roam wild (26, +2), and felt strongly that, if beavers were in an area, there should be support available for people who experience negative beaver impacts (31, +3).

> '*If the beavers flood the river downstream of the village it will negate all of the work the environment agency has done and will result in our houses being flooded again. Before* [...] *the work we couldn't get insurance or sell our houses. We don't want to go back to that situation again. If it should happen because of beavers then we must be compensated for it*.'-Lad11

The factor disagreed more than others that flood management measures should work with nature (2, −1) and preferred human engineered flood management techniques to natural methods (25, +2).

> '*It [human engineered techniques] is predictable*.'-Lad3

3.3 | Factor 3

Three sorts loaded onto this factor, all of whom lived in Lydbrook (Lyd1, Lyd4 and Lyd7). All had personal experience of flooding within Lydbrook and had seen beavers or signs of their activity in person. This factor explained 11% of the variance.

This was a bipolar factor—a factor whose loadings have both positive and inverse correlations with the composite sort (Watts & Stenner, 2012, p. 165). One Q-sort (Lyd7) positively correlated, and two (Lyd1, Lyd4) inversely correlated with the factor. These are 'distinct but connected viewpoints' (Watts & Stenner, 2012, p. 166), so we provide separate 'twinned' interpretations (Watts & Stenner, 2012, pp. 165–166).

3.3.1 | Positive correlation ('pro-beaver, economy-focused')

The factor strongly agrees beavers would be good overall for the environment (34, +3).

> '*They are a keystone species*.'-Lyd7

It believed water stored behind beaver dams would be useful in periods of drought (3, +2) and beaver activity would improve water quality (28, +1). The factor strongly felt they would enjoy seeing beavers (22, +3) and there is a potential for beaver tourism (29, +3). It indicated it would enjoy visiting a beaver wetland (14, +2) and felt beavers may benefit local businesses (18, +1). The factor strongly disagreed that beavers would have a negative impact on fish (19, −3) or cause problems for agriculture (6, −2).

> '*They don't eat fish!*'-Lyd7

The factor felt beavers should be in England (9, +2) and disagreed most out of all factors that beavers would need to be regularly monitored (27, −2). Similarly, the factor was less concerned than those loaded onto other factors that a wild beaver population would need to be managed (20, −1). The factor strongly felt humans could not build woody dams as well as beavers can (24, −3) and strongly disagreed with the statement that human-built flood measures are more reliable than beaver dams (17, −3).

> '*Human solutions to flooding are capital intensive and require ongoing maintenance.*'-Lyd7

3.3.2 | Inverse correlation ('anti-beaver, impact-focused')

The inverse factor strongly felt human-built flood measures are more reliable than beaver dams (17, +3) and humans could build woody dams as well as beavers can (24, +3).

> '*Beaver dams will rot.*'-Lyd1

It strongly felt beavers were not good for the environment (34, −3) and believed more strongly than other factors that beavers would have a negative impact on fish (19, +3). The factor disagreed with the statements that beaver activity would improve water quality (28, −1) or water stored behind beaver dams would be useful in times of drought (3, −2).

> [Regarding statement 19] '*Definitely, speaking to fisherman yes[t]erday. They don[']t want them either especially as all the [Forest of Dean] po[n]ds are artificially stocked.*'-Lyd1

It strongly disagreed there would be a potential for beaver tourism (29, −3) and indicated it would not enjoy seeing beavers (22, −3) or visiting a beaver wetland (14, −2). It did not think there would be a benefit for local businesses (18, −1) and felt more strongly than other factors that beavers would cause problems for agriculture (6, +1). The factor did not believe beavers should be in England (9, −2) and felt that, if beavers were present, they would need to be regularly monitored (27, +2) and a wild beaver population would need to be managed (20, +1).

> '*Seen the damage they do???? Wait til they escape. [...] If you let them go there will be problems and then you'll be spending 20 years getting rid of them.*'-Lyd1

3.4 | Factor 4 ('anti-beaver, management-focused')

Two sorts loaded onto this factor, one from Ladock (Lad4) and one from Sinnington (Sin11). Neither had personal experience of flooding, and only Lad4 had seen beavers or signs of their activity in person. The factor explained 4% of the variance.

This factor strongly felt that a wild beaver population would need to be managed (20, +3) and beavers would need regular monitoring (27, +3).

> '*The only way my concerns would be in some way reduced would be if beavers were put on the general licence for control. The landowner should not have to apply for a licence to control beavers causing problems on their land.*'-Lad4'*If they are as destructive as I have heard them to be their numbers & effects will need monitoring.*'-Sin11

The factor agreed more than others that beavers may cause problems for agriculture (6, +1) or damage human infrastructure (23, +1). It believed beavers would not help to reduce erosion (32, −2), and did not believe their activity would improve water quality (28, −1) or benefit local business (18, −1). The factor disagreed more than other factors that beavers would benefit wildlife (1, −1) and agreed with the statement that beavers would have a negative impact on fish (19, +2). This factor strongly opposed beaver presence in England (9, −3) and did not think benefits would outweigh management costs (12, −2). It was not pleased by beaver presence upstream of their property (7, −2).

> '*England is too small, developed and over-populated with humans to cohabit with a wild beaver population without a negative impact from tree felling and dam building.*'-Sin11

If beavers were to be in an area, the factor agreed more than most other factors that beavers should only be in enclosed areas rather than wild (26, +2).

> '*I think a wild beaver population would take a huge amount of management to constrain their activities where they (and they WILL) cause a problem to river flows, fish passage, tree damage, flooding etc. Once the genie is out of the bottle...*'-Lad4

This factor felt local communities should be involved in beaver management (13, +2) and there was strong agreement that there should be support for people who experience negative beaver impacts (31, +3).

> [Regarding statement 31] *'This goes without saying in my opinion!'* -Sin11

The factor did not think benefits of flood management must outweigh any management costs (5, −3) and disagreed more than other factors that they should help to restore natural environments (10, −2). However, it strongly disagreed with a preference for human engineered flood management techniques rather than natural methods (25, −3).

> *'Natural would seem better if appropriate.'*-Sin11

3.5 | Factor 5 ('pro-beaver, anthropocentric')

Two Q-sorts loaded onto this factor, one from Sinnington (Sin3) and one from Lydbrook (Lyd3). Both had personal experience of flooding within their respective communities, but only Lyd3 had seen beavers or signs of their activity in person. The factor explained 6% of the variance.

The factor was the most pleased of all to have beavers upstream of their property (7, +3) and was not worried that beavers lived nearby (15, −3).

> *'I think it[']s a great idea having beavers upstream and helping to slow the flow.'*-Lyd3

It did not agree beavers should be in enclosed areas rather than wild (26, −2) and felt beavers should be in England (9, +2). More-so than other factors, it believed beavers were good for people overall (33, +2) and the benefits of beaver outweighed management costs (12, +3).

> *'it[']s a natural solution to the flood risk—can't believe management costs would be prohibitory; seems like a worthwhile investment.'*-Sin3

The factor disagreed more than others that a wild beaver population would need to be managed (20, −1) but felt strongly that support should be available for people who may experience negative impacts of beavers (31, +3). Although agreeing more than other factors that humans could build woody dams as well as beavers can (24, +1), this factor strongly disagreed with the statement that human-built flood measures are more reliable than beaver dams (17, −3). It was not worried beaver dams may fail (16, −2) and did not feel beavers would damage human infrastructure (23, −2). Compared with other factors, this factor disagreed more that flood management measures must also benefit wildlife (8, −1), though it agreed flood management measures should work with nature (2, +2) and help to restore natural environments (10, +2). The factor strongly felt flood management benefits did not need to outweigh management costs (5, −3).

> *'Flood management is a key tool in mitigating some of the impacts of climate change. Within reason it costs what it costs.'*-Lyd3

3.6 | Factor 6 ('pro-beaver, beaver-watchers')

Four sorts loaded onto this factor, two from Sinnington (Sin4, Sin6) and two from Lydbrook (Lyd2, Lyd9). Only Lyd9 had not had personal experience of flooding, but only Lyd9 had seen beavers or signs of their activity in person. The factor explained 9% of the variance.

The factor strongly agreed that it would enjoy seeing beavers (22, +3) and would find it enjoyable to visit a beaver wetland (14, +3).

> *'I enjoy seeing all wildlife in natural settings.'*-Sin6

It was not at all worried beavers lived nearby (15, −3) and were pleased they lived upstream of their property (7, +2).

> *'I obviously think it is marvellous that the beavers have been introduced* [upstream]*, and feel confident that they are providing a considerable level of protection from flooding.'*-Sin6

Compared with others, this factor felt they knew less about beavers (4, +2) but felt strongly they are good for the environment (34, +3). It did not agree beavers would have a negative impact on fish (19, −2), nor that beavers would cause problems for agriculture (6, −2). It was not worried beavers would carry disease (21, −3).

> *'Never* [heard] *of this as a concern, and very unlikely to come into that close a contact.'*-Lyd2

The factor was not worried that beaver dams would fail (16, −2) but did not think water stored behind beaver dams would be useful in times of drought (3, −3).

> *'very rare a drought'*-Sin4

The factor did not feel beavers would damage human infrastructure (23, −2) and disagreed more than others that there should be support for people who may experience negative beaver impacts (31, −1). It agreed more that there would be a benefit for local businesses (18, +1). This factor felt flood management should work with nature (2, +2) and, when compared with other factors, it agreed most that flood management benefits must outweigh any management costs (5, +1).

> *'ANY management of the environment should work with nature.'*-Lyd9

4 | DISCUSSION

Using Q-Methodology, we identified a distinct set of perspectives pertaining to beavers and their potential role in NFM, among communities living downstream of beaver projects. In this discussion, we first explore the diversity in these perspectives and value judgements made by participants, then look at what the factors tell us about how beavers are perceived when compared with other NFM approaches. We will then investigate the practical management implications of our findings.

4.1 | Varied perspectives and values

Factors 1, 5, 6 and the positive correlation of Factor 3 were all more favourable towards beavers and agreed with statement 9 ('I think beavers should be in England'). These factors also agreed with statement 7, indicating they were pleased beavers were upstream of their property (+1, +2, +3 and +2, respectively). However, prominent values in each factor varied. Factor 1 exhibited eco-centric values, with a broader perception that flood management measures should work with and for nature and wildlife and held trust in beavers as a flood management measure that would also achieve those environmental goals. Factor 5 agreed flood management should work with nature, but from a more anthropocentric perspective; greater emphasis was placed upon the benefits beavers could provide for people. This factor was pleased to have beavers upstream of their property and saw them as a *'worthwhile investment'* (Sin3).

In Factor 6, the role of beavers in flood alleviation seemed less important and emphasis was instead placed upon participants' enjoyment in the opportunities of seeing beavers and wildlife, with few concerns about negative impacts. The positively correlated interpretation of Factor 3 is similar, however here, the opportunity to see beavers is also linked to tourism potential and perceived benefits to local business; this factor placed value on potential economic benefits.

Factors 2, 4 and the inversely correlated interpretation of Factor 3 however were not favourable towards beavers, with disagreement scores given to statement 9. These participants also disagreed with statement 7, indicating they were not pleased with beaver presence upstream of their property. Again however, the foremost values varied. In Factor 2, emphasis was placed upon a preference for human-engineered flood techniques and a view that beavers would not benefit people or the environment. By reviewing the comments of participants whose Q-sorts loaded onto this factor, it is clear there is a perception that flood risk may increase if beavers were to move downstream. Thus, the factor places value on predictability and the level of human control that human engineered flood techniques would provide, with strong agreement they would be more reliable than beaver dams. Interestingly, all participants whose Q-sort loaded onto Factor 2 were residents in Ladock. Upon further review of the participants' comments, it is possible this may be associated with positive perceptions of human-led flood intervention measures previously implemented in their village; Lad3 and Lad11 both referenced works undertaken by the Environment Agency in Ladock. For example, referring to statement 25 with which Factor 2 exhibited agreement, Lad3 said *'[Human engineered flood management] is predictable. The work that [Environment Agency] have done locally [has] successfully prevented flooding. Beavers cannot be made to build dams where they are needed and they can create flooding if they build dams in the wrong place.'* Factor 4 also expressed the perception that beavers would have negative impacts and did not think these would be outweighed by potential benefits, but emphasis was placed upon potential management requirements, with statements they agreed most strongly with being those concerning needs for monitoring and management.

In the inversely correlated interpretation of Factor 3, potential negative impacts of beavers are again cited, particularly for fish and the environment alongside a preference for human-engineered flood management techniques. Greater emphasis is, however, placed upon disagreement with a potential for beaver tourism, and displeasure is expressed at the possibilities of seeing beavers or visiting a beaver wetland. By reviewing the

comments of participants whose sorts loaded onto this factor, it appears this may be linked to wider opposition to species reintroductions, particularly from local contextual experiences of wild boar and pine marten in the Forest of Dean (for more on these reintroductions, please see Bavin, MacPherson, Denman, Crowley, & McDonald, 2020 and O'Mahony, 2020). This is particularly so for Lyd1: *'Its heartbreaking that yet more species are being released. Horrible and heartbreaking to see the devastating effect on forest floor without yet more invasive species. Sickening.'*

Hence, we have highlighted that not only are there polarised viewpoints on beavers in flood management, but there is observable diversity in values held among communities. These may be associated with local contextual experience (as in Factor 3) but may also associate with different value judgements. For example, whilst both were favourable towards beavers and agreed flood management should work with nature, Factor 1 held ecocentric values on this being for the benefit of the environment whilst Factor 5 held the anthropocentric view of this being an opportunity for people. Consequently, we cannot assume the 'public perspective' is a singular nor that there are simplistic positions of support or opposition towards beavers as a flood management measure. Instead, a much deeper understanding is required that accounts for different perspectives and draws upon understandings of the relationships between beavers, the environment, and society.

4.2 | Community confidence in beaver-led NFM

There is a notable difference between NFM that is delivered by beavers and other NFM interventions. Although NFM works with natural processes, in human-modified riverscapes the decisions on where to undertake NFM interventions/restoration are undertaken by humans. With beaver-led natural flood management, however, damming location is determined by individuals of another species (though it can be encouraged via placement of Beaver Dam Analogues—see discussion below). Outside enclosures, wild beavers tend to build dams in lower order, upper tributaries, and more marginal reaches of watercourses (Graham et al., 2020). Although these reaches are ideal to deliver flow attenuation benefits for human communities, the impact is delivered by nonhuman animals, which act without consideration towards flood prevention effects. This is unique in NFM, though might be considered the very definition of working with natural processes (Burgess-Gamble et al., 2017).

The literature recognises beaver presence may bring challenges in some contexts, for example, when water held behind a dam conflicts with agriculture (Auster, Barr, & Brazier, 2020b; Campbell-Palmer et al., 2015). Here, concerns of negative beaver impacts are observed in factors with more negative opinions towards beavers. This is particularly so for Factor 2 which valued the predictability of human engineered techniques (even though they have not necessarily worked in previous flood years), with participant comments indicating a fear of beaver dams downstream of village infrastructure. Thus, to those with anti-beaver perspectives and anthropocentric values, a reliance on nonhuman decision-making may feel like surrendering some sense of control in flood management, and a reliance on beavers may seem of higher risk.

To others (e.g. factors 1, 5 and 6), beavers may be seen to provide a new opportunity in flood management, and recent evidence has demonstrated flow attenuation effects at all three study sites (Puttock et al., 2020). Such flow attenuation benefits are commonly seen to be beneficial for people and this was instrumental in the establishment of the three beaver projects in this study; the projects were intentionally developed upstream of communities historically at risk of flooding.

4.3 | Management implications

Our research has demonstrated how a range of values can be brought to the table by the people in an area. To account for these practically in management of beaver projects and wild populations will require an approach which provides opportunity for localised engagement with communities and stakeholders (Ulicsni et al., 2020). We argue this is supportive of a catchment-based approach, like that advocated in other NFM approaches (Dadson et al., 2017; Hewett et al., 2020).

This localised approach has been similarly endorsed in the 'Beaver Management Strategy Framework' put forward by the ROBT. To achieve this aim, the Framework recommends employment of a catchment-based Beaver Officer as a means of working with local communities and stakeholders to manage beavers and mitigate negative impacts (River Otter Beaver Trial, 2019). In an alternative strategy—though not strictly a catchment-based approach in this instance—beaver management in the state of Bavaria (Germany) is undertaken at a localised level by approximately 500 volunteer consultants located throughout the region, overseen by two state-employed Beaver Managers for all of Bavaria (70,550 km^2) (Schwab & Schmidbauer, 2003).

Further, we identified a perceived concern among some that beavers are unpredictable and may have negative impacts, dependent upon where dams are built. This was exemplified by Factor 2, which valued the predictability of human-engineered flood management methods. Asides from potential management interventions (see Campbell-Palmer et al., 2016 for a summary of techniques), an element of predictability can be applied to beaver populations. Alongside methods of surveying field signs to estimate present beaver population distributions (Campbell-Palmer et al., 2020), computerised models which assess beaver foraging habitat availability and the capacity for damming within watercourses are achievable (Graham et al., 2020; Macfarlane et al., 2017). Although a degree of uncertainty will remain based upon individual animal behaviours (which will need to be made clear), these models make possible a means of predicting likely future beaver impacts at the catchment scale. We suggest localised dissemination of this available knowledge within catchments may reduce predictability concerns and provide some reassurance for concerned individuals.

Additionally, we acknowledge the use of Beaver Dam Analogues (BDA's). These are human-made structures designed to mimic or reinforce natural beaver dams or their function (Pollock, Lewallen, Woodruff, Jordan, & Castro, 2017; Scamardo & Wohl, 2020). The structural form of a BDA can vary; they may be a series of vertical posts across a watercourse, posts with wicker weave, or more substantial structures with fill material (Pollock et al., 2017). BDA's have been installed to facilitate watercourse restoration in America, with evidence of them being actively maintained by beaver; in a study of stream temperature alteration by natural and artificial beaver dams, 46 BDA's were maintained by North American beavers (Weber et al., 2017). It is also demonstrated that BDA's may assist the establishment of beaver territories by providing 'starter dams' (Beechie et al., 2010; Pollock et al., 2017). In future research, perhaps there is room to explore whether deployment of BDA's could be used to encourage beaver damming activity in locations that provide optimal flow attenuation benefits to address concerns around unpredictability. This may inspire greater confidence in beaver-led flood defence by working with this animal to develop a 'right dam in the right place' strategy.

5 | CONCLUSION

Beavers are unique in flood management as the only measure that relies upon the activity of nonhuman animals, rather than upon decisions taken by people. Where the two beaver species are native throughout Eurasia and North America, beavers provide a significant opportunity for natural flood management and climate change resilience (Puttock et al., 2020), but they also provide multiple benefits as well as challenges. This complexity is reflected in the perspectives of communities towards beavers as a flood management measure. To assume the public perspective as a singular would be overly simplistic when, in truth, a community can bring multiple values to the table. Through our research, we demonstrated links can be drawn with various matters in beaver reintroduction and both anthropocentric and eco-centric values.

We argue that more localised management and interaction with publics and stakeholders may facilitate communication between publics and managers, leading to a better understanding of such varied perspectives in each context. This may also facilitate the sharing of available knowledge on habitat modelling and beaver management, which may go some way to reducing a sense of unpredictability and concerns held by some. Future research should consider how the role of animals in natural flood management can be understood in the context of communicating other (nonanimal) forms of flood management and the specific challenges that may arise.

In line with some other approaches to NFM, we support the principle of a catchment-scale management approach to beavers and public engagement if and where beaver populations exist as a genuine example of working with natural processes. Finally, we recommend further research into whether Beaver Dam Analogues could help to address concerns of unpredictability by encouraging beaver damming in locations that optimise the potential benefits of beavers in natural flood management whilst minimising the potential conflicts.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The anonymised Q-Sort data is available at: https://github.com/exeter-creww/Auster-Barr-Brazier_Beavers-and-Flood-Alleviation_Q-Sort-Data

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